

PERSPECTIVE TAKING
AND KNOWLEDGE ATTRIBUTION IN THE
DOMESTIC DOG (*Canis familiaris*):
A CANINE THEORY OF MIND?

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CONTENTS

Abstract	1
1 Introduction	2
1.1 Theory of Mind	4
1.2 Dogs	39
1.3 The Present Research	65
2 Experiment 1: Human presence affects informant choice by dogs	68
2.1 Method	70
2.2 Results and Discussion.....	81
3 Experiment 2: Dogs discriminate between seeing and unseeing human informants	90
3.1 Method	92
3.2 Results and Discussion.....	95
4 Experiment 3: Dogs differentially respond to attentive and inattentive human informants.....	100
4.1 Method	101
4.2 Results and Discussion.....	104
5 Experiment 4: Dogs are unable to locate food without human communicative cues	109
5.1 Method	111
5.2 Results and Discussion.....	114
6 General Discussion.....	120
7 Acknowledgements	143
8 References	144
9 Appendix	153

LIST OF FIGURES

Figure 2.1. A: A schematic plan view of the experimental room and setup as for Experiment 1. B: A photograph of the apparatus used in Experiments 1-4.....	72
Figure 2.2. A: In the Guesser Absent condition, the Guesser left the room whilst the Knower baited the containers. B: In the Guesser Present condition, the Guesser stayed beside the Knower whilst the Knower baited the containers.	77
Figure 2.3. The pointing technique used by the informants to indicate the location of the bait to the dogs.	78
Figure 2.4. To make a choice, the dog was required to approach and touch with its muzzle or paw, or directly gaze at, one container.	79
Figure 2.5. Mean (± 1 SE) percentage of choices for the Knower, over blocks of four trials for the Guesser Absent condition and the Guesser Present condition in Experiment 1.	81
Figure 3.1: A schematic plan view of the experimental room and setup as for Experiments 2-5.	93
Figure 3.2. In Experiment 2, a third experimenter baited the containers, while the Guesser (left) covered her eyes with her hands and the Knower (right) covered her cheeks with her hands.	94
Figure 3.3. Mean (± 1 SE) percentage of choices for the Knower, over blocks of four trials for Experiment 2.....	95
Figure 4.1. In Experiment 3, a third experimenter baited the containers, while the Knower (right) attended to the baiting. The Guesser (left) was inattentive during the baiting.....	103

Figure 4.2. Mean (± 1 SE) percentage of choices for the Knower, over blocks of four trials for Experiment 3.....	104
Figure 5.1. In Experiment 4, both informants either attended to the baiting (A), or were inattentive during the baiting (B).	113
Figure 5.2. Mean (± 1 SE) percentage of choices for the Knower in the first and last blocks of four trials in “attentive” and “inattentive” trial types in the Identical Knower and Guesser condition.	114
Figure 5.3. Mean (± 1 SE) percentage of choices for the Baited and Non-baited containers, and percentage of trials ending with No Response in the No-Pointing condition. .	116

LIST OF TABLES

Table 2.1. Name, sex, and age at start of testing of subjects included in Experiment 1 and Experiment 2	71
Table 2.2. Number of trials and percentage of responses made to the Knower and Guesser in the Guesser Absent condition.....	84
Table 2.3. Number of trials and percentage of responses made to the Knower and Guesser in the Guesser Present condition... ..	85
Table 3.1. Number of trials and percentage of responses made to the Knower and Guesser in Experiment 2.	97
Table 4.1. Name, sex, and age at start of testing of subjects included in Experiment 3 and Experiment 4.	102
Table 4.2. Number of trials and percentage of responses made to the Knower and Guesser in Experiment 3.	106
Table 5.1. Number of trials and percentage of responses made to the Knower and Guesser in the Identical Knower and Guesser condition.	117
Table 9.1. Name, breed and training history of subjects used in the Experiments 1-4..	153

ABSTRACT

Theory of mind, the ability to attribute mental states to oneself and others, has traditionally been investigated in humans and nonhuman primates. However, non-primate species, such as domestic dogs, may also be potential candidates for such a faculty. Domestic dogs (*Canis familiaris*) evolved from a social-living, wolf-like ancestor, and were the first species to be domesticated, with likely selection for sensitivity to human cues and human-like cognitive abilities. Dogs typically spend their lives in the rich social environment of human families, and thus dogs are naturally enculturated. The combination of these factors make dogs an excellent candidate for having a functional theory of mind.

Yet perhaps surprisingly, prior research on theory of mind in dogs is limited, with inconclusive and contradictory results. The research described in this thesis is a systematic investigation of dogs' potential to demonstrate a functional theory of mind in their interactions with humans. Four experiments are presented, based on the Knower-Guesser paradigm (Povinelli et al., 1990), in which a knowledgeable and an ignorant human informant indicated the location of hidden food to the dog.

In Experiment 1, one informant was absent (Guesser) and one present (Knower) during the food-hiding, and the dogs chose the Knower. However, when both informants were present, the dogs chose the informant that did the baiting, but this preference was less than when the Guesser was absent. In Experiments 2 and 3, a third experimenter hid the food while the informants covered their cheeks (Knower) or eyes (Guesser) with their hands, or were attentive (Knower) or inattentive (Guesser) to the food-hiding. In both cases, the dogs showed a significant preference for the Knower. In Experiment 4, the dogs showed no preference between the informants when they had equal perceptual access to the baiting, and were unsuccessful at selecting any container when the informants did not provide communicative cues.

Overall, the present research provides the most definitive evidence yet that domestic dogs may be able to attribute differential states of knowledge to human observers, and thus may possess a functional theory of mind.

1 INTRODUCTION

The question posed nearly 30 years ago by Premack and Woodruff (1978) – ‘Does the chimpanzee have a theory of mind?’ – sparked a great deal of interest in the capacity for social cognition that nonhuman primates might possess. Primates have traditionally been considered the most likely nonhuman species to show advanced social cognitive skills. However, as research in animal social cognition advanced, the interest has shifted to a number of non-primate species that have emerged as likely candidates for this capacity, such as dolphins (e.g., Marino, 2002), birds (e.g., Emery & Clayton, 2001; Smitha, Thakar, & Watve, 1999) and dogs (Miklósi, Topál, & Csányi, 2004).

There are three main reasons why domestic dogs (*Canis familiaris*) are suitable subjects for studying social cognition. Firstly, they have common ancestry with wolves (*Canis lupus*), a social and cooperative species that may have evolved abilities to help predict the behaviour of others such as conspecifics and prey. Secondly, dogs have a long evolutionary history alongside humans. Throughout their domestication, they may have been selectively bred for skills relevant to humans, such as tameness, initially, and later more specific skills relevant in areas such as herding or companionship. Finally, they are a naturally enculturated species – they live with human families – and this may facilitate the development of advanced social cognitive skills (Cooper et al., 2003). Dogs’ advanced social cognitive skills allow them to communicate effectively with humans (Hare, Brown, Williamson, & Tomasello, 2002).

The research presented in this thesis is a systematic investigation of the social cognition of dogs. Specifically, dogs will be tested in a number of situations for their

ability to take the perspective of human informants, attribute knowledge states to the humans, and respond on the basis of these inferred knowledge states. The major question will be whether dogs will respond consistent with predictions based on their having attributed differential knowledge states to the informants, or whether their performances can be explained more simply in other terms. If the dogs are able to respond consistent with knowledge state attribution, then to the extent that other explanations can be ruled out, the research may provide evidence for dogs having a functional ‘theory of mind’ in their interactions with humans.

The first chapter presents a literature review. Initially, in the first section of the introduction, theory of mind will be defined, and its importance will be explained. After this an overview of constructs that may be a part of, or preconditions for, theory of mind will be presented, accompanied by a brief review of research associated with these constructs. An analysis of the major methodologies will then follow, explaining the main paradigms used to study theory of mind in nonverbal animals, including the Knower-Guesser paradigm.

In the second section of the introduction, the evolutionary history of dogs, both before and after their association with humans, will be discussed, with reference to the development of social cognition skills in dogs. Studies that have examined theory of mind in dogs will be reviewed. Finally, a rationale for the present research is given and specific hypotheses to be tested are described.

1.1 THEORY OF MIND

1.1.1 *What is a Theory of Mind?*

To have a ‘theory of mind’ is to have the ability to attribute mental states to oneself and others (Horowitz, 2002; Premack & Woodruff, 1978). With reference to these mental state attributions, explanations and predictions about another’s behaviour can then be made (Horowitz, 2004; Pearce, 1997; Whiten, 1991b). Heyes (1998) considers an individual to have a theory of mind if they possess mental state concepts, and subsequently use them to ‘explain’ and predict behaviour. Mental states include such constructs as *knowledge, belief, desire, intention, and feeling* (Cooper et al., 2003; Premack & Woodruff, 1978; Whiten & Perner, 1991).

An organism with a theory of mind is able to infer mental states from the outward behaviour or other observable features of others, and often to guide their own behaviour from this inferred information (Horowitz, 2002). The theory of mind system is defined as a theory not only because the mental states that are inferred cannot be directly observed, but also because the system generates ‘testable’ predictions of the behaviour of other individuals (Premack & Woodruff, 1978; Whiten & Perner, 1991).

Horowitz (2002) suggested that many species show some degree of theory of mind ability, and that this ability is graded. She suggests a hierarchy, consisting of a “theory of behaviour”, and a “rudimentary theory of mind” as precursors to a full “theory of mind”. A theory of behaviour is basically associative learning; the animal learns that a particular event predicts another event, or a particular behaviour results in a particular

outcome. A rudimentary theory of mind is intermediate to a theory of behaviour and a theory of mind. It suggests that the animal understands that there is a mediating variable between the behaviour and its observed outcome, however the animal may not have a representation of what this mediating variable is. A full theory of mind suggests that the animal understands that these mediating variables are constructs of the mind. A rudimentary theory of mind should allow an animal to predict future behaviour from current and past behaviours (Horowitz, 2002), and is essentially “behavioural abstraction” (Povinelli & Vonk, 2003). Behavioural abstraction entails forming abstract representations of behaviour, which allows behaviours to be categorised into classes of behaviours, which can apply across contexts. The animal can then make predictions about future behaviour, and adjust its own behaviour in response to these predictions (Povinelli & Vonk, 2003). A *functional* theory of mind simply proposes that an animal can behave as if it has a theory of mind, but the precise mechanisms governing its theory of mind may be different to those of humans’ theory of mind.

1.1.2 Evolutionary and Ecological Relevance of Theory of Mind

Cognitive capacities and behaviours generally evolve for a particular function, which proves beneficial not only to the individual (Griffin & Speck, 2004), but also to the species as a whole (Smith, 2003). The ability to ascribe mental states allows one to predict the behaviour of others, and this could be an important tool for survival (Whiten & Perner, 1991). By contrast, (Gallup, 1985) has suggested that it has been beneficial for

species to “act as if they had minds”. In terms of human psychological evolution, Gallup suggested that due to the social pressures that early humans faced, such as competition and cooperation, there was selection pressure to develop a theory of mind. However, these pressures would also have been apparent for other species, and thus other species facing similar situations should also possess elements of a theory of mind, or functional analogues. Due to the relatively continuous nature of evolutionary adaptation, it might be expected that theory of mind evolved gradually. As a result, the greater the phylogenetic distance between a pair of species, the greater the likely distance in theory of mind. A number of researchers have also proposed a similar continuum in terms of nonhuman theory of mind. For example, Tomasello, Call, & Hare (2003a; p.156) suggested that chimpanzees lack a “full-blown, human-like theory of mind”, and Horowitz (2002) suggested that theory of mind ability is graded. Unfortunately, researchers have tended to assume extreme positions, either with purely associative, low-level explanations for the social cognitive abilities of nonhuman species, or else with higher-level, mentalistic explanations (Miklósi & Soproni, 2006). Perhaps intermediate results which pose problems for these positions could be explained more readily if the continuous nature of such abilities was considered.

The majority of studies on theory of mind in animals have been conducted with nonhuman primates, typically chimpanzees (*Pan troglodytes*; e.g., Premack & Woodruff, 1978) and monkeys such as macaques (*Macaca* species; e.g., Hampton, Zivin, & Murray, 2004). The reasoning for this has been based on the homology between these species and humans. Thus, chimpanzees, who diverged from humans relatively recently in the course

of evolution – an estimated 6 million years ago (Pough, Janis, & Heiser, 2002) – are of particular interest to researchers due to their common phylogeny with humans.

However, convergent evolution is another valid source of theory of mind (or its functional analogues). Over the course of evolution, the faculty of a theory of mind may have emerged independently a number of times in different species (e.g., dolphins, Marino, 2002; Reiss & Marino, 2001; Xitco, Gory, & Kuczaj, 2004, and dogs, see below), much like the ability to fly has emerged independently in insects, birds and bats.

If an animal does not have a theory of mind, then it is only able to respond on the basis of observable behaviour, and learned contingencies between behaviours. However, if an animal has a theory of mind, then it can understand the mental implications of behaviour, such as knowledge, and can respond on the basis of inferred mental states, which can also be generalised to other contexts. For example, in a competitive foraging situation, if an animal has an understanding of a dominant conspecific's knowledge, it may be able to forage more effectively, by taking food the dominant conspecific does not know about, thus avoiding aversive interactions with the dominant (Bräuer, Call, & Tomasello, 2004). Frequently, research tends to overlook the functional (or lack thereof) aspects of having a theory of mind (Whiten, 1991a).

1.1.2.1 Why would humans be the only species with a theory of mind?

Many people consider humans to be in a distinct group to all other animals, even phylogenetically (Dennett, 1995; Pough et al., 2002). This is particularly true in terms of

subjective qualities such as emotion and cognition, including theory of mind. However, the differences between humans and nonhumans are likely of degree, not kind (Dennett, 1995). As Gallup (1985) succinctly said: “the only thing that defines man as special or even rational is man” (p. 631).

In some cognitive tasks, such as uncertainty monitoring, humans perform at approximately the same level as other animals, such as rhesus monkeys (Smith, 2003; Smith, Shields, Schull, & Washburn, 1997). Yet, different explanations are often provided to explain the performance of humans compared with other species. For instance, in the uncertainty monitoring tasks mentioned above, the performance of humans is explained metacognitively (i.e., humans are declaratively uncertain), whereas the performance of monkeys is often explained by low-level associative mechanisms (Smith, 2003). Therefore, if a human is attributed a theory of mind due to performance in a particular task, likewise, a nonhuman with equivalent performance should also be attributed a theory of mind (Smith, 2003). Conversely, if a human known to have a theory of mind (either through established tests or verbal report) fails a test purported to show theory of mind, then it is likely that the test is flawed in some respect to measuring theory or mind. It is important when designing these tests, to establish *a priori* predictions of what patterns of behaviour would be expected (from both humans and animals) if theory of mind was present or absent.

1.1.2.2 Why other animals could have a theory of mind

Characteristics of a species evolve according to the demands of the ecological niche they occupy (Pearce, 1997). Because these demands include interactions with the environment, conspecifics and heterospecifics, differences will exist across species in terms of physical, social and cognitive characteristics (Pearce, 1997). These characteristics therefore need to be taken into consideration when deciding what traits should be expected, in what capacity, and subsequently how they should be tested for. Abilities will also vary depending on the necessity or relevance to the particular species at hand.

It is rare for a phenomenon so complex as theory of mind to be present in its entirety in some species and completely absent in others (Westergaard & Hopkins, 1994). The social environment contains many challenges particularly relating to interactions with conspecifics. Therefore, group-living animals would be at an advantage if they could predict the behaviour of others, and thus may have evolved abilities which allow them to do so (Cooper et al., 2003). As a result, social animals may possess at least some aspects of a theory of mind.

The following section reviews the cognitive faculties that may be necessary for theory of mind, or that may be indicative components of theory of mind. Examples from the animal literature are also provided to give an outline of the field as it stands.

1.1.3 Previous Research on Theory of Mind and Related Constructs

1.1.3.1 Self awareness

Self-awareness is the ability to be the object of one's own attention (Gallup, 1985). Gallup (1985) suggested that if an animal is self-aware, then it can model the experience of others on its own past experiences. This ability would give an animal an advantage as it would enable it to predict the behaviour of others.

A popular way to attempt to determine if an animal is self-aware, or can recognise or perceive itself, is the mirror test (Heyes, 1998). In this test, the animal is exposed to a mirror, usually for a number of days, and its behaviour is observed. The important test is when a mark is unknowingly placed on the animal in a place where it cannot see without the aid of a mirror. If the animal subsequently investigates this mark with the aid of the mirror, then it is said to be self-aware. It has been suggested that if a species is capable of mirror self-recognition, then it may be capable of some mental state attribution (Povinelli, Rulf, & Bierschwale, 1994). Among the primate species that pass this test are humans, chimpanzees, orangutans (Gallup, 1985), gorillas and tamarins (Hauser, Kralik, Botto-Mahan, Garrett, & Oser, 1995). A non-primate has also shown mirror self-recognition – the bottlenose dolphin (Reiss & Marino, 2001). Dolphins were tested with the traditional mark test, and used mirrors and other reflective surfaces to investigate these marks. These findings suggest that it is not only primates that are capable of mirror self-recognition, and the ability may arise via evolutionary convergence as a consequence or co-factor of complex cognitive ability in general (Reiss & Marino, 2001). This convergence of

cognitive ability may be a by-product of the complex social environment in which both dolphins and primates live (Marino, 2002).

However, a number of species have been shown to fail the mirror test, including, in some studies conflicting those above, gorillas and tamarins (Hauser et al., 1995), and also dogs (Douglas, 2000). However, Hauser et al. (1995) suggested that these conflicting findings and apparent failures may be due to methodological issues. For instance, instead of simply putting a spot on a tamarin's face, which has given negative results, Hauser et al. dyed their distinctive white hair bright colours which, through mirror guided behaviour, subsequently indicated that the tamarins were aware of themselves.

Additionally, Hauser et al. (1995) argued that the mirror test does not adequately test for self-awareness, and what mirror self-recognition ability really means is ambiguous. Others have speculated as to whether mirror-self recognition provides an adequate test for a species-typical capacity for introspection (Westergaard & Hopkins, 1994). Salience may be a factor in an animal's success at the mirror test (Hauser et al., 1995). It may also be possible that an animal sees its reflection in a mirror, initially reacts to it as a conspecific, realises it is, in fact, itself, and has no further interest in it. Negative outcomes do not necessarily show a lack of self recognition, but may simply show that the animal may not have any interest in their external appearance (Csányi, 2005). In sum, self-directed mirror guided behaviour does not seem to be a valid test of self awareness.

1.1.3.2 Metacognition

It is useful to have access to what one knows, for instance what one has seen, because it may enhance problem solving skills by allowing the animal to focus on acquiring information it doesn't already possess (Bräuer et al., 2004). Metacognition is “cognition about cognition” (Smith, Shields, & Washburn, 2003), and more specifically, it follows that metaknowledge is ‘knowing what one knows’. Metacognition may also indicate self-awareness in both humans and animals, as in humans, one typically verbalises what one knows personally, for instance, ‘*I know...*’ (Smith, 2003).

Shettleworth & Sutton (2006) outlined a method to test animals' metaknowledge. In the task, animals are given the option of completing a memory or discrimination test, or ‘passing’ on any given trial. If the animal takes the test and is correct, it receives the reward. However, if it is incorrect, it goes unrewarded. If, however, the animal chooses to pass, it will receive a reward of less value than a correct answer, for example a small or delayed reward. Thus, if the animal knows that it knows the answer it should opt to take the test, whereas if it knows that it doesn't know the answer it should opt to pass. This tactic allows for maximal reinforcement. Importantly, the trials should differ on aspects such as difficulty and time delay. The response pattern can then be compared to performance on forced trials in which the ‘pass’ response was not available, or to transfer tests, in which either new stimuli are introduced or different presentations of stimuli are used (e.g., different presentation times; Shettleworth & Sutton, 2006).

Call & Carpenter (2001) suggested tasks to demonstrate metaknowledge (via apparent understanding of one's own perception and knowledge) as an alternative to the

traditional mirror test. Metaknowledge, or metamemory, can be considered to demonstrate self-awareness (Griffin & Speck, 2004). In Call and Carpenter's study, chimpanzees and orangutans had to choose a tube containing food from a number of tubes that they had or had not seen baited. The apes demonstrated that they knew if they did not know where the food was, by looking in the tubes before choosing; whereas if they had seen the baiting, and subsequently knew the location of the food, then they immediately chose the correct tube. Similar findings have been obtained with Rhesus macaques (Hampton et al., 2004). In this study, the monkeys sometimes looked in the tubes in the seen trials, but when this happened, it was the baited tube that they looked in, indicating that they perhaps had the knowledge of where the food was, but were just checking (possibly due to the relatively low cost associated with checking compared with the higher cost of getting a trial wrong). Memory awareness tests, which may demonstrate the understanding that an animal has of its own knowledge (Call & Carpenter, 2001), coupled with mirror tests, which may demonstrate an understanding of one's physical self, may provide measures of different aspects of self-awareness in animals (Hampton et al., 2004).

1.1.3.3 Imitation

Imitation involves the copying of the observable behaviour of another (Zentall, 2004), and may require the animal to understand both the goal and the means of the activity it is imitating (Topál, Byrne, Miklósi, & Csányi, 2006). A possible mechanism of

imitation is via secondary representations. Therefore, if an animal can competently imitate, then it may have secondary representations (Csányi, 2005; Suddendorf & Whiten, 2001). Furthermore, it has been suggested that imitation may involve the attribution of mental states, such as the intentions of the individual being imitated, and therefore may be relevant to theory of mind (Heyes, 1998). However, in contrast, Heyes (1998) argued that imitation is not a valid indicator of theory of mind. The imitator must only represent what the demonstrator does, and not necessarily what it intended.

Horowitz (2003) studied the imitative abilities of human adults, and compared these abilities with those of chimpanzees and human children from a previous study (Whiten, Custance, Gomez, Teixidor, & Bard, 1996). The task was to imitate the experimenter unlocking a box (“artificial fruit”), but the subjects were given minimal verbal instruction as to the nature of the task. It was found that the human children were the best imitators, while the adult humans performed at about the same level as the chimpanzees. Imitation is often thought of as indicative of one’s understandings of attention in others. However, if this meaning was inferred, it would suggest that adult humans do not have an understanding of intentional states in others (Horowitz, 2003). Instead, it could be considered that imitation does not reveal any information about the mental states attributed to others (Heyes, 1998), and cannot allow inferences about the understanding of the mental states of others to be made (Horowitz, 2003). It is also interesting (but perhaps not surprising) that verbal instruction has a major impact on performance in the task. With instruction, the propensity to imitate is greatly increased in both humans and chimpanzees. Evidently, the ability and the action of imitating are separate entities (Horowitz, 2003).

1.1.3.4 Language

Language ability may play a key role in the development and expression of theory of mind in humans, and may be the most significant difference between humans and other species, such as chimpanzees, in terms of theory of mind (Gallup, 1985). With regard to many complex cognitive functions, language may pose a means simply to communicate what is known, and also may have the added benefit of allowing manipulation of the thought of others (Gallup, 1985). However, in terms of testing for a theory of mind, language may provide humans with an unfair advantage over other animals. With language, humans can express their thoughts, and thoughts about others' thoughts, and so on, which is often considered to be evident enough of theory of mind. Perhaps if an animal had these communication abilities, then its competence for theory of mind would be accepted? However, even in cases of language trained animals, the answer is not definitive. For example, an African Grey Parrot (Alex) can verbally express his thoughts and feelings, as can a number of symbolic-language trained chimpanzees (Griffin, 2000). However, this is not always taken as decisive evidence of being at least self-aware, as the possibility of the behaviour being an associatively learned response cannot be entirely eliminated (Wynne, 2001).

1.1.3.5 Intentionality and deception

The appreciation by one animal that another's actions are predictable based on what it knows, allows it to influence behaviour by manipulating the information that is

available to the other animal (i.e., it can deceive it; Pearce, 1997). Deception requires that the deceiver can take the perspective of another individual, and withhold or provide misleading information (Gallup, 1985). Call and Tomasello (1998) conducted an experiment to see if orangutans, chimpanzees, and children differentially chose a baited box from intentional or accidental marking by an experimenter. They found that all three subject groups chose the box that had been intentionally marked significantly more often than the accidentally marked box (Call & Tomasello, 1998). Tomasello et al. (2003a) reported unpublished findings that chimpanzees differentially responded to humans unwilling or unable to give the individual an item of food. When the humans were unwilling, the chimpanzees behaved more impatiently, and left the test area sooner, compared with when the human was unable (but 'trying') to give the chimpanzee the food. It appears the chimpanzees were able to discriminate between intentional and accidental behaviours, and showed different behaviours accordingly (Tomasello et al., 2003a).

Deception has also been shown in caching behaviour in ravens and jays (Bugnyar & Kotrschal, 2002; Emery & Clayton, 2001). In ravens, cachers avoided conspecifics, and tended to cache behind structures. If interrupted by a raider, caching birds stopped caching and moved to a new site, or recovered their recent caches. Meanwhile, raiders maintained a distance between themselves and the cachers. Observing the location of caches was essential for a later theft. These results suggest that the ravens, both cachers and raiders, are capable of manipulating other birds by withholding information, and subsequently may be intentionally deceiving conspecifics (Bugnyar & Kotrschal, 2002). Similarly, scrub jays have been shown to change their caching strategies based on their

past experience. Like ravens, they will opportunistically thief from conspecific caches. The jays were subjected to two experimental conditions in Emery & Clayton's (2001) study: private caching and public caching. After the caching, the jays were allowed back to the caching site. Those jays that had previous experience of stealing from another bird's cache re-cached their food significantly more often if they had cached it in the public condition than if they had cached it in the private condition. If the jay had no previous experience of stealing, then it very rarely re-cached, regardless of the initial condition it was in (proportion re-cached was 0.10 and 0.06 for the observed and private conditions, respectively). The experimenters suggested that this may be an instance of tactical deception or mental state attribution (Emery & Clayton, 2001).

1.1.3.6 Gaze

Gaze following is important as it indicates information such as the object or subject of attention, and some intentions. For example, gaze-related cues may signal the direction in which an animal intends to move (Coren, 2000; Santos & Hauser, 1999). Subsequently, an understanding of gaze direction in others is a prerequisite to attributing mental states to others (Miklósi, Polgardi, Topál, & Csányi, 1998). Povinelli & Eddy (1996) stipulated three levels to visual perception. At the first level, animals can attend and respond to eyes with no reference to function. At the second level, animals can understand that vision "subjectively links an individual to the world" (p. 18). Finally, at

the third level, animals have the understanding that visual perception leads to changes in the state of knowledge of an individual (Povinelli & Eddy, 1996).

The ability to follow the gaze of others can provide valuable information about the environment, both physical and social (Call & Carpenter, 2001). Mutual gaze can also be a mode of communication between individuals. A number of species, including chimpanzees (Povinelli & Eddy, 1997), humans (Call & Carpenter, 2001), and macaques (Anderson & Mitchell, 1999) have been shown to follow the gaze of others. Chimpanzees have been shown to follow the gaze of another individual outside of their own visual space (Povinelli & Eddy, 1997; Tomasello et al., 2003a). Chimpanzees, bonobos, orangutans and gorillas have all been found to follow the gaze of humans, and also moved so they could follow a human's gaze (Bräuer, Call, & Tomasello, 2005). A number of species have been shown to use the gaze of a human in an object choice paradigm, for example, chimpanzees (Call, Hare, & Tomasello, 1998), domestic goats (Kaminski, Riedel, Call, & Tomasello, 2005), and South African fur seals (Scheumann & Call, 2004). Povinelli and Eddy suggested two reasons for the similarity of gaze following in chimpanzees and humans. Firstly, it may be that both species have a similar mentalistic understanding of other individual's minds, or secondly, gaze following may have originated as a source of information about salient environmental events such as predators and social interactions of conspecifics (Povinelli & Eddy, 1997).

1.1.3.7 Attention

Attention is a primary process of cognition (Gómez, 1991), and is important in visual communication (Gácsi, Miklósi, Varga, Topál, & Csányi, 2004). Understanding attention may also involve some understanding of mental states (Gómez, 1991). The ability to perceive the attention of others, such as conspecifics, prey, or predators, is a biologically useful skill (Suddendorf & Whiten, 2001). Attention is often broken down into numerous levels, ranging from an animal having the ability to attend to something, to understanding attention in oneself and others (Horowitz, 2002). Call (2004) outlined three important aspects of (visual) attention: reading attention (what others can see), following attention (e.g., gaze following), and directing attention (e.g., attention getting behaviours). Horowitz (2002) further expanded this by proposing seven levels of visual attention, ranging in complexity from simply being able to look at (“attend to”) something (level 1), to possessing an understanding of attention across multiple contexts (level 7), which equates to a ‘theory of attention’.

While investigating dolphins’ performance in a symbolic communication study, Xitco, Gory, & Kuczaj (2001) found dolphins to monitor the attention of human observers. When pointing to objects, the dolphins showed gaze alternation, and were also sensitive to the orientation and proximity of receivers. This suggests that dolphins have the ability of referential communication (Xitco et al., 2001). Additionally, it was shown that the dolphins never performed any of these behaviours in the absence of a human audience. In a later study, Xitco et al. (2004) found that dolphins directed more pointing and monitoring at humans in a position consistent with attending to the dolphin. The orientation of the receiver was manipulated, and the dolphins gestured significantly more

to a receiver in a forward facing position rather than a backwards facing position or swimming away position. The dolphins were also more likely to leave the area when the receiver was in the back facing and swimming away position than when in the forward facing condition (Xitco et al., 2004). The dolphins used in these studies had experience using a symbolic communication system, and it was suggested that this experience may have had an influence on their behaviour (Xitco et al., 2004). In general, language training, or human enculturation, may have an influence on other species' abilities to take the perspective of others (Xitco et al., 2004).

1.1.3.8 Perspective taking

There are a number of advantages available to an individual in a social species if it can know and exploit what another can see (Bräuer et al., 2004). For example, one can glean information from another knowledgeable conspecific, or know whether to try to get a resource (e.g., food or mates) based on what a dominant conspecific can see. Visual perspective taking is the “ability to understand how objects and events may appear from another’s perspective” and to understand that this may lead to different states of knowledge (Povinelli, Nelson, & Boysen, 1990, p. 204). In order to impute mental states to others, an animal must have experienced those particular mental states, and then must take the perspective of the other. From this, the animal can then infer mental states to the other, based on this direct experience (Whiten & Perner, 1991).

The ability to take another's perspective is an important aspect of a theory of mind. One way in which to measure this ability is through visual perspective taking. The question posed by studies on visual perspective taking is whether an animal will take the perspective of a conspecific (or a human), and reason about mental states in the conspecific from this perspective. For example, can an animal infer what the individual knows from what they may have seen, and behave differently according to the inferred mental states of the social partner? In a series of experiments, Karin-D'Arcy & Povinelli (2002) found that chimpanzees did not prefer to take food that was hidden from a rival conspecific's view, which was contrary to the predictions if the chimpanzees were taking the visual perspective of their conspecifics (Karin-D'Arcy & Povinelli, 2002). Hare et al. (2003) found that the behaviour of capuchin monkeys in a similar paradigm was also inconsistent with visual perspective taking, and was instead consistent with behaviour-reading (i.e., responding on the basis of the behaviour of the conspecific, rather than taking the visual perspective of the conspecific; Hare, Addessi, Call, Tomasello, & Visalberghi, 2003).

However, Premack & Woodruff (1978) tested an adult chimpanzee, Sarah, by showing her videotapes of a human in a particular problematic situation, followed by several photographs, one of which depicted the solution. When the person in the video tape was one of Sarah's preferred trainers, she chose the correct photograph, but when it was a less-liked figure, she chose a bad outcome from the photos (e.g., falling over). Premack & Woodruff considered this to be evidential of a theory of mind. Not only was Sarah showing an empathic response (i.e., putting herself in the actors situation, or perspective taking), but she was altering her responses depending on who the actor was.

Studies on perspective taking may provide an insight into the theory of mind abilities of animals. An individual that has had visual access to an event is likely to possess knowledge regarding that event (i.e., ‘seeing is knowing’), however, if it has not had this access, then it is probably ignorant towards the event. Thus if an observer animal spontaneously behaves differently in these two situations, as would be expected if differentiating between knowledgeable and ignorant individuals, then this would provide evidence suggestive of mental state attribution by the observer animal (Heyes, 1998). Therefore, a modified version of Povinelli et al.’s (1990) “Knower-Guesser” paradigm (see section 1.1.5.4) may provide evidence supporting the presence of a theory of mind (Pearce, 1997).

1.1.4 Methodological Considerations

One problematic aspect in research on nonhuman social cognition is the lack of a clear definition of theory of mind or its component constructs. Consequently, different research groups test different constructs (Horowitz, 2002). At best, cognitive functions of animals, especially metacognitive functions such as theory of mind, are extremely difficult to study effectively and objectively (Horowitz, 2002). Results are often ambiguous, depend heavily on interpretation, and can often be explained by multiple theories (Heyes, 1998). For example, deceptive behaviour can often be explained by both theory of mind, and also by the animal relying on observable features of the situation (Heyes, 1998), and basing its behaviour on learned contingencies. Horowitz (2002)

suggested that theory of mind can only be definitively shown in animals with verbal language ability, therefore, in non-verbal species, the only way to assess the ability to ascribe mental states is through inference from changes in behaviour (Cooper et al., 2003). However, some suggest that there is still no convincing evidence of theory of mind in humans when the criteria used in animal testing are applied (Gordon, 1998).

In many studies, the species' evolutionary history seems to have been disregarded, however this can, and does, have huge impacts on the performance of the species at hand. For instance, chimpanzees are often tested in food-related paradigms, which require cooperation between conspecifics or with humans. However, chimpanzees tend to be competitive regarding food, rather than cooperative (Tomasello et al., 2003a), thus the test may not reflect the true ability of the chimpanzees, as it is opposite to their natural behavioural tendencies. The physiological, social and environmental differences between species tend not to be thoroughly considered when planning these studies (Horowitz, 2002). Scenarios and equipment used are often far from what the animal would encounter naturally (Horowitz, 2002), which may interfere with the animal's ability to perform the task. Although this question seemingly gets little consideration in planning such studies, it is vitally important. A species with (evolutionarily) minimal social contact, for instance, will most likely have less ability for a theory of mind than a group living species. Also, the task that the individual needs to complete must be ecologically relevant to the natural history of the species (Tomasello et al., 2003a).

For example, Povinelli & Vonk (2004) described experiments from their laboratory, in which chimpanzees must choose to beg for food from one of two trainers in four different conditions. In the first condition, one trainer is facing the chimpanzee,

whereas the other has her back to the chimpanzee. The chimpanzees were successful in begging from the appropriate person in this condition (the forward-facing person). This successful result is probably a product of the chimpanzees' prior experience of interactions with trainers; when the trainer is in the cage with the chimpanzee, it is likely to be attending to the chimpanzee, and when it is leaving the room, with its back to the chimpanzee, the trainer is unlikely to be attending to the chimpanzee. Thus the chimpanzee would have had experience dealing with both of these situations, which likely facilitated performance during the test. In subsequent conditions, the chimpanzees had to choose between a trainer with a bucket on her head versus a trainer without a bucket on her head, between a trainer facing directly forward versus a trainer looking away from the chimp, and between a trainer blindfolded either across the eyes or the mouth. In these three conditions, the performance of the chimpanzees was poor (Povinelli & Vonk, 2004). However, the failure of the chimpanzees to respond correctly may likely be a consequence of the experimental design rather than a deficit in ability. In terms of both the natural history of the species and the ontogeny of the individual chimpanzees involved, the last three conditions were ecologically irrelevant. Firstly, the chimpanzees were begging from a human for food. In terms of the species, this is unusual, on one hand because of the species difference, and on the other because chimpanzees typically compete for food resources rather than share or cooperate (Tomasello et al., 2003a). Secondly, one might assume that the chimpanzees would have had limited experience with both buckets and blindfolds. Due to the element of learning involved in the development of a theory of mind, it is not surprising that chimpanzees would not immediately understand the state of the individual. Over the course of many trials, with

differential feedback, the chimpanzees were later more successful at the task (Povinelli & Vonk, 2004). Thirdly, the animal may have needed to experience the situation of the informant first-hand, to enable it to introspect and thus attribute a mental state to the other individual. Accordingly, for this to be successful, the chimpanzees would have needed experience not only with wearing a bucket and blindfold, but also at being the object of another individual's begging (i.e., the 'beggee'). It is unrealistic to expect that an animal will spontaneously produce ecologically irrelevant behaviours with which it has no prior experience during an experiment. Thus the ecological validity of a behaviour must be considered to determine whether a particular test is a valid one for theory of mind (Gácsi et al., 2004).

In determining appropriate methodology to use when experimentally testing for theory of mind, consideration should be given to the context that the ability of a theory of mind may have evolved in. The ability of the animal to perform will probably be greater when a more naturalistic approach is taken (Horowitz, 2002). By contrast, Gallup (1985) suggested that for a definitive test of theory of mind, the mental states to be attributed should be as far from biological relevance as possible. However, this may result in false negatives, as it is a very stringent criterion to be met. An animal doesn't necessarily need to be able to impute all mental states to all other organisms in all situations to have a theory of mind. It is also important to note that possessing a certain ability which is used in some situations does not necessarily mean that the ability will be used in other unrelated contexts (Szetei, Miklósi, Topál, & Csányi, 2003) such as an experimental setting. Therefore, researchers must also consider that "absence of evidence is not necessarily evidence of absence" (Hare et al., 2003, p. 141).

Due to the difficulty of determining metacognitive faculties from behaviour, it is perhaps best to break the construct down into more easily measurable units, such as attention and communication (Horowitz, 2002). By designing appropriate experiments, we should be able to determine what level of understanding of mental states is required for specified levels of performance in these tests. Gallup (1985) suggested that for a successful test for theory of mind, a number of components must be incorporated into the research. First, there need to be particular, well-defined criteria that must be met; second, data from a number of psychological sub-disciplines needs to be integrated; and finally, from the resulting concepts developed in the previous steps, there need to be testable predictions about the effects that a theory of mind would have on behaviour (Gallup, 1985). Additionally, there must be no *a priori* reasons why a species could not succeed at the given task (Miklósi et al., 2004). In the case of comparative studies, all species must have equivalent experience with the situation they will be tested in and the environment in general (Miklósi et al., 2004).

1.1.5 Paradigms to Investigate Theory of Mind

A number of methods have been used to attempt to find evidence for theory of mind in animals. When completing these tasks, there are two mechanisms proposed that animals use. The first is that animals can use cues learned through experience, and respond based on learned responses to these cues. However, if this is the case, novel problems would need to be re-learned to be successful. Alternatively, animals could learn

associations, and also obtain general knowledge leading to understanding. Thus, they can generalise this knowledge to new situations, and perform successfully (Call, 2004).

Among the methods used to assess theory of mind are the “Competitive Conspecific” paradigm, the “Ignorant Helper” paradigm, false belief tasks, and the “Knower-Guesser” paradigm. Research using each of these tasks will be briefly reviewed in the following sections.

1.1.5.1 Competitive Conspecific paradigm

In the “Competitive Conspecific” paradigm, two animals contend for food. The subject can observe whether the other conspecific has perceptual access to the location that the food is hidden. Subsequent behaviour of the subject is then analysed (Virányi, Topál, Miklósi, & Csányi, 2006).

Unlike the results of the competitive conspecific tests with chimpanzees and capuchins described above, there has been positive evidence from domestic goats in this paradigm (Kaminski, Call, & Tomasello, 2006). First, the animals are tested to determine pairs of dominant and subordinate individuals. In one of the test conditions, both animals could see one piece of food, but the dominant’s view of the second piece was blocked. They found that goats who had been the subject of aggression from the dominant during the experiment preferred the hidden piece of food. However if they had not received aggression, they first obtained the visible food, then the hidden food. In a non-social control, there was no significant difference in preference for the hidden or visible piece of

food. This finding suggests that goats are able to take the visual perspective of conspecifics, and react accordingly (Kaminski et al., 2006).

1.1.5.2 Ignorant Helper paradigm

Virányi et al. (2006) suggest for a test to appropriately detect knowledge attribution abilities, it must involve ‘object specificity’ and ‘subject specificity’. Object specificity refers to ‘what’ the parties have had perceptual access to, whereas subject specificity considers ‘who’ has the perceptual access.

The “Ignorant Helper” paradigm can also be used to test knowledge state attributions. It tests whether subjects are sensitive to the past perceptual access of others, and is an object specific test. Typically, a human Hider and a human Helper are present. There is a desirable object and a tool to get the object. The Hider hides the goal object and the tool, while the Helper is present for either the hiding of both, one or none of these objects. The test is the frequency that the animal indicates the location(s) of the object(s) to the Helper, depending on whether or not the Helper was present during the hiding of each object. If the animal uses knowledge state attribution, it should indicate the location of the objects more if the Helper had been absent when they were hidden; that is, the animal should recognize that the Helper does not know where the object is, and attempt to supply that knowledge (Virányi et al., 2006; see section 1.2.3).

1.1.5.3 False-Belief tasks

A common test for measuring false-belief in children is the “Sally Anne” paradigm (developed by Wimmer & Perner, 1983, and so-called by Baron-Cohen, Leslie, & Frith, 1985). This paradigm is acted out with dolls, puppets or live actors, while a child watches. In the presence of both characters, an object is hidden in one location. Then one of the characters leaves the room, during which time the object is moved to a second location. The child must then say which location the absent character will look for the object in. If the child can attribute false-beliefs, then he or she will indicate the first location. However, if the child cannot attribute false-belief, then the present location of the object will be indicated (Call & Tomasello, 1999).

Tschudin (2006) tested dolphins (*Tursiops sp.*) in a nonverbal version of this false-belief task. A training phase was first administered, in which a baiter hid a fish in one of two boxes (behind a screen so that the dolphin could not see the location), while a communicator watched. The baiter then removed the screen, and the communicator tapped the box containing the fish. The dolphin was then allowed to choose a box, and received the fish if it was correct. The dolphins were then tested with the false-belief trials, interspersed with true-belief and “dud”-belief trials. The trials proceeded as in the training phase, with the following exceptions. In the false-belief trials, the communicator left after the boxes had been baited, and the baiter switched the boxes. When the communicator returned, she indicated the box she thought was baited (now empty). True-belief trials were the same, except that the boxes were switched when the communicator returned, and she therefore indicated the box containing the fish. Finally, in the dud-belief

trials, the boxes were not switched, and so the communicator indicated the correct location. Importantly, the dolphins never knew the location of the fish until the communicator had indicated a box. The dolphins needed to choose the baited box on all occasions to show attribution of false-belief, which means that on the true-belief and dud-belief trials, they had to choose the indicated box, but on the false-belief trials, they had to choose the un-indicated box. Although the sample sizes were very small and so had low statistical power, the pattern of responses was indicative of the dolphins attributing false and true beliefs to the communicator (Tschudin, 2006).

However, Call & Tomasello (1999) tested orangutans and chimpanzees in a similar nonverbal false-belief task. Despite being able to choose the correct location in visible and invisible displacement trials, and ignore the marker used by the communicator if it was incorrect in the same setting, the apes were unable to pass the false-belief trials. The apes instead chose the container that was indicated (incorrectly) by the communicator, which suggests that these apes could not attribute false beliefs.

1.1.5.4 Knower-Guesser paradigm

The “Knower-Guesser” paradigm can be used to measure the extent of visual perspective taking and subsequently attribution of knowledge to the observed individuals (Povinelli et al., 1990). Basically, the paradigm consists of an animal observing (usually) human actors in a food-hiding task. One of the actors (the Knower) hides the food, while the other (the Guesser) is out of the room or otherwise cannot see the baiting (e.g., has his

eyes closed). Then, both actors point to different containers, which may conceal the food. The Knower points to the correct container, whereas the Guesser points to the incorrect container. If the animal has an understanding of the concept of seeing, can take the visual perspective of others, and subsequently attributes knowledge to the actor that has seen the baiting, then it should indicate the food container that the Knower is pointing to. A chance performance would indicate that the animal does not have a concept of seeing and does not attribute the state of knowledge. Povinelli has used the Knower-Guesser paradigm in a number of studies with chimpanzees (e.g., Povinelli et al., 1990; Povinelli et al., 1994), with variable outcomes. Povinelli et al. (1994) found that young chimpanzees under four and a half years old failed the test, whereas Povinelli et al. (1990) found that chimpanzees aged from seven to 28 years were successful at the task. Povinelli et al. (1994) suggested that this discrepancy was due to the age difference of the chimpanzees, with the ability to attribute mental states emerging sometime between four and half and seven years of age in chimpanzees.

However, the Knower-Guesser paradigm has been criticised, because it only tests for subject specificity (i.e., the animal must discriminate between two informants with different perceptual access), and so performance can be explained in terms of learning about discriminative cues and reinforcers (Virányi et al., 2006). Nevertheless, the Knower-Guesser paradigm has the potential to provide, at least, preliminary evidence for theory of mind, when designed appropriately. Povinelli et al. (1990) suggested that the Knower-Guesser paradigm addresses whether an animal can “understand that access to visual information leads to knowledge – the cognitive underpinnings of an ability to discriminate between guessing and knowing” (p. 209). Heyes (1998) also suggested that

the Knower-Guesser paradigm is “particularly promising” for investigating theory of mind.

The logic of the Knower-Guesser paradigm relies on “triangulation” (Heyes, 1993; Heyes, 1998). Triangulation requires an animal to be able to differentiate between two different (but related, e.g., knowledge and ignorance) mental states, across at least two situations, in which cues related to the mental states differ. Heyes (1998) suggests that methods involving triangulation may be able to show perspective-taking abilities. Initially, the animals receive discrimination training, for instance one informant does the baiting while the other is absent. Each behaviour is correlated with each knowledge state (i.e., the baiter is knowledgeable of the food location, and the absent person is ignorant). Following this there is a transfer phase, in which the knowledge states are correlated with a new set of features, for instance, the person with their eyes covered is unknowledgeable. If the animal immediately responds the same in the transfer test as it did in the discrimination training phase, then it has probably attributed mental states, and reacted accordingly.

Povinelli et al. (1990) investigated whether chimpanzees were able to understand the visual perspectives of others (humans), and the consequences of the visual perspectives that they held. They tested chimpanzees in a Knower-Guesser paradigm (as outlined above). In the first phase (discrimination training), four chimpanzees were extensively trained in the task. The Guesser left the room, and then the Knower baited one of four containers (including false baitings) out of view (covered by a hood manipulated by a third experimenter) of the chimpanzee. The Guesser then re-entered the room, and the Knower pointed to the baited container and the Guesser pointed to an

unbaited container. The chimpanzee then responded by selecting one of the containers. If the chimpanzee chose the Knower's container, it received the food reward, however, if it chose the Guesser's container, it was told it was wrong and the Knower typically revealed the contents of his container (but the chimpanzee did not receive the food).

After three to four weeks of training, performance stabilised, so the procedure was then altered by having the third experimenter and Knower wear blue hats during baiting and pointing. The Knower and Guesser conspicuously passed the hat between them as they changed roles. Combining the initial discrimination training and the modified version including the hats, the chimpanzees were extensively trained, with 300 trials each. The second phase was a transfer phase, in which they returned to the original routine excluding the hats.

Phase three explored what the chimpanzees had learned in a transfer test. The chimpanzees completed a total of 30 trials each in Phase 3. This phase was different in that both the Knower and the Guesser stayed in the room during the baiting, while the third experimenter hid the food. The Knower and Guesser stood beside each other where they could see the baiting, and just as the third experimenter was about to start the baiting, the Guesser put a paper bag over his head. When the baiting was finished, the Guesser removed the bag from his head and both informants pointed to a container each.

In Phase 1 overall, all four chimpanzees showed a significant preference for the Knower's location over the Guesser's location, and there was little or no change when the hats were introduced. However, the individual preferences for the Knower in blocks of 50 trials did not reach significant levels until the third block for two chimpanzees, and the fifth and sixth block for the remaining two chimpanzees. This means that they had

completed at least 100 trials before showing a significant preference for the Knower, and clearly had to learn the discrimination. In Phase 2 (hats eliminated) there appeared to be little change from the general level of preference in Phase 1. This suggests that although the chimpanzees had to learn the discrimination, it would appear that they were not using associative cues or rules, such as 'choose the person wearing the blue hat' to guide their choices.

In Phase 3, the critical transfer phase, 3 of the 4 chimpanzees retained a significant preference for the Knower, so it appears they extended what they had learned in Phase 1 to the transfer test. Because of this immediate transfer, Povinelli et al. (1990) suggested that this provided evidence that the chimpanzees were able to infer different knowledge states to the informants based on what they had visually experienced.

Povinelli et al. (1990) concluded that the chimpanzees' performances provided preliminary support for the hypothesis that chimpanzees can take the visual perspective of others, and understand that people with different perspectives from others possess different knowledge states, for instance, someone who has seen an event will have more (accurate) knowledge about that event compared to someone who did not witness the event. The chimpanzees can show an understanding of this by altering their behaviour to benefit from these differential knowledge states.

Povinelli & Eddy (1996) criticised Povinelli et al.'s (1990) study, because of the extensive training the chimpanzees went through before the transfer tests were administered. Also, the chimpanzees were not tested in a variety of situations with different levels of visual deprivation, and the chimpanzees also did not perform above chance in the first several trials in the transfer test. This suggests that the preference may

be due to rapid learning instead. Thus, to improve on the Knower-Guesser paradigm, it should be conducted with minimal (or no) discrimination training prior to testing.

Additionally, performance during transfer testing needs to be examined to ensure that the animals are not rapidly learning the discrimination rather than applying their knowledge of mental states.

1.1.6 Learning and Experience

A recurring controversy in the literature has been whether animals' ability to respond accurately in experimental tests of theory of mind might be explained simply in terms of associative learning (Premack & Woodruff, 1978). However, it could be argued that humans do not show a theory of mind without some learning. This can be exemplified by the performance of children on theory of mind tests. The necessary abilities for theory of mind begin to emerge at around 2-3 years in human children, but are far from fully developed at that stage (Berk, 2001). There is a significant improvement in children's abilities by age four (Kamawar & Olson, 1998). Premack and Woodruff (1978) suggested that a level of experience is necessary for human adults to possess a full theory of mind.

Developmental processes and learning may play a significant role in the development of a theory of mind in animals. This may be shown by the apparent lack of certain behaviours, such as self recognition in juvenile chimpanzees, which later occur in adult chimpanzees (Povinelli et al., 1994). Additionally, animals reared in isolation,

compared to socially-raised conspecifics, do not have the ability to respond appropriately based on the behaviour of conspecifics (Horowitz, 2002). This suggests that social animals, such as herd and pack animals, have a greater likelihood of possessing a theory of mind than non-social animals (Horowitz, 2002). Specifically, domestic dogs would be a likely candidate species for theory of mind, due to their common ancestry with wolves, who live in packs, and also because of their lifestyle living in human 'packs' (Csányi, 2005).

Additionally, to attribute a mental state to another, one must be expected to have a first-hand knowledge of that state, that is, one has experienced the state personally (Gallup, 1985). This emphasises the suggestion that to have a successful, complete theory of mind, the individual must have the relevant experience and learning. A laboratory raised chimpanzee may, therefore, not have the prerequisite experience necessary to succeed at its given theory of mind tasks, in comparison to group-housed or free-living chimpanzees.

Learning over the course of experimentation can also play a critical role in an animal's performance. Many experiments have numerous training trials, which allow the animal to learn a set of rules to enable successful performance in the task; and typically, a performance criterion must be reached before testing begins. When an experiment is conducted this way, it enables the animal's performance to be explained in terms of associative learning, rather than higher-order mechanisms (Pearce, 1997). Additionally, if extensive training in artificial tasks is required, then the animals may learn an association that is not expected by the experimenters (Gómez, 1998), which may subsequently provide invalid results.

A typical criticism of the Knower-Guesser paradigm is that the animals have learned to use the informants as discriminatory cues rather than making the distinction between the different knowledge states of the informants (Cooper et al., 2003). However, before an animal can make this discrimination, the animal must first realise that there is, in fact, a difference between the Knower and the Guesser that affects their perceptual access. Particularly if performance is spontaneous and stable across trials, then it is less likely that the animals are establishing rules from which to base their responses (Povinelli et al., 1990).

Often, experimenters wish to prevent any learning of associative cues over the course of testing trials. To achieve this, they avoid differential reinforcement. However, this could result in the opposite learning, and could thus impair the sensitivity of the test to find what it is looking for. For example, Virányi, Topál, Gácsi, Miklósi, & Csányi (2004) never rewarded dogs in a begging situation, regardless of their choice, and although they initially responded on all trials and had high rates of correct responding, by only the fourth trial, total responding had dropped by about 10%, and correct responding also decreased accordingly. It is therefore important to examine performance over the course of trials, regardless of whether the subjects are rewarded differentially or not. Changes in performance across trials could indicate any cumulative effects of reinforcement or nonreinforcement during the experiment.

Another problem with methodologies that require extensive training before administration of testing is the possibility that this training may coach the animals away from any natural tendency to use mental states to solve the tasks, thus resulting in underestimation of their abilities (Gómez, 1998). Furthermore, for tests to be maximally,

effective, they should occur in relatively naturalistic situations, with responses that don't need to be intensively trained. This manner of testing is more likely to expose abilities of animals, in situations that they evolved for. Moreover, in testing for mental state attribution, the animals should not be trained to make a discrimination. If they can attribute mental states, then they should immediately make the distinction, between, for instance, knowledgeable and ignorant individuals. The test then only needs a target response that is a spontaneous reaction on the part of the animal (Gómez, 1998).

The potential for using extraneous cues also affects many experimental interpretations. For instance, dogs have a very good sense of smell, and can detect smells at far lower concentrations (thousandths-millionths) than humans (Thorne, 1995). Thus, appropriate controls need to be implemented in order to assess the effects of such cues. A potential problem that is more difficult to control for is cues inadvertently provided by experimenters. For example, in the Knower-Guesser paradigm, animals may be able to discriminate between subtle (likely unconscious) differences between the informants (Cooper et al., 2003). This effect of unintentional experimenter-given cues is known as the "Clever Hans effect" (Miklósi et al., 1998). Hans was indeed a very intelligent horse, however, not in the ways initially purported. Instead, he was able to 'solve' mathematical problems and answer other questions by responding to subtle changes in body posture and tension by the people around him (Wynne, 2001). Thus, if experimenters must be present when testing animals, they must endeavour to include control conditions testing for the abilities of the animals to respond only on the basis of these subtle cues.

1.2 DOGS

1.2.1 *Why Would Dogs have a Theory of Mind?*

1.2.1.1 The ancestry of dogs

It is well known that domestic dogs evolved from wolves (*Canis lupus*; Brewer, 2001a). This has been determined from behavioural, morphological, and genetic evidence (Clutton-Brock, 1995; Coppinger & Schneider, 1995; Leonard et al., 2002; Nystrom, 2004; Vilá, Maldonado, & Wayne, 1999). Input from a number of subspecies of wolf, or from different wolf populations at different times and places, probably lead to some of the variation seen in dogs (Brewer, 2001b; Clark, 2001). Although genetic analysis has suggested that dogs had genetic input from several maternal wolf lines (Savolainen, Zhang, Luo, Lundeberg, & Leitner, 2002) or from more than one wolf population (Vilá et al., 1999), it is suspected that dogs originated from a single main gene pool, possibly in East Asia (Savolainen et al., 2002). Further evidence from genetic sequences implicates a divergence between modern wolves and dogs from a common ancestor around 135 000 years ago (Vilá et al., 1999). However, gene flow between wolves and dogs would have continued, and even today modern dogs and wolves can produce viable offspring (Morey, 1994).

Wolves are highly social animals, and live and hunt cooperatively (Thorne, 1995), in packs of about 7-8 members at optimum, but can range from 2-3 (Csányi, 2005) to up to 60 in some cases (Brewer, 2001a). Because of their social lifestyle, wolves have a well

developed social intelligence. For instance, if a wolf is attacked by a conspecific, it needs to interpret the situation in terms of its own and the aggressor's social rank, evaluate the objective of the attack, and consider status of others in the pack when it reacts. Context is an important consideration, as it affects the meaning of signals of wolves (Csányi, 2005).

Schleidt & Shalter (2003) suggested that the social aspects of canid ecology, such as cooperation, precede those of humans, and that they (“dogs, like wolves”) are aware of the identity of others, where they are, and what they are doing. This allows them to fit into both canine and human ‘packs’.

1.2.1.2 Domestication

Modern *Homo sapiens* appeared around 200 000 years ago (Pough et al., 2002). Although the exact time is uncertain, it appears that the early domestication of dogs started close to the appearance of *Homo sapiens*, and it would have been advantageous for both the dogs and humans involved (Csányi, 2005). Schleidt & Shalter (2003) suggested that early in the evolutionary history between humans and dogs (wolves), their co-living had mutual benefits, and therefore any changes could be considered as coevolution. Although genetic evidence suggests wolves and dogs diverged over 100 000 years ago (Vilá et al., 1999), archaeological evidence suggests that dogs were morphologically distinguishable from wolves, and closely associated with humans at least 10 000 to 15 000 years ago, and so this is usually suggested as the time of

domestication (Byrne, 2005; Clutton-Brock, 1995; Savolainen et al., 2002; Serpell, 1995b; Wynne, 2004).

Ancient humans and wolves would have occupied similar niches, resulting in interactions between the two species. Wolves that were less fearful towards humans probably lived in close proximity to human groups, and potentially scavenged rubbish and scraps (Thorne, 1995). It is also a possibility that wolves and humans followed each other during hunts (Brewer, 2001b). Humans probably took wolf pups (Brewer, 2001b; Clutton-Brock, 1995). However, when the pups reached maturity, they may have become less submissive, in which case they would have been driven away or killed. If they remained submissive, then it is likely they would have stayed with the humans and been allowed to breed (either naturally or artificially selected) with other ‘tamer’ wolves, resulting in ever tamer successive generations of wolves (Clutton-Brock, 1995), thus shaping the evolution of the domestic dog (Brewer, 2001b). Dogs were the first species to be domesticated (Clutton-Brock, 1995). Dogs may have been sources of food and fur (Serpell, 1995a), and their bones may have been used to make tools (Morey, 1994). Once “tameable and trainable”, they may have become working assistants and companions (Coppinger & Schneider, 1995; Morey, 1994).

Through this selection for tameness, other traits would also have changed, without selective breeding by humans, such as floppy ears, change in tail position, different coat colours and even a change in estrous cycle to become diestrous (Byrne, 2005; Coppinger & Schneider, 1995), as demonstrated by Belyaev (1979; as cited in Coppinger & Schneider, 1995). Belyaev bred silver foxes (a melanistic form of the red fox, *Vulpes vulpes*; Byrne, 2005) for tameness, which resulted in other traits changing to forms not

present in the founding population (and therefore could not have been selected for [genotype versus phenotype]; Coppinger & Schneider, 1995). Hare et al. (2005) tested this population of foxes on social tasks, after 45 years of selective breeding for tameness (chosen on the basis of approaching humans fearlessly and non-aggressively). Fox kits performed equally well as dog puppies in an object choice task (food location) with point and gaze cues provided by a human experimenter (Hare et al., 2005). Both the experimentally bred and control foxes scored above chance in this task, however, the experimental foxes were correct significantly more than the control foxes. This suggests that the socio-cognitive skills of dogs may be a by-product of domestication (Hare et al., 2005). However, this is not definitive, as other reasons could have also caused this change in dogs, for instance, selection by humans for responsiveness to human gestures (Byrne, 2005).

An important aspect of dogs' domestication was the ability to understand the communicative cues of humans (Bräuer, Kaminski, Riedel, Call, & Tomasello, 2006). Thus, functional behavioural analogues between dogs and humans may have occurred as a by-product of domestication (Miklósi, Polgárdi, Topál, & Csányi, 2000; Miklósi et al., 2004). Csányi (2005) suggests that, through domestication, dogs acquired mental traits that "resembled those of humans in many respects", and that through this likeness, humans and dogs became close. More recently in the evolution of dogs, there was likely to have been direct selection for social skills, suitable for dogs' working roles in human society (Cooper et al., 2003).

1.2.1.3 Dogs are naturally enculturated

Throughout the dog's evolution, it has become adapted (both naturally and artificially) for its natural ecological niche, human society (Csányi, 2005; Miklósi et al., 2004; Wynne, 2004). Dogs treat humans as if they are conspecifics and are attracted to the presence and touch of humans. Humans would have selectively bred dogs for their responsiveness to humans' communicative efforts, cooperation, and so on (Csányi, 2005).

Dogs are a naturally enculturated species, and by living in the human social setting, they have much experience at interpreting human social cues (Virányi et al., 2004). Unlike non-human apes that are often enculturated by rearing in a human environment, domestic dogs are “enculturated as part of their natural development” (Miklósi et al., 2004, p. 998). Animals closely associated with humans have the opportunity to learn to use human behaviour (whether intentional or not) to predict future events. This is likely to be due to learned associations/contingencies, but may facilitate development of more complex skills (Cooper et al., 2003).

Dogs may be successful at communicative tasks with humans in part because of their individual ontogenies with humans. Human families are the natural, and social, environment of dogs, which exposes them to high levels of social experience. This enculturation also has a strong effect on the responsiveness of animals to humans' directional cues (Soproni, Miklósi, Topál, & Csányi, 2001).

1.2.1.4 Convergent cognitive evolution with humans

Dogs have flexible and human-like social skills in a number of situations, often more so than species closely related phylogenetically, such as chimpanzees (Hare & Tomasello, 2005). The similar mental traits possessed by dogs and humans are a product of evolutionary analogy or convergent evolution – caused by similar selective pressures or conditions in similar environments (Csányi, 2005). Specifically the social cognitive skills of dogs are adapted to communication and other social situations with humans (Hare & Tomasello, 2005).

Both humans and dogs show evidence of neoteny, where juvenile characteristics are maintained into adulthood. Neoteny is a trait seen in many domesticated species. The behavioural plasticity that neoteny provides may enable both humans and dogs to advance their cognitive skills, including social cognitive skills, beyond those of their phylogenetic relatives (Cooper et al., 2003). Dogs retain both physical and behavioural juvenile traits (like those of juvenile wolves; Morey, 1994).

In all, the evolution and ecology of dogs provides a solid platform for dogs to possess a theory of mind. First, dogs evolved from wolves, a social animal that lives and hunts with its conspecifics. This requires a certain ability to interpret and predict the behaviour of conspecifics. Second, over the dog's evolutionary history with humans, it is likely that they would have been both artificially and naturally selected to be responsive to human cues, and to behave as if they have psychological capacities like those of humans (Csányi, 2005). This history may have resulted in similar mental traits through

convergent evolution, as dogs lived in human society, and to an extent were under similar selective pressures. Finally, dogs are a naturally enculturated species. Their natural social environment is with humans, and therefore, development of advanced social cognition may be enabled within individual lifetimes.

1.2.2 Previous Social Cognition Studies with Dogs

Although there is a relatively extensive body of literature concerning dogs' abilities to use human-given cues and respond to human attention levels, the literature in other areas of dog social cognition is limited.

1.2.2.1 Understanding intentionality

In the previous section, understanding intentionality was outlined as one of the potential indicators of theory of mind. However, in an object choice task, in which dogs had to choose between two cups that had been marked either intentionally (deliberately placed on the cup) or accidentally (knocked 'accidentally' onto the cup) with an inanimate marker by an experimenter, the dogs did not appear to differentiate between the cups (Riedel, Buttelmann, Call, & Tomasello, 2006). Instead, the dogs appeared to follow the rule 'pick the cup that was touched last'. Thus, the negative results may be due to a confound in the experimental design, in that both cups were touched in each trial, and the distinction between accidental and intentional marking may not have been clear to the

dogs. Thus, without further research in this area, conclusions cannot be drawn as to dogs' abilities to understand intentionality.

1.2.2.2 Imitation

Dogs may show some ability to imitate. Although they cannot identically reproduce most human actions due to anatomical differences, they can functionally copy. For example, Topál et al. (2006) trained a dog in the “Do as I do” paradigm, by training him to repeat human demonstrated actions on the command “Do it!”. They used “functional correspondence” as indicative of success. That is, if the behaviours had the same goal and were performed in similar ways as demonstrated (accounting for species-specific differences), they were considered successful. During testing, the dog was able to generalise his past experiences to perform a number of matching actions/sequences based on those of a human (Topál et al., 2006).

Pongrácz, Miklósi, Timár-Geng, & Csányi (2003) tested dogs in a situation similar to a two-action test, in which dogs were shown a detour around a V-shaped fence. The advantage to this was that, unlike traditional two action tests which require two different motor actions, this task had two solutions, equal in terms of required motor functions, and without any pre-existing preference for either action. The dogs predominantly chose the detour that had been demonstrated by a human. Pongrácz et al. (2003b) concluded that dogs are effective social learners, and that this may be due to

local enhancement, or response facilitation. Accordingly, dogs may be capable of imitation, although again, more research is needed in this area.

1.2.2.3 Metaknowledge

Bräuer et al. (2004) investigated dogs' knowledge about their own visual access. The dogs were either shown food being placed in a box (only one box was handled), or their view was occluded by screens in front of the two boxes (both boxes were handled so the dog did not know which one contained the food). The dogs were then allowed to inspect the contents of the boxes (each had a Plexiglas window) before making their choice by pressing a lever on the side of the box. The experimenter then lifted the box the dog chose, allowed the dog to eat the food if the response was correct, and then lifted the unchosen box (regardless of whether the dog was correct or incorrect). If the dog's response was incorrect then the dog was not allowed to eat the food. Although the dogs were highly accurate in the 'seen' condition and performed near chance in the 'unseen' condition, the dogs rarely checked for the food in either condition. The implication is that when the dogs did not know where the food was, they did not check more often. The authors noted one potential factor that could have affected the results is that the dogs had to be trained to press the lever, and therefore received a food reward whenever they pushed the lever. As a result of this training, they may have been unable to inhibit the response even though they were unsure of the location of the food. However, this is a speculative explanation, and overall results provide no conclusive evidence that dogs are

capable of metacognition, that is, there is no conclusive evidence that they are able to recognize when they do not know something and act on the basis of this awareness.

1.2.2.4 Understanding human cues

Human eyes have a substantial amount of sclera (the white region), which contrasts with the colour of the iris. This allows the eye gaze direction to be easily determined, which is an important communication tool (Coren, 2000). Dogs have less sclera than humans, as they tend to move their heads in the direction of their gaze rather than simply moving their eyes.

Numerous studies have been conducted investigating the ability of dogs to use human-given cues to find hidden food in the object choice paradigm. The first was Miklósi et al. (1998), who tested dogs with various momentary (lasting 1-2 seconds) gestures. These gestures included pointing (facing dog), bowing (looking at pot), nodding (looking at pot), head-turning (gaze horizontal), and glancing (gaze horizontal). When the person was an experimenter, overall, the dogs responded above chance for pointing and bowing. However, they appeared to learn the nodding and head-turning gestures, as preference for the indicated location was not significantly more than chance in the first block, but was significantly greater than chance by the last block. When the cues were provided by the owner (with a different group of dogs), they were initially above chance with all cues but glancing, which was above chance at the last block of trials. They were also able to generalise to the experimenter from the owner. It would appear that the dogs

could use the cues of a referential nature (i.e., bowing, nodding) immediately, but had to learn the non-referential cues (i.e., discriminative; head-turning, glancing). This is an important result because the former cues may be more valid predictors of human attention (Miklósi et al., 1998).

Soproni et al. (2001) elaborated on the study by Miklósi et al. (1998), and found that when informants turned their head and gazed at the target, the dogs were highly successful at choosing the right location (about 75% accuracy). However, when the cue was the head turned towards the target, but gaze was directed above the target, or only gazing at the target, they were less successful. Soproni et al. (2001) described the 'head-turn and gaze at target' cue as a combination of referential (head direction) and attentional (gaze direction) components. They further suggest that the cue of having the head turned towards the target may serve only a discriminative function (lacking referential information).

Soproni, Miklósi, Topál, & Csányi (2002) investigated the key components necessary for human pointing to be a successful communicative tool for dogs. The dogs performed best when the human pointed with outstretched arm and forefinger, and also showed some generalisation to novel gestures, further indicating the referential nature of pointing to dogs (Soproni et al., 2002).

McKinley & Sambrook (2000) also examined dogs' ability to respond to human given cues in an object choice task. Dogs were more accurate with pointing (no head or eye movement; about 85% correct), than with head-turning and gaze cues (with 65% and 60% of trials correct, respectively). When there was no cue, the dogs performed at chance. The dogs were also more successful when the pointing was close to the object,

rather than distal. McKinley & Sambrook (2000) also compared the performance of working gundogs, pet gundogs, and pet non-gundogs, finding that working gundogs used pointing significantly better than the other two groups. Both gundog groups were also better than the non-gundogs with the head-turn cue, but this difference was not significant. This finding illustrates that both breed differences and past training and/or experience may affect the ability of dogs to use human given cues.

Miklósi et al. (2003) investigated the effects of domestication by testing enculturated wolves (4 months old) in an object choice task, and comparing the abilities of dog puppies and young wolves in two problem solving tasks (opening a bin containing food and pulling on a rope attached to food, which was fixed so it could not move on the test trial). In the object choice task, the wolves could use a touching cue and proximal pointing, but could not initially use distal pointing (although they did improve). This highlights differences between wolves and dogs, as dogs are much more flexible in terms of the more subtle cues they can use in this paradigm. In the problem solving tasks, the dogs looked back at the human, and gazed at the human for longer than did the wolves. Miklósi et al. (2003) suggested that this finding could be due to a genetic predisposition of dogs to look at humans in a problem solving situation, a quality that may have increased the fitness of individuals with this tendency. This tendency appears to be absent in wolves, even if they had been raised in a “dog-like” environment.

Bräuer et al. (2006) compared the abilities of dogs and apes (chimpanzees and bonobos) to use various cues to find hidden food. They used communicative (pointing and looking), behavioural (reach and try to open) and causal (auditory & visual) cues. Dogs performed significantly better with social (communicative and behavioural) cues

than with causal cues or in the control condition. Specifically, they were more accurate with communicative compared to behavioural cues. Apes performed well with both social and causal cues with the use of causal cues significantly greater than in control trials. For communicative cues, dogs were more successful with pointing (about 90% accuracy) rather than looking/gazing, and performance was better for both types of cues when they were continuously presented (compared with only 4 seconds of presentation). They also differentiated between pointing and reaching (more responses to pointing), which the apes did not do. The dogs had limited success using causal cues. They responded to noise cues, but were more successful if the cup had been handled by the human. When the humans shook the wrong (empty, therefore quiet) cup, the dogs choose that cup, when they should have reasoned that it was the empty cup, and that therefore, the other cup contained the food. Thus, human touching is salient to dogs. A similar pattern was found with the visual cues. Apes however, used the causally relevant aspects of the cues (Bräuer et al., 2006).

Bräuer et al. (2006) emphasised the communicative nature of (the conventional human gesture of) pointing, compared with looking, which is sometimes an intentional communicative cue, and sometimes not. Subsequently, it makes sense for dogs to respond more to pointing than to looking as it is the more communicative cue (Bräuer et al., 2006). These results highlight the differences between dogs and apes, potentially due to the different nature of social interaction that occurs in natural groups.

Domestic dogs are successful at using human cues to find hidden food.

Agnetta, Hare, & Tomasello (2000) also looked at the cues that dogs can use to find hidden food. They used an inanimate marker (a sponge) and gaze with 5 conditions: place

marker and gaze at bowl, place marker/no gazing at bowl, gaze at bowl, hide marker behind barrier (but show dog the marker before hiding) and have marker already placed before the dog entered the room at the start of a trial. As a group, dogs performed above chance for all conditions except for when the marker was placed when the dog was absent. Because they did not use or even learn this cue over testing, it would support the idea that dogs do not use associative learning to pass these types of tasks (only one dog showed an increase from first block of controls pre-testing to the last block of controls post-testing for this cue). It also suggests that unintentional experimenter-given cues play a minimal role when testing dogs in this sort of situation; otherwise they might have performed above chance, because the human was present and knew the correct choice in each trial. Agnetta et al. (2000) also looked at age, and found no difference in performance from 4 months to 4 years, suggesting that dogs have a rapid ontogenetic process. They also tested young wolves (about 1 year old), who performed at control levels with point and gaze, and gaze cues (Agnetta et al., 2000). This contrasts with the finding of Miklósi et al. (2003) that young wolves could use pointing as a cue. However, the wolves in Miklósi et al.'s (2003) study were raised in human families, and this environment may have enhanced their responsiveness to human-given cues. Hare et al. (2002) also found wolves to be unsuccessful at using such cues, further highlighting the substantial effect of extensive enculturation.

Riedel et al. (2006) further investigated the ability of dogs to use a physical marker to locate food, by seeing what effect the visibility of different parts of the human during baiting had. Dogs performed better when they could see the hand placing the marker. In contrast with Agnetta et al. (2000), Riedel et al. (2006) found chance

performance when marker placing was done behind a screen, although this approached being significantly greater than chance ($p = 0.055$), and successful performance when the dog was unable to see the human during placement. However, the latter difference could be due to the fact that both the experimenter and the dog remained in the room (whereas in Agnetta et al., (2000), the dog was absent during the marker placement). Riedel et al. (2006) also included trials where the marker was removed in view of the dog before the dog was allowed to choose – the dogs performed above chance in all conditions when they saw the marker removed. Apparently, dogs are only successful at using an inanimate marker in an object choice task if they can directly infer that the marker has been manipulated by a human.

It is also important to assess whether dogs can use conspecific cues as well as those provided by humans. Hare & Tomasello (1999) found that, in an object choice task, dogs as a group were able to use both local enhancement and gaze and point cues ('pointing' with the body in the case of the dog informant) equally well. However, there was substantial individual variation, with some better at human-given cues, some better at dog-given cues, and some better at either local enhancement or gaze and point cues. The youngest dog (6 months) was above chance on the dog-given cues but not human-given cues, whereas the two oldest (4 years) dogs were above chance on human-given cues but not those of dogs (Hare & Tomasello, 1999). This suggests that, while many dogs can use both human and conspecific cues, this ability may be affected by the amount of exposure and socialisation the individual has with each species.

Like wolves, dogs have well-developed olfactory abilities (MacKay, 2004; Szeteci et al., 2003). Thus, a potential confound in food finding tasks with dogs is that they are

sensitive to the slight gradient in smell between the choices (typically food is permanently hidden in all choices, but additional food is added during the baiting). Szeteci et al. (2003) found that in an object choice situation, dogs were able to use olfactory and visual (watch baiting) cues to locate the food (odouriferous sausage) in open bowls, but if they were provided with human cues, they chose the bowl pointed at by the human. Also, if they saw the food 'hidden' (deceptive baiting), they chose that location (even if the food was actually in the other bowl). However, if the dogs saw the baiting, and then a human pointed to the other bowl, dogs performed at about chance. When dogs were allowed to sniff the (now covered) bowls before choosing, they chose the correct one. But again they followed deceptive pointing, unless they had witnessed the hiding themselves (Szeteci et al., 2003). Thus it seems that although dogs can use other sensory modalities, such as sight and smell, they will often choose to use human-given cues instead, even if they are contradictory to their own visual and olfactory sources of information.

Overall, this body of research suggests that dogs are sensitive to a number of human-provided cues, although their sensitivity to such cues can vary. It appears that the most universal and effective cue for canids is proximal pointing, with an associated shift in gaze direction, which lasts more than a few seconds. This natural propensity for dogs to use human cues is an important consideration when designing experiments to test their social cognition. Specifically, it means that the dogs do not need to be extensively trained in order to complete an object choice task, and thus the likelihood of subjects learning discriminative rules during pretraining is greatly reduced. Additionally, it may provide an explanation for the relatively poor performance of other species, such as some apes, on

more complex social cognition tasks, as the use of social cues is not in their natural behaviour repertoire.

1.2.2.5 Dogs and attention

Call, Bräuer, Kaminski, & Tomasello (2003) investigated whether domestic dogs were sensitive to the attentional states of humans. Their study consisted of a number of conditions, differing in the body orientation and gaze location of a human, during which the dog was forbidden to take a piece of food. They found that when the human was in an inattentive position (such as eyes closed, back turned or distracted – compared to eyes open and facing the dog), the dogs were more likely, and faster to take the food, and were also more direct in their approach to the food. They suggested that this showed the dogs were sensitive to the attentional states of humans. Although the dogs may have been responding to simple cues such as direction of eye gaze, or behaving based on other learned experiences (such as punishment when misbehaving whilst a human can see them), Call et al. (2003) suggested that the dogs can apply previous experiences and have an idea of peoples' knowledge based on what they have seen or not. Schwab & Huber (2006) also investigated dogs' discrimination of humans' attentional states, as expressed by differing everyday body postures, and found similar results to Call et al. (2003).

Virányi et al. (2004) manipulated the focus of a human's visual attention in an everyday situation. The owner, who was chatting to another person, commanded the dog to lie down. When issuing the command, the owner was either facing the dog, facing the

person they were chatting with, facing and looking into space between the person and the dog, or facing the dog, but from behind a barrier so that the dog could not see them. All of the dogs obeyed when faced by the owner. When visually separated, or when the owner was looking at the other person, the dogs were reluctant to obey or ignored the command completely. The interesting finding is that when the owner was looking away from both the dog and the other person, the dogs showed intermediate responsiveness (Virányi et al., 2004). Thus, it appears that the dogs knew to not obey the owner's command if the owner was attentive to another person, whereas the dogs were uncertain to obey when the owner wasn't attentive to either the dog or the other person. This supports Call et al.'s (2003) finding that dogs are sensitive to the visual attention of humans.

Gácsi et al. (2004) investigated the ability of dogs to differentiate between attentive or inattentive humans in another context, a ball fetching game, and also in an object fetching task. Dogs were more hesitant when they were returning the ball or fetching the object when their owners were blindfolded. When the owner was sitting, the dogs fetched the object to the front of the owner, but they were less successful in the standing/game situation. It appeared that in a game context, dogs were less discriminative, whereas in a fetching task, they were more differentiating. Gácsi et al. (2004) suggested that dogs were able to discriminate the attending person, but their choices were more definitive if there was an obvious difference in the head orientation.

Dogs have also been tested in a begging situation, which found that the dogs had a significant preference for the person facing the dog over the person turned away (Virányi et al., 2004). In a similar experiment, Gácsi et al. (2004) found that the dogs begged from

the attentive person (about 70% of the time). Gácsi et al. also found that dogs' were more likely to choose a human that was not blindfolded (approximately 60% of choices were made to the person that was not blindfolded).

'Showing' is a functional behaviour that can be defined as communicative in nature, and which consists of both a directional component and an attention getting component (Miklósi et al., 2000). Miklósi et al. (2000) found that dogs manipulated the attention of their owners by "showing" them the location of hidden food. They exhibited an increase in attention getting behaviours such as vocalisation and gaze alternation between the owner and the hidden food, which was far greater than when only the owner or food was present, and which enabled the owner (who was ignorant of the correct food location) to find the food.

Overall these studies show that dogs are sensitive to the states of visual attention of their human counterparts. The dogs also seemed able to differentiate between people that were attending to them or not, which provided preliminary evidence that dogs are able to attribute mental states (of attention) to humans, suggesting that they may have a theory of mind. The 'showing' behaviour found by Miklósi et al. (2000) goes further to suggest that dogs are also able to attribute knowledge states to humans, based on what the humans have seen.

1.2.2.6 Perspective taking

Bräuer et al. (2004) investigated whether dogs behaved differently depending on the visual perspective of a human. In their experiment, different types of barriers blocked the visual perception of a human when the dogs were prohibited by the human from taking a piece of food. When a large opaque barrier was positioned blocking the human's view of the dog, but not blocking the dog's view of the human, the dogs took significantly more food than when the barrier did not block the human's view. This suggests that dogs are sensitive to the visual access of humans. Bräuer et al. (2004) further investigated this effect with a large barrier that blocked the human's view of the dog's approach to the food and the actual retrieval of the food, a small barrier that did not block the path but did block the taking, and a large barrier with a window, which allowed the human to see the taking, but not the approach. Before testing, the dogs were familiarised with the window barrier. Dogs took the food significantly more with the large barrier than with either the small or window barriers, and there was no difference in the number of food pieces being eaten with the small and window barriers. When compared to the visible condition from the first experiment, there was no difference between the small barrier and visible conditions, but there was a difference between the window condition and the condition where there was no barrier, which suggests that the dogs particularly wanted to hide their approach. Overall, their results suggested that the dogs were sensitive to being seen when both approaching and taking a piece of forbidden food, and based this behaviour on what others can see rather than what they themselves can see (Bräuer et al., 2004).

1.2.3 *Theory of Mind Studies*

Currently, only a handful of studies on theory of mind in dogs have been published. However, it has been established that dogs are sensitive to human-given cues, and to human attentional states, as reviewed above. Because of the nature of the evolutionary history of dogs, and their close association with humans, it is likely dogs also have a theory of mind. Accordingly, the research is gradually shifting from general social cognition of dogs to theory of mind in dogs. The following section reviews the literature on domestic dogs' theory of mind thus far.

A modified version of the Knower-Guesser paradigm involves animals begging from either a person attentive ('knowledgeable') to them or not. Cooper et al. (2003) reported an unpublished study (similar to those by Virányi et al., 2004; and Gácsi et al., 2004; reported above) by their research group (Bishop & Young, in press), in which they tested dogs in this situation. They used a range of visual obstructions, including blindfolds, buckets and books. The dogs preferentially solicited for food from a person whose eyes were visible. Prior experience seems to play an influential role, as indicated by the more successful performance of dogs when choosing between a person with a book concealing their face and a person holding a book. It is very likely that dogs living in human families would have experience with people reading books, and therefore may have learned that reading humans are less responsive to behaviours such as begging than humans not reading books. However, they are far less likely to have prior experience with people wearing blindfolds or having buckets over their heads. This previous experience may have enhanced dogs' performance in this begging paradigm. However, the dogs also

showed a preference for the 'seeing' person in the other conditions, although the preference was not as marked as in the book-holding condition. Over all of the conditions, the dogs begged from the appropriate person on 68% of trials (Cooper et al., 2003). This study suggests that dogs are sensitive to the attentional states of humans, and differentially respond based on these states. It also suggests that although the dogs performed best under familiar circumstances (book-holding), it appeared that they were also able to generalise to other situations.

A further test of the knowledge attribution abilities of dogs was carried out by Virányi et al. (2006), with the "Ignorant Helper" paradigm. Virányi et al. (2006) suggested that the Ignorant Helper paradigm would be suitable for testing knowledge attribution in dogs, because it may be similar to situations encountered in daily life. In their experiment, a human Hider (the experimenter) and Helper (the owner) were present. The dogs received warm-up sessions, in which they were introduced to the use of sticks in a playful situation in the owner's home, where the experiment was based. During test sessions, the Hider placed a stick (the tool) and the toy in positions that the dog could not reach, either with the Helper present for the hiding of both the stick and the toy, the stick only, the toy only, or neither, in the guise of play. After a waiting phase, the Helper could retrieve the objects, relying on her knowledge if she knew their location (was present during hiding) or on 'showing' behaviour exhibited by the dogs during the waiting phase (she had to find the stick, then use it to reach the toy when she had found it). The dog was then rewarded with a short playing phase. The dogs signalled the location of the toy significantly more than the stick in all conditions, which suggests that they dogs were either not sensitive to the knowledge of the Helper, or alternatively, were unaware of the

significance of the stick. They may also have been unable to inhibit behavioural indications of their interest in the toy. In the second session, the dogs signalled the location of the toy more frequently if the Helper was ignorant of it.

Virányi et al. (2006) also tested children in this paradigm, and found that the children tended to indicate the location of the object that was unknown to the Helper more often than the known object location, and showed no significant difference between the two objects when both or neither locations were known. However, the children were still unlikely to indicate the stick location overall, and the difference between stick ignorant trials and stick knowledgeable trials failed to reach significance for both dogs and children

These findings suggest, that particularly in the case of the dogs, that the salience of the target plays an important role in the Ignorant Helper paradigm. The dogs may have signaled the toy more as it was more salient to them. That is, they had a high play drive (one of the preconditions of the experiment) and so were focused predominantly on, or motivated more, by the toy. Moreover, the pretraining was meant to familiarise the dogs with the use of the stick in the experimental context, it may not have overcome previous experience they had with their owners getting out of reach toys by other means.

Alternatively, they may not have understood the significance of the relationship between the stick and the toy. The results may have been an indication of the desire of the dogs to play, rather than their ability to inform an ignorant helper. Overall, this paradigm has some potential, but may need to be modified so that one object is not significantly more salient than the other, or so that it is a more accessible routine for the dogs to understand (i.e., involves behaviours from the humans that are more indicative of everyday life)

Horowitz (2002; PhD dissertation) studied the behaviours of dogs in a naturalistic setting, whilst playing in a dog park. She found that the dogs signaled play requests to other dogs that were attentive (designated 'receivers'). If the receivers were not attentive, the signaling dogs would act to obtain their attention, in many different ways if necessary (i.e., moved to get their attention, used various attention getting behaviours) before showing communicative behaviours soliciting play. Horowitz inferred from these results that the dogs had an understanding of attention, that is, they knew that there was a mediating variable ("attention") that predicted the other dogs' behaviour, and posits this as a rudimentary theory of mind. In terms of attention, this means that the dogs realised that their actions can change the attentional state of another, and followed this state-changing behaviour with actions that require attention (Horowitz, 2002).

The Cooper et al. (2003) research group modified the Knower-Guesser paradigm developed by Povinelli et al. (1990) so that the informants were conspecifics. Their rationale for this change is that dogs are adept at using cues provided by conspecifics (Hare & Tomasello, 1999). Initially, the dogs were trained to locate food that had been hidden behind one of four screens. They were then 'blinded' by covering the start box with a blanket, in which case they made more errors and were slower to respond. Another dog was then introduced, so that the 'blind' dog could use this other dog as an informant. The 'blind' dogs followed the dog informant, resulting in faster and more accurate responding. The dogs were then tested in the Knower-Guesser paradigm. The 'blind' dogs had to choose to follow either a dog who had seen where the food was hidden or one that had not (both had been trained to fixed locations). The dogs always followed one of the dogs, but did not discriminate between informed or uninformed. The authors

suggested that the dogs appeared to be more interested in socialisation rather than finding the food (Cooper et al., 2003). If taken at face value, this study suggests that dogs cannot attribute knowledge states to others, although perhaps a more likely explanation is a lack of motivation for the task at hand.

Cooper et al. (2003) reported another unpublished study again using a modified version of Povinelli et al.'s (1990) method. They tested 15 dogs, in 6 trials each, in the paradigm where they had to choose one of two locations (from three) pointed at by two human informants. While the targets were baited, the dog and the Knower were in the room, with the Knower in a position to see where the food was hidden. During the baiting, the Guesser was outside the room. When the baiting was finished, the Knower pointed to the baited location and the Guesser pointed to an unbaited location. In the first trial, 14 /15 dogs chose the Knower's location. However, on subsequent trials, performance was not different than expected by chance (which required 12/15 dogs to choose the Knower on each trial), although overall the Knower was preferred on 64% of trials. The initial accurate performance suggested that the dogs generalised knowledge from previous situations in their everyday life, and defends against the criticism that performance on these types of tests is due to associations learnt rapidly over the course of testing. Why their performance dropped after the first trial is unclear. The decrease may reflect interference from the previous trial, that is, returning to the previously rewarded informant or location (Cooper et al., 2003). However, it is unclear from Cooper et al.'s (2003) recount of the study as to whether the dogs received differential reinforcement or not. This may reduce the likelihood of dogs responding differentially, because they would

either receive or do not receive reinforcement regardless of their choice, thus reducing the sensitivity of the test, explaining the pattern of responding found in this situation.

Results of these studies using variants of the Knower-Guesser paradigm suggest the possibility that dogs may be more adept at using social cues provided by humans rather than dogs, a subtle difference that could be due to their domestication history with humans. Alternatively, the play drive of those dogs in the conspecific version simply may have exceeded the drive to respond correctly in the task and receive the (likely less valuable) food reinforcer.

Overall, although prior studies on theory of mind in dogs have some conflicting results, many of the negative findings might be explained in terms of motivational differences (e.g., failure in the Ignorant Helper paradigm, Virányi et al., 2006; and the conspecific Knower-Guesser paradigm, Cooper et al., 2003). The present research builds upon these studies, in an effort to find more evidence of the theory of mind abilities of domestic dogs.

1.3 THE PRESENT RESEARCH

1.3.1 *The Knower-Guesser Paradigm Reapplied*

As the prior literature review has shown, there are relatively few published studies which have examined the possibility that dogs have a theory of mind. The goal of the present research is to increase our knowledge of nonhuman social cognition by adapting the Knower-Guesser paradigm for dogs, and hopefully to provide an ecologically relevant test for a species that is naturally enculturated.

The Knower-Guesser paradigm has been suggested to be a suitable technique for assessing theory of mind in nonhuman animals (e.g., Heyes, 1998). Additionally, dogs are a highly suitable species to use in this paradigm, due to their extensive history with humans. Dogs have evolved advanced cognitive abilities, through both natural and artificial selection, equipping them for life in human society, and this includes sensitivity to human-given cues. Humans also provide food for their dogs, and so humans and dogs interact cooperatively with regard to food, to the extent that humans often show dogs where food is (Bräuer et al., 2006). Thus, they are suitable participants for this research, as it is ecologically valid in respect to their sensitivity to humans given cues, and their cooperative nature involving food (i.e., not using a species that tends to compete for food such as chimpanzees; Tomasello et al., 2003a). It provides a relatively naturalistic (in that human society is the dog's natural environment, and humans are the providers of food) setting to test an ability that would be a useful construct for the species to possess.

The present research is based on Povinelli et al.'s (1990) Knower-Guesser paradigm, initially designed for testing chimpanzees. A major point of difference in the methodologies between the two studies is that Povinelli et al. (1990) extensively trained the chimpanzees in a simple discrimination, before testing in transfer phases. However, in the present study, this initial discrimination phase forms the first condition of Experiment 1. The dogs were not put through any discrimination training prior to testing, and so results cannot then be attributed to learning of associative cues during training. Subsequently, the present research looked for spontaneous behaviour, rather than transfer after extensive training. Additionally, the conditions were not subject to inanimate objects used in bizarre or unusual ways, such as buckets and paper bags (cf., Povinelli et al., 1990; Povinelli & Vonk, 2004), which may prove distracting to the animals (Heyes, 1993). The present study will use differential reinforcement, in order to maintain response levels, and will have trial numbers intermediate between those previously used with chimpanzees (Povinelli et al., 1990) and dogs (Cooper et al., 2003). This will enable more sensitivity to find an effect, but will not provide the dogs with extensive experience in each condition. To determine whether the dogs do learn over the course of testing, analysis of performance across trials will also be completed.

As the prior literature review has noted, dogs are likely candidates for a theory of mind. Consequently, the primary hypothesis of the present research is that, when tested in the Knower-Guesser paradigm, dogs will respond as if they have a functional theory of mind for interaction with humans. Specifically, when given a choice between two human informants, one with perceptual access (i.e., is 'knowledgeable') to an event, and another without such perceptual access, if the dogs are responding solely on the basis of 'theory

of mind' then they should show a preference for the knowledgeable informant. Moreover, such preference should be evident from the start of testing because of their prior history of interaction with humans. By contrast, if the two informants have equivalent perceptual access, then dogs should not show a preference between them.

Four experiments are described, which systematically explore variables influencing dogs' performances in a Knower-Guesser paradigm. Experiment 1 compares dogs' preferences for the Knower in conditions in which just the Knower, or both the Knower and Guesser, are present during baiting. Experiments 2 and 3 attempt to minimize the availability of associative cues related to handling the food by having a third experimenter do the baiting, while perceptual access of the informants is manipulated through hand position (Experiment 2) or attentive/inattentive gaze (Experiment 3). Finally, in Experiment 4 the informants' knowledge was equated by having them both be attentive or inattentive on different trials, and the role of communicative cues was tested by a condition in which neither informant indicated a food container.

2 EXPERIMENT 1: HUMAN PRESENCE AFFECTS INFORMANT CHOICE BY DOGS

Experiment 1 employed a Knower-Guesser paradigm (see section 1.1.5.4), involving two human informants. Food (bait) was hidden in one of four containers, out of sight of the dog, after which the informants each pointed to a different container supposedly concealing the food. The dog was then required to choose a container in order to receive the food. In the “Guesser Absent” condition, the dogs chose between the person who had been present during the food-hiding, and therefore knew the location of the food (designated the “Knower”), and the person who was absent during the food-hiding, and therefore did not know the location of the food (designated the “Guesser”). The “Guesser Present” condition was identical in all respects except that the informant who did not hide the food (the “Guesser”) was present and thus also observed the baiting.

If the dogs were able to attribute knowledge states based on what the human informants had or had not seen, and based their choices solely on these attributions, then they should show a significant preference for the Knower in the Guesser Absent condition ($p[\text{Knower}_{\text{GA}}] > .50$). By contrast, the dogs should be equally likely to choose the Knower or the Guesser in the Guesser Present condition because both informants knew the food location ($p[\text{Knower}_{\text{GP}}] = p[\text{Guesser}_{\text{GP}}] = .50$). Alternatively, if dogs were using associative cues entirely to guide their choices, they should show a significant preference for the Knower in the Guesser Absent condition, and an equivalent preference for the Knower in the Guesser Present condition ($p[\text{Knower}_{\text{GA}}] = p[\text{Knower}_{\text{GP}}] > .50$). If dogs used both knowledge state attribution and associative cues in making their choices, then a significant preference for the Knower might be obtained in both conditions, but

that preference should be greater in the Guesser Absent condition ($p[\text{Knower}_{GA}] > p[\text{Knower}_{GP}] > .50$). Examination of any changes in performance during testing was also planned. If the dogs' choices were determined primarily by associative cues, then performance should improve gradually across trials due to reinforcement learning. On the other hand, if choices were determined by knowledge state attribution, then presumably the dogs' histories of interactions with humans would allow them to perform at maximal accuracy from the start of testing. Additionally, examination of the relationship between the dogs' performance and their age and sex was also planned.

2.1 METHOD

2.1.1 *Subjects*

Sixteen experimentally-naïve domestic dogs (6 males, 10 females; mean age = 4.7 years, range: 10 weeks – 13 years) participated in the experiment with their owners. The age and sex of the dogs are listed in Table 2.1, and the breeds and training history of the dogs are listed in the Appendix. Two dogs were excluded from the study at the pretraining stage due to a lack of motivation to perform the task, and one dog was excluded after completing the Guesser Absent condition because the owner withdrew participation. Results from these dogs were excluded from analyses. The owners of the dogs were recruited via advertisements at the University of Canterbury and through personal contacts by the experimenter. The only selection requirements for dogs in the study were those of basic obedience and a strong food drive. Owners were asked to ensure their dogs had not eaten any food for approximately 2 hours prior to each session. Dogs were tested individually, and owners were present at all times throughout testing. They were seated beside their dog, and were instructed how to behave during the testing (see below). All but one of the owners assisting in the experiment were female, and their ages ranged from 9 to 54 years.

2.1.2 Apparatus

The testing took place in a room (4.5m x 3.7m x 1.6m x 3.7m) at the University of Canterbury that was unfamiliar to all dogs and owners. The arrangement of the room is depicted in Figure 2.1. An extractor fan in the front left upper corner of the room provided white noise during testing. The room was lit with a fluorescent tube light fixture. There was a small table (38cm height x 40cm depth x 80cm width) at the back of the room, on which a notebook computer with inbuilt camera used to record the sessions was placed. In front of the table, there was a panel heater (183cm width x 23cm height, raised 22cm from the floor), which the dog sat in front of during training and testing (see

Table 2.1. Name, sex, and age at start of testing (in years unless stated) of subjects included in Experiment 1 and Experiment 2.

Dog	Sex	Age
AJ	male	13
Asha	female	7.5
Bonnie	female	7
Boss	male	1.5
Daphne	female	10 weeks
Fluff Fluff	female	8
Jasmine	female	2
Libby	female	9 months
Lucy	female	2
Max 1	male	4.5
Max 2	female	2
Ronin	male	6
Rouke	male	8 months
Saffie	female	8
Zeb	male	11
Zoe	female	8 months

Figure 2.1). The dog's owner sat on a stool on the dog's left for half of the trials and on its right for the other half. The informants knelt at the front of the room, behind a removable screen. The screen consisted of a piece of chipboard (220cm width x 56cm height x 0.4cm thickness) with an 'L' shaped brace at either end, so that the board was free-standing, but could be lowered flat onto the floor. This enabled easy manipulation of the screen by the experimenters, and also allowed the dog to walk over the board during

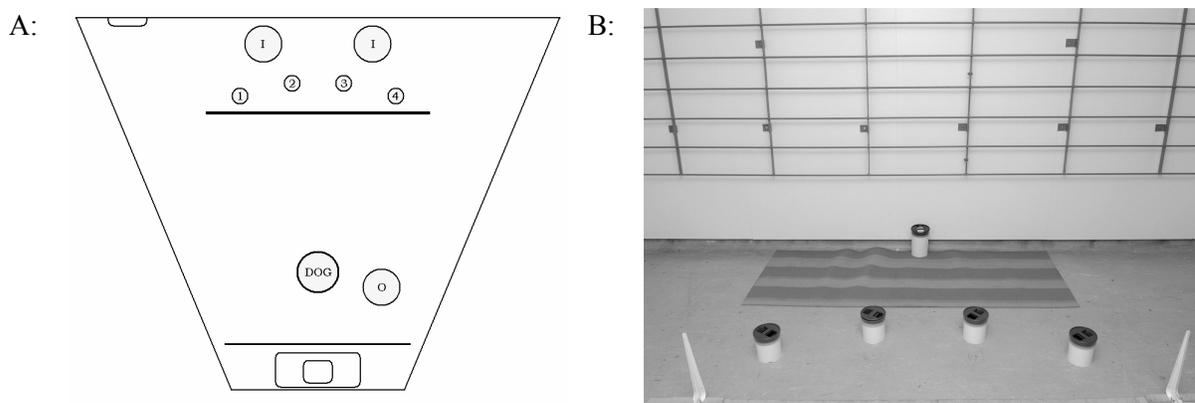


Figure 2.1. **A:** A schematic plan view of the experimental room and setup as for Experiment 1. The two informants (I) knelt behind four containers (1-4), arranged in a semicircle behind a screen. The dog sat near the centre of the room facing the informants, restrained by its owner (O), who was on the dog's left for half of the trials and on the dog's right for the other half of the trials. Behind the dog was a table with a notebook PC recording the sessions. **B:** A photograph of the apparatus used in Experiments 1-4. The experimenters knelt on the mat behind the containers; the dog was below the vantage point of the photographer. The screen is shown in its lowered position.

the trials (the braces were at either end of the screen and so did not interfere with the dog's line of travel, and protruded 32cm from the floor when the screen was in a lowered position). The height of the screen was such that when it was raised, the dog could see the

experimenters' faces and upper torsos, but not their hands or the containers. Four containers (13cm height, 10cm diameter) were placed between the experimenters and the screens. The containers were air-tight "Click Clack[®]" containers, which had been covered in opaque white plastic covering. They were also lined with a layer of thick fabric (non-woven wadding; approximately 8mm thick) around the sides, and two layers in the bottom. This prevented the food from making a noise when deposited into the containers. A piece of food was also hidden between the two layers of fabric in the bottom, so that all the containers smelt of food regardless of whether they were baited with food for a particular trial or not. The containers were placed 45cm apart, in a semicircle arrangement, and equidistant from the dog. The food treats (bait) were small (approximately 15mm x 15mm x 10mm) pieces of commercial dog food ("TUX[®] Small Dog"), or commercial dog treats ("Schmackos[®]"; approximately 10mm x 10mm x 2mm) for the smaller dogs. The supply of treats were kept in an airtight "Click Clack[®]" container, covered with opaque plastic covering (17.5cm height, 10cm diameter), centred behind the two experimenters.

2.1.3 Procedure

After pilot testing with two dogs, the following procedures were used for the experiment proper.

2.1.3.1 Pre-Training

All dogs were exposed to a pre-training procedure. During pre-training, both experimenters were present and one container was initially used. One of the experimenters showed the bait to the dog (restrained by its owner), then, in full view of the dog, put the bait into the container. The experimenter that hid the food then pointed to the container. The pointing technique used was an extended arm, with extended forefinger touching the lid of the container, with gaze directed to the container (see below). The owner restrained the dog for a further two seconds from the commencement of pointing, then released the dog and allowed it to make a response. If the dog made the designated response of approaching and gazing at the container, it was given the food from the container. The dog was then called back to the starting position by its owner, and the next trial began. Trials were repeated until the dog had made the correct response on two consecutive trials. The experimenters alternated pseudo-randomly, with the constraint that the same experimenter was not the baiter for more than two consecutive trials, and so that the dogs had approximately equal exposure to each experimenter at each level of pre-training. The number of containers was then progressively increased to 2, 3 and 4, provided that the dog had responded correctly on at least two consecutive trials at each level. Upon reaching this criterion, the screen was introduced. The screen was raised at the start of each trial, and the experimenter hiding the food got the dog's attention by calling it, and showed the dog the piece of food above the screen, before hiding it in a container. Then the experimenter lowered the screen, pointed to a container, and the dog was allowed to make its choice as above. After four consecutive correct

trials, false baitings were introduced. False baiting consisted of opening and closing each container, while pretending to put the bait into each (described below). Only one of the containers was actually baited. This continued for an additional 6 consecutive correct trials. Across dogs, the total number of pre-training trials required to reach criterion ranged from 18 to 33 trials. Although both experimenters were present during pre-training, at no time was the dog required to choose between the two experimenters.

2.1.3.2 Testing

Experimental testing consisted of two conditions in which the Guesser was either absent (“Guesser Absent”) or present (“Guesser Present”) during the baiting. The order of completing the conditions was counterbalanced across dogs. The dogs were given a short break after completing pre-training, which was immediately followed by testing.

Guesser Absent condition

The test trials implemented a Knower-Guesser paradigm (see 1.1.5.4), adapted from Povinelli et al. (1990). There were two female experimenters; each designated the role of Knower or Guesser on a given trial. Across trials, the experimenters’ roles alternated pseudo-randomly, with the constraint that the roles were not the same for more than 3 consecutive trials.

An experimental trial in the Guesser Absent condition proceeded as follows: The dog was led to the middle of the room, approximately 1.2 metres away from the

containers, and told to sit by its owner, who restrained the dog at all times by holding its collar or a short lead. The experimenter designated as the guesser (hereafter the “Guesser”) left the room, following which the remaining experimenter (hereafter the “Knower”) raised the screen (Figure 2.2). The Knower then baited the container designated for that trial according to a standard procedure, including false baitings. False baitings were used to equate the amount of handling the containers received on each trial. The baitings proceeded as follows: The Knower obtained the dog’s attention by calling its name, and showed the dog the food that was to be hidden. The Knower began from the left or right container (counterbalanced), and baited each container once. On each trial, three of the baitings were false. Baiting involved opening the container, putting the hand into the container, leaving the piece of food if it was a real baiting, and removing the hand and putting the lid back on the container, then repeating with all of the containers. Baitings occurred behind the screen, which occluded the dog’s view of the containers, but not of the experimenter’s upper torso. The screen was then lowered, and the Guesser re-entered the room and resumed her position by the Knower. After two seconds, the informants each pointed to a container.

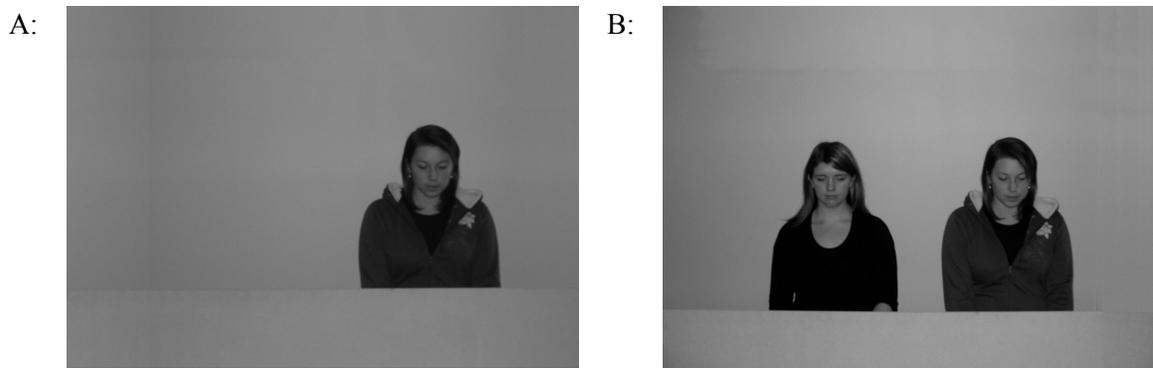


Figure 2.2. **A:** In the Guesser Absent condition, the Guesser left the room whilst the Knower baited the containers. The dog could see the upper torso and head of the Knower (who conducted the baiting) throughout the experimental trial. **B:** In the Guesser Present condition, the Guesser stayed beside the Knower whilst the Knower baited the containers. The dog could see the upper torsos and heads of both the Knower and the Guesser throughout the experimental trial.

The cue used by the experimenters to indicate a container to the dogs was pointing and gazing, which is a familiar cue for most dogs (Miklósi et al., 1998). The pointing gesture was standardized as follows: The experimenter's body was oriented forward, with the closest arm extended towards the container, and forefinger touching the lid of the container, while her head and eye gaze were oriented towards the indicated container (Figure 2.3). The pointing gesture continued until the dog made the choice response or until the trial ended. Aspects of this pointing method have been shown to be successful communicative cues between dogs and humans (Miklósi, Pongrácz, Lakatos, Topál, & Csányi, 2005; Soproni et al., 2001). The experimenters positioned themselves at the outset of each trial to avoid cross-pointing, as this has been shown to decrease the



Figure 2.3. The pointing technique used by the informants to indicate the location of the bait to the dogs.

efficacy of the pointing gesture (Soproni et al., 2002). The Knower pointed to the baited container, whereas the Guesser pointed to an un-baited container. These locations were counterbalanced and pseudo-randomly assigned for each trial prior to the experiment, subject to the constraint that either the Knower or the Guesser did not point to the same container more than twice in a row. After a two second delay, during which the informants continued to point at the respective containers, the dog was released by its owner, and allowed to make its choice. A choice was defined as having occurred when the dog approached one container, and touched or gazed directly at it (Figure 2.4). If the dog did not respond within 60 seconds, then the trial was stopped and recorded as no-response. If the dog made the correct choice (i.e., chose the container pointed to by the Knower), then it received the food reward and verbal praise. If the dog made an incorrect response, it did not receive the food reward, and the owner called it back to the starting position. During the choice phase, the owner was allowed to provide the dog with a release command or verbal encouragement (for example, “okay”, “go”, “where is it” and so on).



Figure 2.4. To make a choice, the dog was required to approach and touch with its muzzle or paw, or directly gaze at, one container.

The position of the bait, identity of Knower and Guesser, the side they were on, and pointing locations were counterbalanced across trials. Each dog completed 24 trials in the Guesser Absent condition.

Prior to testing, the owners were instructed to restrain their dog at all times except during the choice phase, when they were to release the dog after the informants had been pointing at the containers for two seconds. The owners were able to watch the baiting, but because their visual perspective was similar to that of the dogs' they were unable to see the actual location of the bait. The owners were also asked not to look at the informants during the choice phase, to reduce the likelihood of the dogs using their gaze direction as a choice cue. At the end of each trial, the owner called the dog back for the commencement of the next trial, which began when the informants had repositioned themselves for the next trial and the dog was ready in the starting position.

Guesser Present Condition

The procedure in the Guesser Present condition was identical in all respects to the Guesser Absent condition, with the exceptions that both informants were present for the entire time (Figure 2.2), and that both of the containers that were to be pointed to were baited. Thus, although the Knower did the baiting as before, the Guesser also witnessed it and thus both informants knew the location of the food. The dog received the food reward regardless of its choice of informant. Each dog completed 24 trials in the Guesser Present condition.

All training and testing in Experiment 1 occurred during two sessions. The first consisted of pre-training and either the Guesser Absent condition or the Guesser Present condition; the remaining condition was tested in the second session. Each session had a break in the middle, for approximately 5-10 minutes, for the dog to go outside, and a smaller break after half of the trials for each condition, in which the dog was allowed into the adjoining room for a drink of water and a break.

An independent observer coded a randomly-selected 12.5% of the trials (3 trials per dog) in both conditions. The percentage of inter-observer agreement was 97.9% (Cohen's $\kappa = 1.00$) and 100% (Cohen's $\kappa = 1.00$) for the Guesser Absent and Guesser Present conditions, respectively.

2.2 RESULTS AND DISCUSSION

Overall, dogs responded to the location pointed at by the Knower or the Guesser on 97% of trials ($N = 745$). Trials with no responses ($N = 7$), or in which the dog chose a container that was not pointed at by the Knower or the Guesser ($N = 16$) were omitted from subsequent analyses.

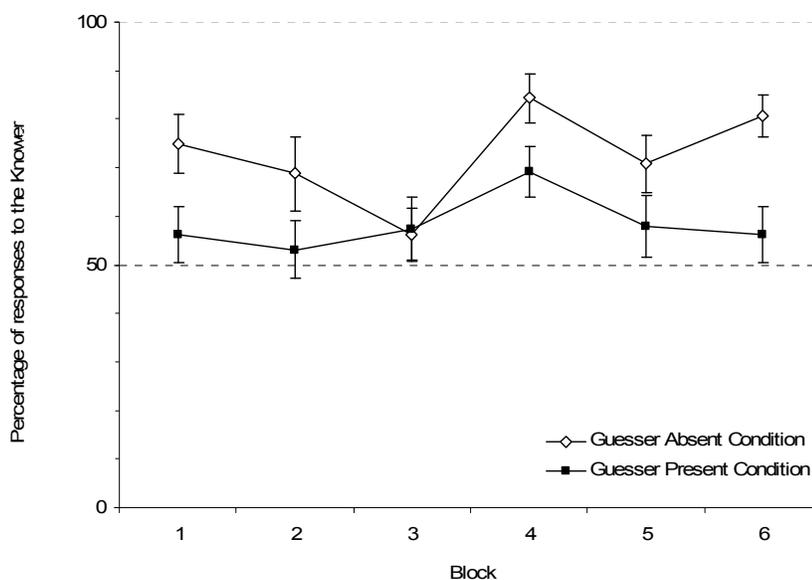


Figure 2.5. Mean (± 1 SE) percentage of choices for the Knower, over blocks of four trials for the Guesser Absent condition and the Guesser Present condition in Experiment 1. The dashed line represents chance (50% of trials with a Knower or Guesser response).

Figure 2.5 shows the percentage of choice responses made for the Knower across successive trial blocks for both the Guesser Absent and Guesser Present conditions in Experiment 1. To determine whether the choices for the Knower were different between the two conditions, and whether it depended on the amount of practice or the order in

which the conditions were completed, individual data from Figure 2.5 were entered into a repeated-measures analysis of variance (ANOVA) with condition and block as within-subject factors, and order (i.e., Guesser Absent – Guesser Present; or Guesser Present – Guesser Absent) as a between-subjects factor. There was a significant effect of condition, $F(1,14) = 19.552, p < 0.001$, indicating that the proportion of choices for the Knower was greater in the Guesser Absent ($M = 0.73$; 95% CI: 0.66 to 0.79) than the Guesser Present condition ($M = 0.58$; 95% CI: 0.51 to 0.65). There was no significant effect of presentation order, $F(1,14) < 1, ns$, and there were no significant interactions. There was, however, a significant main effect of block, $F(5,70) = 3.822, p < 0.01$. Across blocks, performance varied from 56% (Block 3) to 84% (Block 4) and 53% (Block 2) to 69% (Block 4) in the Guesser Absent and Guesser Present conditions, respectively. To test whether performance changed systematically across blocks, linear contrasts were conducted, which failed to reach significance for the Guesser Absent or Guesser Present conditions, $F(1,14) = 1.516, ns$; $F(1,14) < 1, ns$, respectively. A series of Tukey HSD tests showed that preference for the Knower in Block 4 was significantly greater than preference in Blocks 2 and 3. No other pairs of Blocks were significantly different. Overall, these results are consistent with the hypothesis that the dogs used knowledge attribution cues to determine their choices.

Next, the overall preference for the Knower was assessed, to determine if it was significantly greater than chance (i.e., 0.50). For the Guesser Absent condition, the overall proportion of choices for the Knower was $M = 0.73$ [95% CI: 0.66 to 0.79], which was significantly greater than 0.50, $t(15) = 8.55, p < 0.001$. For the Guesser Present condition, the overall proportion of choices for the Knower was $M = 0.58$ [95% CI: 0.51

to 0.65], which was also significantly greater than chance, $t(15) = 2.54, p < 0.05$. Thus, the dogs showed a significant preference for the Knower in both conditions.

Taken together, the results that the Knower preference was significantly greater than chance in the Guesser Absent condition, and greater in the Guesser Absent than Guesser Present condition are consistent with the hypothesis that the dogs used knowledge state attribution cues to guide their choices.

Performance in individual dogs was then examined. Tables 2.2 and 2.3 show the percentage of choices for the Knower and the Guesser for each dog in the Guesser Absent and Guesser Present conditions, respectively. In the Guesser Absent condition, preference for the Knower ranged from 52.17% (AJ) to 91.67% (Fluff Fluff), with 10 out of 16 dogs demonstrating a significant preference (binomial test, $p < 0.05$), and a further three approaching significance ($p < 0.10$). The remaining three dogs also showed a preference for the Knower, however, these preferences were not significantly more than expected by chance. In the Guesser Present condition, preference ranged from 37.5% (Lucy) to 91.3% (Max 1). Thirteen of the 16 dogs responded at chance levels, whereas three dogs (Libby, Max 1 and Zeb) showed a preference for the Knower at a level significantly greater than chance. Of the dogs that did not respond at significant levels, nine dogs showed a preference for the Knower, two dogs (Daphne and Lucy) showed a preference for the Guesser, and one dog (Saffie) showed equivalent preference for the Knower and Guesser. The finding that more dogs showed a significant preference for the Knower in the Guesser Absent condition than the Guesser Present condition provides further support for the hypothesis that the dogs used knowledge state attribution to guide their choices.

Table 2.2. Number of trials and percentage of responses made to the Knower and Guesser (excluding responses to containers not pointed at and trials ending with no response) in the Guesser Absent condition, and results of significance testing (binomial test against chance of 50%).

Dog	<i>N</i>	% Knower	% Guesser
AJ	23	52.17	47.83
Asha	22	68.18 [#]	31.82
Bonnie	24	83.33 ^{***}	16.67
Boss	23	65.22 [#]	34.78
Daphne	23	82.61 ^{**}	17.39
Fluff Fluff	24	91.67 ^{***}	8.33
Jasmine	24	70.83 [*]	29.17
Libby	24	79.17 ^{**}	20.83
Lucy	24	66.67 [#]	33.33
Max 1	21	85.71 ^{***}	14.29
Max 2	24	70.83 [*]	29.17
Ronin	23	73.91 [*]	26.09
Rouke	23	73.91 [*]	26.09
Saffie	22	59.09	40.91
Zeb	24	79.17 ^{**}	20.83
Zoe	23	60.87	39.13

[#] 0.1 > p > 0.05 * p < 0.05 ** p < 0.01 *** p < 0.001

Table 2.3. Number of trials and percentage of responses made to the Knower and Guesser (excluding responses to containers not pointed at and trials ending with no response) in the Guesser Present condition, and results of significance testing (binomial test against chance of 50%).

Dog	N	% Knower	% Guesser
AJ	24	54.17	45.83
Asha	22	63.64	36.36
Bonnie	24	58.33	41.67
Boss	23	56.52	43.48
Daphne	24	45.83	54.17
Fluff Fluff	24	58.33	41.67
Jasmine	24	58.33	41.67
Libby	23	69.57 *	30.43
Lucy	24	37.50	62.50
Max 1	23	91.30 ***	8.70
Max 2	24	45.83	54.17
Ronin	24	58.33	41.67
Rouke	24	54.17	45.83
Saffie	24	50.00	50.00
Zeb	22	72.73 *	27.27
Zoe	21	52.38	47.62

0.1 > p > 0.05 * p < 0.05 ** p < 0.01 *** p < 0.001

To determine whether individual differences in performance were consistent across conditions, a correlation was computed between Knower choice in the Guesser Absent and Guesser Present conditions. The correlation was positive, although failed to

reach significance, $r(16) = 0.44$, $p = 0.089$. This suggests that there may have been some tendency for the Knower preference to be consistent across conditions, which may reflect individual differences in terms of the dogs' ability to use knowledge attribution or additional cues to solve the Knower-Guesser paradigm.

The relationship between age and performance was also assessed. There was no relationship in either the Guesser Absent condition ($r(16) = -0.12$, *ns*) or the Guesser Present condition ($r(16) = 0.24$, *ns*), which suggests that learning over the dogs' lifetimes did not extensively affect their performance. Comparisons were also made between performances by male and female dogs. There was no significant sex difference in Knower preference in the Guesser Absent condition ($M_{\text{MALE}} = 0.72$, 95% CI: 0.59 to 0.84, $M_{\text{FEMALE}} = 0.73$, 95% CI: 0.66 to 0.81, $t(14) = -0.29$, *ns*). In the Guesser Present condition, the female dogs showed little preference ($M_{\text{FEMALE}} = 0.54$, 95% CI: 0.47 to 0.61), whereas the male dogs showed a greater preference for the Knower ($M_{\text{MALE}} = 0.72$, 95% CI: 0.59 to 0.84). However, this difference was not significant, $t(14) = 1.75$, $p = 0.10$. This suggests that there may be sex differences in the strategy used by male and female dogs, with males more successful with associative cues, and females either more successful at using knowledge attribution cues, or conversely, less successful at using associative cues to solve the task.

Because the identity of the experimenters (Knower/Guesser) and food location were counterbalanced across trials, the fact that Knower preference was significant in both conditions suggests that there were no substantial biases for particular experimenters or locations. However, a series of analyses were conducted to test whether significant biases were present. In the Guesser Absent condition, there was no preference between

the experimenters: Experimenter 1 (178 responses), Experimenter 2 (193 responses); $\chi^2(1, N = 371) = 0.61, ns$. There was also no side preference (of the pointed-at containers): Left (191 responses), Right (180 responses); $\chi^2(1, N = 371) = 0.33, ns$. Container position also had a lack of significant preference: Position 1 (110 responses), Position 2 (80 responses), Position 3 (87 responses), Position 4 (100 responses); $\chi^2(3, N = 377) = 6.02, ns$. In the Guesser Present condition, there was no preference between the experimenters: Experimenter 1 (185 responses), Experimenter 2 (189 responses); $\chi^2(1, N = 374) = 0.04, ns$. There was also no side preference (of the pointed-at containers): Left (193 responses), Right (181 responses); $\chi^2(1, N = 374) = 0.39, ns$. Container position also had a lack of significant preference: Position 1 (105 responses), Position 2 (90 responses), Position 3 (91 responses), Position 4 (97 responses); $\chi^2(3, N = 383) = 1.49, ns$. Thus, there were no detectable preferences for particular experimenters or locations.

Overall, results of Experiment 1 suggest that dogs may be capable of using knowledge attribution cues to find the location of hidden food. In the Guesser Absent condition, the dogs showed a strong preference for the Knower, which was significantly greater than that expected by chance. However, the above-chance levels of preference for the Knower shown in the Guesser Present condition indicate that associative cues may have also influenced the dogs' choices. Because both informants had equivalent knowledge about the food location in the Guesser Present condition, if dogs had based their choices entirely on knowledge attribution cues then they should not have shown a significant Knower preference in that condition. Importantly, the level of preference for the Knower in the Guesser Present condition was significantly less than that in the

Guesser Absent condition, resulting in a level of preference intermediate between that of chance and the Guesser Absent condition. This suggests that the dogs were using a combination of knowledge state attribution and associative cues.

The lack of a relationship between age and performance suggests that the dogs' ability to respond correctly in the Knower-Guesser task does not depend on the amount of interaction they have had with humans. For example, the youngest dog (Daphne) was only 10 weeks of age but made 83% correct responses in the Guesser-Absent condition. Instead, the dogs' performances may depend on an evolved sensitivity to human-related cues, based on their status as a domesticated species and co-evolutionary history with humans (Miklósi et al., 2004). There were also no significant differences in preference levels between the male and female dogs.

The significant block effect, showing increased performance in Block 4 compared with Blocks 2 and 3 suggests that motivational factors may influence performance in the task. Accuracy decreased as time spent on the task increased, until the dogs had a break from testing after Block 3. Following the break, performance rebounded in Block 4. Importantly, however, performance did not systematically increase or decrease across blocks, which suggests that the dogs were not learning over the course of testing. This suggests that the dogs were performing at maximal accuracy from the outset of testing, providing further evidence for the hypothesis that they were using knowledge state attribution to guide their choices.

To eliminate any associative cues related to the baiting or the presence or absence of experimenters, Experiment 2 employed an experimenter additional to the two informants. The third experimenter manipulated the screen and baited the containers,

whereas the two original experimenters were only involved as informants to the dogs. This change meant the dogs could not use obvious associative cues to make their decisions. If they still showed a preference for the Knower, then this would likely be due to differences in what the experimenters could see.

3 EXPERIMENT 2: DOGS DISCRIMINATE BETWEEN SEEING AND UNSEEING HUMAN INFORMANTS

Experiment 1 tested dogs' preference between informants when one had either left the room while the other baited the containers (Guesser Absent condition), or when both informants had been present while one baited the containers (Guesser Present condition). The dogs showed a Knower preference that was significantly greater than chance in the Guesser Absent condition. Although the Knower preference in the Guesser Present condition was significantly less than that in the Guesser Absent condition, it was also greater than chance. This finding suggested that the dogs may have used associative cues to some extent during the Knower-Guesser task.

To reduce the potential effect of associative cues, Experiment 2 aimed to minimise differences between the two informants. The dogs chose between two informants who had both been present during the food hiding, and so the obvious cue of presence during the baiting was consistent between the informants. To eliminate associative cues relating to manipulation of the apparatus, a third experimenter was involved as the baiter. Thus, the salience of the two informants, in terms of handling of the food and the containers, was equivalent. While the third person baited the containers, one informant covered her eyes with her hands (the Guesser) and the other covered her cheeks with her hands (the Knower). Consequently, the only difference between the two informants was in their hand position, and whether their eyes were visible and they could observe the baiting or not.

If the dogs were able to attribute knowledge states based on what the human informants had or had not seen, then they should show a significant preference for the

Knower ($p[\text{Knower}] > .50$). However, if the dogs were unable to use knowledge state attribution to guide their choices, no preference should be evident ($p[\text{Knower}] = p[\text{Guesser}] = .50$). If dogs used experiment-specific associative cues (e.g., learned through trial and error that the experimenter who covered her eyes during baiting always pointed to the incorrect container) then preference for the Knower should increase systematically across blocks.

3.1 METHOD

3.1.1 *Subjects*

The same sixteen domestic dogs (6 males, 10 females; mean age = 4.7 years, range: 10 weeks – 13 years), as in Experiment 1 participated individually in Experiment 2. Owners were present throughout testing, and the same requirements pre- and during testing applied (see Experiment 1, section 2.1.1).

3.1.2 *Apparatus*

The apparatus and experimental set up were identical to that of Experiment 1 (section 2.1.2).

3.1.3 *Procedure*

The dogs completed pre-training and Experiment 1 before commencing Experiment 2, which was completed in the second session of testing. The procedure for Experiment 2 was similar to that described for Experiment 1 (section 2.1.3.2), with a few exceptions as follows:

In Experiment 2, a third experimenter was present, who sat between the two original experimenters (Figure 3.1). The role of the third experimenter was assumed by the same male for all of the sessions, except for three, in which the third experimenter

was one of three different females. The third experimenter was responsible for manipulating the screen, interacting with the dog, and hiding the food, whilst the other two experimenters (the informants) acted as either Knower or Guesser. This eliminated any cues additional to the experimental manipulation, such as the act of baiting and manipulation of the screen, which might differentiate the Knower and Guesser.

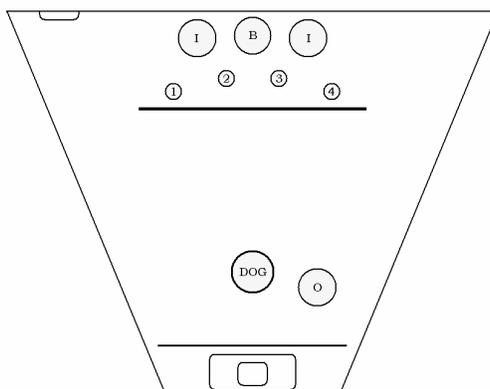


Figure 3.1: A schematic plan view of the experimental room and setup as for Experiments 2-4. The two informants (I) and the baiter (B) knelt behind four containers (1-4), arranged in a semicircle behind a screen. The dog sat near the centre of the room facing the informants, restrained by its owner (O), who was on the dog's left for half of the trials and on the dog's right for the other half of the trials. Behind the dog was a table with a notebook PC used to record the sessions.

The Knower and Guesser assumed their positions before the screen was raised by the third experimenter. During the baiting, the Guesser covered her eyes with her hands, whereas the Knower covered her cheeks with her hands (see Figure 3.2). Once the screen was lowered, the Knower and Guesser simultaneously placed their hands on their lap, then the Knower pointed to the baited container, and the Guesser pointed to an un-baited

container. The locations of baited and unbaited containers were pseudo-randomly determined and counterbalanced across trials, with the constraint that the Knower or Guesser did not point to the same container on more than two consecutive trials. After two seconds of pointing, the dog was allowed to make its choice. Each dog completed 24 trials in Experiment 2.



Figure 3.2. In Experiment 2, a third experimenter baited the containers, while the Guesser (left) covered her eyes with her hands and the Knower (right) covered her cheeks with her hands. The dog could see the upper torso and head of the baiter and informants throughout the experimental trial.

An independent observer coded a random 12.5% of the trials (3 trials per dog) in Experiment 2. The percentage of inter-observer agreement was 98% (Cohen's $\kappa = 1.00$).

3.2 RESULTS AND DISCUSSION

The dogs responded to the location pointed at by the Knower or the Guesser on 96.1% of trials ($N = 369$). Trials with no responses ($N = 4$), or in which the dog chose a container that was not pointed at by the Knower or the Guesser ($N = 11$) were omitted from subsequent analyses.

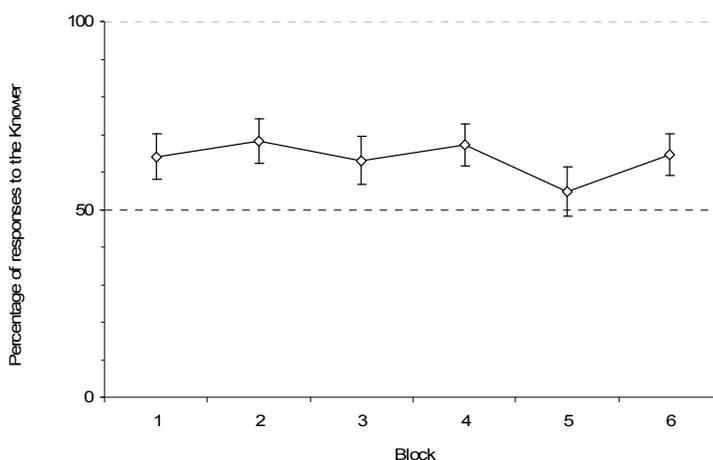


Figure 3.3. Mean (± 1 SE) percentage of choices for the Knower, over blocks of four trials for Experiment 2. The dashed line represents chance (50% of trials with a Knower or Guesser response).

Figure 2.5 shows the percentage of choice responses made for the Knower across successive blocks of four trials for Experiment 2. The percentage of choices for the Knower appeared to be approximately stable, varying between 55% (Block 5) and 68% (Block 2). To determine whether performance changed over blocks of trials, a repeated-measures analysis of variance was conducted with block as a within-subjects factor.

There was no significant effect of block, $F(5,75) < 1$, *ns*. A planned linear contrast also failed to reach significance, $F(1,15) < 1$, *ns*. The lack of any systematic change in performance across blocks suggests the dogs were not responding on the basis of associative cues.

Next, the overall preference for the Knower was assessed, to determine if it was significantly greater than .50. Averaged across blocks, the overall proportion of choices for the Knower was $M = 0.64$, [95% CI: 0.59 to 0.69], which was significantly greater than 0.50, $t(15) = 6.02$, $p < 0.0001$. Thus, the dogs showed a significant preference for the Knower. Coupled with the lack of systematic change in responding across blocks, the significant Knower preference suggests that the dogs were using knowledge state attribution to guide their choices.

Table 3.1 shows the percentage of choices for the Knower and the Guesser for individual dogs in Experiment 2. Performances of individual dogs ranged from 45.83% (Bonnie) to 82.61% (Jasmine), with 15 out of 16 dogs showing a preference for the Knower. Results for four dogs were statistically significant (binomial test, $p < 0.05$), and approached significance for four more ($p < 0.10$). Only one dog (Bonnie) showed a preference for the Guesser, which was not significant. Thus, a Knower preference was evident in the behaviour of the majority of individual subjects, providing further support for the hypothesis that dogs were responding on the basis of knowledge state attribution.

Table 3.1. Number of trials and percentage of responses made to the Knower and Guesser (excluding responses to containers not pointed at and trials ending with no response) in Experiment 2, and results of significance testing (binomial test against chance of 50%).

Dog	N	% Knower	% Guesser
AJ	23	78.26 **	21.74
Asha	17	52.94	47.06
Bonnie	24	45.83	54.17
Boss	24	58.33	41.67
Daphne	23	65.22 #	34.78
Fluff Fluff	24	70.83 *	29.17
Jasmine	23	82.61 **	17.39
Libby	24	66.67 #	33.33
Lucy	24	66.67 #	33.33
Max 1	23	65.22 #	34.78
Max 2	22	59.09	40.91
Ronin	24	58.33	41.67
Rouke	24	70.83 *	29.17
Saffie	24	62.50	37.50
Zeb	24	58.33	41.67
Zoe	22	59.09	40.91

$0.1 > p > 0.05$ * $p < 0.05$ ** $p < 0.01$

A correlation was conducted to determine if there was any relationship between age and performance. The correlation was close to zero, $r(16) = -0.05$, *ns*, implying that there was little difference in the performance of the dogs relative to age. Performance by the male and female dogs was also compared. There was no significant difference in

Knower preference of males and females ($M_{\text{MALE}} = 0.65$, 95% CI: 0.56 to 0.74, $M_{\text{FEMALE}} = 0.63$, 95% CI: 0.56 to 0.70; $t(14) = 0.36$, *ns*).

The finding that Knower preference was significant, and the fact that the identity of the informants (Knower/Guesser) and food location were counterbalanced across trials, suggests that there were no substantial biases for particular experimenters or locations. However, a series of analyses were conducted to test whether significant biases were present. There was no preference between the informants: Informant 1 (180 responses), Informant 2 (189 responses); $\chi^2(1, N = 369) = 0.22$, *ns*. There was also no side preference (of the pointed-at containers): Left (202 responses), Right (167 responses); $\chi^2(1, N = 369) = 3.32$, *ns*. Container position also had a lack of preference: Position 1 (111 responses), Position 2 (98 responses), Position 3 (91 responses), Position 4 (80 responses); $\chi^2(3, N = 380) = 5.32$, *ns*. Thus, there were no systematic preferences for particular informants or locations.

Performance in Experiment 2 was also compared with that in Experiment 1, to determine if individual differences in responding were stable. The correlations between Knower choice in Experiment 2 and both the Guesser Absent and Guesser Present conditions were not significantly different from zero, $r(16) = -0.15$, *ns*, and $r(16) = -0.07$, *ns*, respectively. Thus variability in performance across dogs was not systematic between Experiments 1 and 2.

Overall, results of Experiment 2 provide further evidence that dogs may be capable of using knowledge attribution cues to find the location of hidden food. The dogs showed a moderately strong preference for the Knower, which was significantly greater than chance. That both informants were present during the baiting but neither touched

the food or container reduces the possibility that the Knower preference was due to associative cues. Apparently, the dogs were able to respond on the basis of what each informant had seen during the baiting, consistent with the hypothesis that they were able to attribute states of knowledge regarding food location.

The lack of a significant block effect or linear trend analysis showed that performance did not systematically increase or decrease across blocks, which suggests that the dogs were not learning over the course of testing. Dogs were performing at maximal accuracy from the outset of testing, providing further evidence for the hypothesis that they were using knowledge state attribution to guide their choices.

Nevertheless, one possible criticism of Experiment 2 is that having one informant with her eyes covered during the baiting may have been particularly salient to the dogs because it is an unusual way for humans to appear. Thus, to eliminate any associative cues that might have been relevant for Experiment 2 – specifically, the visibility of the informants' eyes or the differential hand positions, Experiment 3 again employed a third experimenter additional to the two informants. However, the informants either attended to the baiting or were inattentive during the baiting. To achieve this, the Knower watched the baiting, with attentive gaze, whereas the Guesser was inattentive to the baiting, whilst “gazing into space”. This change meant the dogs could not use possible associative cues, such as eye visibility, to make their decisions. Additionally, Experiment 3 addressed the potential influence of owner-given cues, by having the owners remain ignorant as to the identity of the Knower. Subsequently, if they showed a preference for the Knower, then it must be due to differences in the level of attention displayed by the informants.

4 EXPERIMENT 3: DOGS DIFFERENTIALLY RESPOND TO ATTENTIVE AND INATTENTIVE HUMAN INFORMANTS

Previous studies have shown that dogs are sensitive to the attentional states of humans (Call et al., 2003). Thus, Experiment 3 tested whether attentional states could serve as the basis for responding by dogs in the Knower-Guesser paradigm. A third person baited the containers, while one of the informants (the Knower) attended to the baiting, and the other informant (the Guesser) was inattentive (gazed at the ceiling, away from both the dog and the baiting). If the dogs were able to attribute knowledge states based on what the human informants had or had not attended to, and based their choices on these attributions, they should show a significant preference for the Knower ($p[\text{Knower}] > .50$). Conversely, if the dogs were unable to respond on the basis of what the informants had attended to, there should be no Knower preference ($p[\text{Knower}] = p[\text{Guesser}] = .50$). As in previous experiments, performance across blocks was examined for systematic changes, which might show evidence that dogs' performance was affected by trial and error learning. Finally, to control for the possibility that the dogs were using cues that the owners supplied inadvertently, the owners were unable to watch the baiting, and therefore were ignorant as to the identity of the Knower and Guesser. Thus, if the dogs were using owner-related cues in the previous experiments, there should be no preference for the Knower in Experiment 3 ($p[\text{Knower}] = p[\text{Guesser}] = .50$).

4.1 METHOD

4.1.1 *Subjects*

Twelve domestic dogs (5 males, 7 females; mean age = 4.5 years, range: 10 weeks – 13 years) participated individually in the experiment with their owners. The age and sex of the dogs are listed in Table 4.1, and the breeds and training histories of the dogs are listed in the Appendix. All of the dogs had participated in the preceding experiments. Owners were present at all times throughout testing, and the same pre- and during-testing conditions applied (see section 2.1.3.2). All but one of the owners assisting in the experiment were female, and their ages ranged from 10 to 54 years.

4.1.2 *Apparatus*

The apparatus and experimental set up were identical to that of Experiment 1 (section 2.1.2).

Table 4.1. Name, sex, and age at start of testing (in years unless stated) of subjects included in Experiment 3 and Experiment 4.

Dog	Sex	Age
AJ	male	13
Boss	male	1.5
Daphne	female	10 weeks
Fluff Fluff	female	8
Jasmine	female	2
Libby	female	9 months
Lucy	female	2
Max 1	male	4.5
Max 2	female	2
Rouke	male	8 months
Saffie	female	8
Zeb	male	11

4.1.3 Procedure

The dogs completed pre-training and Experiments 1 and 2 before commencing Experiment 3. Experiment 3 was completed in the third testing session. The procedure was identical to that of Experiment 2, except for the actions of the Knower and Guesser. A third experimenter (the same male for all sessions) was again present, and assumed the same role as in Experiment 2. This eliminated any extraneous cues differentiating the Knower and Guesser, such as the act of baiting and manipulation of the screen. Before the screen was raised, the Guesser assumed an inattentive position by gazing at the ceiling at the other end of the room (away from the baiting and the dog), whereas the Knower assumed an attentive position by having her gaze follow the baiting (Figure 4.1). The Knower and Guesser maintained the direction of their gaze until the screen had been lowered. Additionally, the owner was asked to close his or her eyes or to look away until

after the screen was lowered, so that they could not watch the baiting procedure. This prevented the owner from knowing which informant was the Knower or Guesser, and therefore eliminated any owner-related cues that the dog may have responded to. Each dog completed 24 trials in Experiment 3.



Figure 4.1. In Experiment 3, a third experimenter baited the containers, while the Knower (right) attended to the baiting. The Guesser (left) was inattentive during the baiting. The dog could see the upper torsos and heads of the baiter and informants throughout the experimental trial.

A random 12.5% of the trials (3 trials per dog) in Experiment 3 were coded by an independent observer. The percentage of inter-observer agreement was 100% (Cohen's $\kappa = 1.00$).

4.2 RESULTS AND DISCUSSION

On 97.2% of trials ($N = 280$), the dogs responded to the location pointed at by either the Knower or the Guesser. Trials resulting in no response ($N = 2$), or in which the dog chose a container that was not pointed at by the Knower or the Guesser ($N = 6$) were excluded from subsequent analyses.

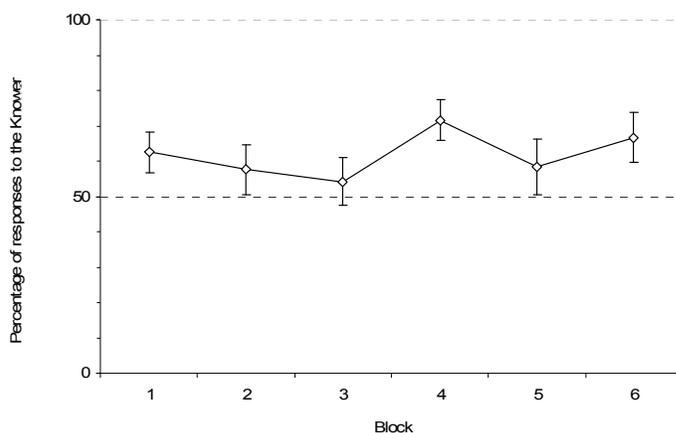


Figure 4.2. Mean (± 1 SE) percentage of choices for the Knower, over blocks of four trials for Experiment 3. The dashed line represents chance (50% of trials with a Knower or Guesser response).

The percentage of choice responses made to the Knower across successive blocks of trials in Experiment 3 (Figure 4.2) was relatively consistent, ranging from 54% (Block 3) to 72% (Block 4). A repeated measures analysis of variance was conducted to determine whether performance changed over blocks of trials. No significant effect of block was found, $F(5,55) < 1$, *ns*, and a planned linear contrast failed to reach significance, $F(1,11) < 1$, *ns*. The lack of a systematic increase over blocks suggests the

dogs were not learning through trial and error learning over the course of testing, and is therefore consistent with the hypothesis that the dogs were using knowledge attribution cues to guide their choices.

The overall preference for the Knower was assessed, to determine if it was significantly greater than .50. The overall proportion of choices for the Knower was $M = 0.62$, [95% CI: 0.58 to 0.66], which was significantly greater than 0.50, $t(11) = 6.42$, $p < 0.0001$. Thus, there was a significant overall preference for the Knower.

Performance in individual dogs was then examined. Table 4.2 shows the percentage of choices for the Knower and the Guesser for each dog in Experiment 3. Preference for the Knower ranged from 52.38% (Max 1) to 69.57% (Max 2 and Saffie). All of the dogs showed a preference for the Knower, and for two of the 12 dogs, this preference was significant (binomial test, $p < 0.05$), with a further four dogs approaching significance ($p < 0.10$). This finding that all dogs showed a greater preference (which was significant or approaching significance for half of the dogs) for the Knower than the Guesser provides further support that the dogs were reasoning with knowledge state attribution.

The relationships between performance and age and sex were also analysed. There was a positive relationship between age and Knower preference, however, this relationship was not significant, $r(12) = 0.41$, *ns*. There was no significant difference between the sexes in Knower preference ($M_{\text{MALE}} = 0.60$, 95% CI: 0.52 to 0.68, $M_{\text{FEMALE}} = 0.63$, 95% CI: 0.57 to 0.69; $t(10) = -0.86$, *ns*). Thus, age-related factors may have some influence on performance, but there appears to be no effect of sex in the ability of dogs to perform in the Knower-Guesser paradigm.

Table 4.2. Number of trials and percentage of responses made to the Knower and Guesser (excluding responses to containers not pointed at and trials ending with no response) in Experiment 3, and results of significance testing (binomial test against chance of 50%).

Dog	<i>N</i>	% Knower	% Guesser
AJ	23	65.22 [#]	34.78
Boss	24	54.17	45.83
Daphne	23	65.22 [#]	34.78
Fluff Fluff	24	66.67 [#]	33.33
Jasmine	24	54.17	45.83
Libby	24	54.17	45.83
Lucy	24	62.50	37.50
Max 1	21	52.38	47.62
Max 2	23	69.57 [*]	30.43
Rouke	24	62.50	37.50
Saffie	23	69.57 [*]	30.43
Zeb	23	65.22 [#]	34.78

[#] $0.1 > p > 0.05$ ^{*} $p < 0.05$

Although the identity of the informants (Knower/Guesser) and food location were counterbalanced across trials, a series of analyses were conducted to test whether significant biases were present. There was no preference between the informants: Informant 1 (135 responses), Informant 2 (145 responses); $\chi^2(1, N = 280) = 0.36, ns$. There was, however, a significant preference for the left of the pointed-at containers: Left (184 responses), Right (96 responses); $\chi^2(1, N = 280) = 27.66, p < 0.0001$. There was also a preference in container position: Position 1 (97 responses), Position 2 (78

responses), Position 3 (50 responses), Position 4 (61 responses); $\chi^2(3, N = 286) = 17.69$, $p < 0.001$. Although reasons for the significant bias in favour of the left of the pointed-at containers were unclear, the Knower preference remained significant nevertheless.

A correlational analysis was conducted to determine whether performance in Experiment 3 was related to that obtained in previous experiments. There was a negative correlation between Knower choice in Experiment 3 and the Guesser Present condition of Experiment 1 that approached significance, $r(12) = -0.57$, $p = 0.054$. Because performance in the Guesser Present condition effectively provides a measure of the relative influence of associative cues versus knowledge state attribution (as informants' knowledge was equivalent), this correlation suggests that those dogs which were more accurate in Experiment 3 were less likely to have been responding on the basis of associative cues in Experiment 1. Correlations between performance in Experiment 3 and the Guesser Absent condition and Experiment 2 were negative but not significantly different from zero, $r(12) = -0.18$, *ns*, and $r(12) = -0.20$, *ns*, respectively.

As in previous experiments, dogs' performance was not related to age or sex, and there was no systematic change in performance over the course of testing. However, there was a significant preference (evident to some extent in 10 of the 12 dogs) for the left side of the container array. Although reasons for this bias are unclear, the identity of the informants (Knower/Guesser) and food location were counterbalanced across trials, and thus any tendency to respond to the left pointed-at container would attenuate preference for the Knower. Nevertheless, the percentage of Knower choices remained significant and was overall similar ($M = .62$) to that observed in Experiment 2 ($M = .64$).

Overall, results of Experiment 3 provide further evidence that dogs are able to respond on the basis of what informants have seen in the Knower-Guesser paradigm. The dogs showed a consistent preference for the Knower, which was again significantly greater than chance. Because the only difference in the behaviour of the Knower and the Guesser was that pertaining to attention state (i.e., gaze direction), these results are unlikely to be due to the use of associative cues, and suggest that dogs were able to respond solely on the basis of informants' gaze direction during the baiting. The significant Knower preference also suggests that the results of Experiment 2 cannot be attributed to the possible distinctiveness of the informant with hands covering the eyes. Finally, because the owner was unable to watch the baiting, and did not know the identity of the Knower and Guesser, they were unable to provide the dogs with unintentional cues as to the correct choice. Results suggest that the dogs were able to respond on the basis of what the informants had or had not observed during the baiting, consistent with the hypothesis that they are capable of knowledge state attribution.

Although results of Experiments 1-3 are consistent with the view that dogs are able to use knowledge state attribution to guide their choices, an alternative explanation is that unintentional cues may somehow have been provided by the experimenters (i.e., "Clever Hans effect", Miklósi et al., 1998; Rilling, 1993), and used by the dogs. Experiment 4 tested this possibility by examining dogs' performance under conditions in which both informants had equivalent knowledge of food location. In addition, Experiment 4 tested the possibility that dogs' were using subtle cues regarding food location or baiting (e.g., odour-related cues) by including a condition in which neither informant pointed at a container.

5 EXPERIMENT 4: DOGS ARE UNABLE TO LOCATE FOOD WITHOUT HUMAN COMMUNICATIVE CUES

The goal of Experiment 4 was to test two alternative explanations for the significant Knower preference shown by the dogs in previous experiments. One possibility is that the informants (or third experimenter, or owner) may have unintentionally provided cues relating to food location. Thus in Experiment 4 the dogs' performance was examined under conditions in which both informants had equivalent knowledge. In the "Identical Knower and Guesser" condition, both informants either attended or did not attend to the baiting and therefore both either knew or did not know the correct food location. If dogs' responding in previous experiments was based on unintentional cues provided by the informants, then they might show a preference for the experimenter who pointed at the correct container (designated the Knower) on trials for which both informants had knowledge of the food location, but not on trials when they lacked such knowledge. However, if the dogs were responding on the basis of knowledge state attribution, there should be no preference for the Knower or Guesser ($p[\text{Knower}] = p[\text{Guesser}] = .50$) on both types of trials, because both informants had equivalent knowledge. Another alternative explanation for the results from previous experiments is the use of subtle cues related to food location such as odour. If dogs were able to use such cues, then they should show a preference for the Knower regardless of the informants' knowledge state ($p[\text{Knower}] > .50$).

Experiment 4 also included a "No-Pointing" condition in which, after the food had been hidden, neither informant pointed to a container. If the dogs had previously relied on knowledge state attributions to guide their choices, there should be no

preference for the baited container ($p[\text{Baited}] = .25$). However, if the dogs had been using subtle or extraneous cues to make their choices, then a preference for the baited container should be present ($p[\text{Baited}] > .25$).

If the dogs were able to locate the food in the Identical Knower and Guesser condition but not in the No-Pointing condition ($p[\text{Baited}_{\text{IKG}}] > 0.50$, $p[\text{Baited}_{\text{NP}}] < .25$), then the implication would be that the dogs cannot use physical cues such as odour or auditory cues to choose the correct container, but can use cues provided unintentionally by the informants, the third experimenter, or the owners.

5.1 METHOD

5.1.1 *Subjects*

The same twelve domestic dogs (5 males, 7 females; mean age = 4.5 years, range: 10 weeks – 13 years) as in Experiment 3 participated individually in the experiment with their owners present.

5.1.2 *Apparatus*

The apparatus and experimental set up were identical to that of the previous experiments (see section 2.1.2).

5.1.3 *Procedure*

All of the dogs completed pre-training and Experiments 1, 2 and 3 before commencing Experiment 4. The dogs participated in Experiment 4 in the third test session, after completing Experiment 3. The procedure for Experiment 4 was almost identical to that of Experiment 3. However, there was no difference between the actions of the “Knower” and “Guesser” in any given trial (Figure 5.1), and additionally, the owners were not asked to look away or close their eyes during each trial. As with the Guesser Present condition in Experiment 1, the labels “Knower” and “Guesser” were assigned based on who was pointing to the container that was baited (the “Knower”

pointed to the baited container). All dogs were tested in the Identical Knower and Guesser condition first, followed by the No-Pointing condition.

Identical Knower and Guesser condition

Each dog completed eight trials for the Identical Knower and Guesser condition. On half of the trials, both informants attended to the baiting, and on the other half of trials, both informants were inattentive to the baiting. The type of trial (“attentive” or “inattentive”) was determined pseudo-randomly, with no more than three consecutive trials of the same type. Dogs received reinforcement for a response to either of the pointed-at containers; however, only one (pointed to by the “Knower”) actually contained food.

No-Pointing condition

The dogs each completed 2 trials for the No-Pointing condition after completion of the Identical Knower and Guesser condition. Each trial proceeded as in the Identical Knower and Guesser condition, however, after the baiting, neither the Knower or Guesser pointed.

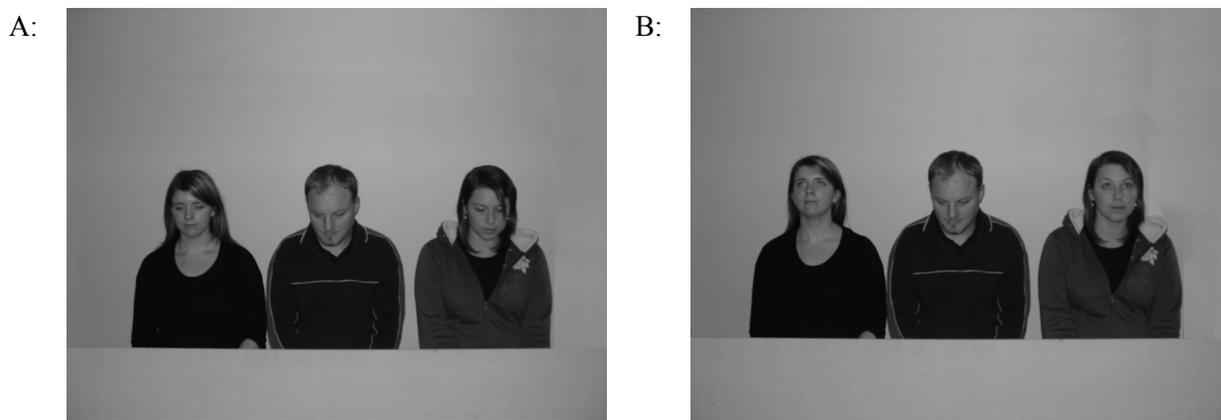


Figure 5.1. In Experiment 4, both informants either attended to the baiting (A), or were inattentive during the baiting (B).

An independent observer coded a randomly-selected 12.5% of the trials (1 trial per dog) in the Identical Knower and Guesser condition and a randomly-selected 50% of the trials (1 trial per dog) in the No-Pointing condition. Inter-observer agreement was 100% (Cohen's $\kappa = 1.00$) for both conditions.

5.2 RESULTS AND DISCUSSION

In the Identical Knower and Guesser condition, the dogs responded to the location pointed at by the Knower or the Guesser on 96.9% of trials ($N = 93$). Trials ending with no response ($N = 1$), or in which the dog chose a container that was not pointed at by the Knower or the Guesser ($N = 2$) were omitted from subsequent analyses. In the No-Pointing condition, the dogs chose a container on 29% of trials ($N = 7$). The baited container was chosen on 4% of trials ($N = 1$), and non-baited containers were chosen on 25% of trials ($N = 6$). The dogs made no response on 71% of trials ($N = 17$).

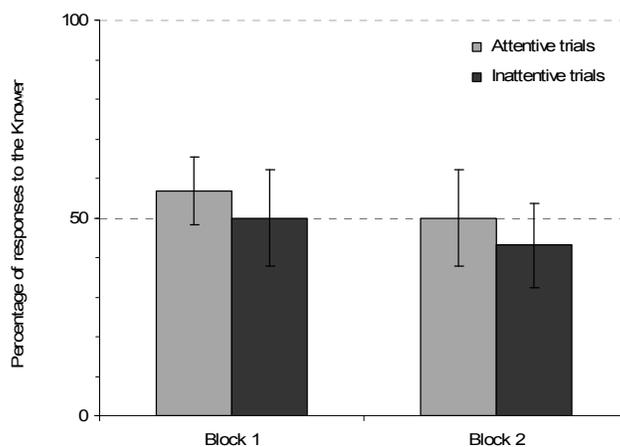


Figure 5.2. Mean (± 1 SE) percentage of choices for the Knower in the first and last blocks of four trials in “attentive” and “inattentive” trial types in the Identical Knower and Guesser condition. The dashed line represents 50% of trials made to the Knower or Guesser.

A repeated measures ANOVA was computed on the data from Figure 5.2, with Block and Trial Type (i.e., attentive or inattentive) as within-subjects factors. There was

no significant difference in the proportion of responses to the Knower in the trials where both informants were attentive and observed the baiting ($M = 0.53$, 95% CI: 0.37 to 0.70), or when both informants were inattentive ($M = 0.47$, 95% CI: 0.26 to 0.67), $F(1,11) < 1$, *ns*. There was no significant difference in performance between the first and last blocks, $M_{1st\ Block} = 0.53$ [95% CI: 0.41 to 0.66], $M_{2nd\ Block} = 0.47$ [95% CI: 0.28 to 0.65], $F(1,11) < 1$, *ns*. The interaction between Trial Type and Block also failed to reach significance, $F(1,11) < 1$, *ns*.

The overall preference for the Knower was assessed in the Identical Knower and Guesser condition, to determine if it was significantly different from chance. Overall, the proportion of choices made to the Knower was $M = 0.50$, [95% CI: 0.42 to 0.57], which was not significantly different from chance, $t(11) = -0.13$, *ns*. This suggests that dogs' choices were essentially random when both informants had equivalent knowledge of the location of the food baited by the third experimenter.

Figure 5.3 shows the pattern of results from the No-Pointing condition. The dogs were unable to successfully choose the container that had been baited. The majority of trials ($N = 17$) in the No-Pointing condition resulted in no response, suggesting that the dogs were reluctant to select a container without the human-given cues. A Friedman ANOVA showed a significant overall difference in the percentage of responses for the baited container, non-baited containers, and trials ending with no-response, $\chi^2(2, N = 12) = 10.17$, $p < 0.01$. The proportion of choices to the baited container was significantly lower than 0.25, $M = 0.04$, [95% CI: -0.05 to 0.13], $t(11) = -5.00$, $p < 0.001$. The proportion of choices to any container ($M = 0.29$, 95% CI: 0.07 to 0.52) was not

significantly lower than the proportion of no responses ($M = 0.71$, 95% CI: 0.48 to 0.93), although this difference did approach significance, $t(11) = -1.82$, $p = 0.096$.

Overall, results from both conditions show that the dogs were unable to choose the correct container when there was no difference in the informants' knowledge state and when the informants did not point at the containers. These results are consistent with the hypothesis that the dogs had been using knowledge state attribution to guide their choices in previous experiments, rather than unintentional cues provided by the experimenters and/or owners, or physical cues, such as odour, related to the baiting.

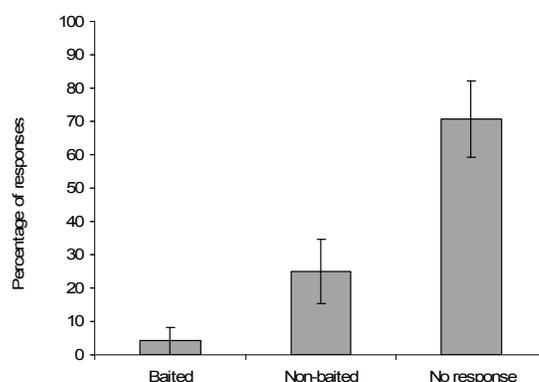


Figure 5.3. Mean (± 1 SE) percentage of choices for the Baited and Non-baited containers, and percentage of trials ending with No Response in the No-Pointing condition.

Table 5.1 shows the percentage of choices for the Knower and the Guesser for each dog in the Identical Knower and Guesser condition. Percentage of responses made to the Knower ranged from 25% (Max 1) to 71.43% (Daphne). Overall, none of the dogs' preferences were significant when tested with binomial tests ($p < 0.05$). Three out of the

Table 5.1. Number of trials and percentage of responses made to the Knower and Guesser (excluding responses to containers not pointed at and trials ending with no response) in the Identical Knower and Guesser condition. No dogs showed a preference greater than expected by chance (binomial test against chance of 50%).

Dog	<i>N</i>	% Knower	% Guesser
AJ	8	50.00	50.00
Boss	8	50.00	50.00
Daphne	7	71.43	28.57
Fluff Fluff	8	37.50	62.50
Jasmine	8	62.50	37.50
Libby	8	50.00	50.00
Lucy	8	50.00	50.00
Max 1	8	25.00	75.00
Max 2	7	42.86	57.14
Rouke	8	62.50	37.50
Saffie	7	42.86	57.14
Zeb	8	50.00	50.00

12 dogs demonstrated a preference for the Knower (Daphne, Jasmine and Rouke), whereas five dogs (Fluff Fluff, Max 1, Max 2, and Saffie) showed a preference for the Guesser. The remaining five dogs showed equivalent preference between the Knower and Guesser. The finding that none of the dogs showed a significant preference in the Identical Knower and Guesser condition suggests that the dogs were unable to solve the task by using subtle cues such as odour, or with unintentional cues provided by the informants.

The relationship between age and performance in the Identical Knower and Guesser condition was also assessed, which showed a negative, but non-significant relationship, $r(12) = -0.37$, *ns*. Additionally, there was a lack of a significant difference in the performance of male and female dogs in the Identical Knower and Guesser condition ($M_{\text{MALE}} = 0.48$, 95% CI: 0.31 to 0.65, $M_{\text{FEMALE}} = 0.51$, 95% CI: 0.40 to 0.62; $t(10) = -0.47$, *ns*). This supports the findings in the previous experiments that there are no significant sex differences or significant age-performance relationships in the ability of domestic dogs to reason with knowledge state attribution.

A series of analyses were conducted to test whether significant biases were present in the Identical Knower and Guesser condition. There was no preference between the informants: Informant 1 (42 responses), Informant 2 (51 responses); $\chi^2(1, N = 93) = 0.87$, *ns*. There was also no side preference (of the pointed-at containers): Left (48 responses), Right (45 responses); $\chi^2(1, N = 93) = 0.10$, *ns*. Container position also had a lack of preference: Position 1 (25 responses), Position 2 (27 responses), Position 3 (17 responses), Position 4 (26 responses); $\chi^2(3, N = 95) = 2.64$, *ns*. Thus, there were no detectable preferences for particular experimenters or locations.

Correlations were used to compare individual preferences in the Identical Knower Guesser condition of Experiment 4 with those of the previous experiments. None of the correlations reached significance. The correlations between Knower choice in Experiment 4 and previous experiments were: Guesser Absent condition of Experiment 1, $r(12) = -0.16$, *ns*; Guesser Present condition of Experiment 1, $r(12) = -0.52$, $p = 0.09$; Experiment 2, $r(12) = 0.28$, *ns*; Experiment 3, $r(12) = 0.06$, *ns*. Overall, these correlations suggest that variability in dogs' performances across experiments was unsystematic.

Taken together with results from previous experiments, Experiment 4 provides additional evidence that dogs are able to respond in the Knower-Guesser paradigm on the basis of informants' knowledge of food location. The Identical Knower and Guesser condition showed that the dogs did not preferentially respond to the informant that pointed to the container with food when there was no difference in the behaviour or knowledge of the informants, and that their choices did not differ depending on whether the informants both either knew or did not know the correct food location. This suggests that the dogs were not responding to subtle unintentional cues provided by the informants, the third experimenter, or the owner; but instead used the intentional communicative cues provided by the informants. The No-Pointing condition provided evidence that the dogs were unable to locate the food successfully without the cues given by the informants. Therefore, the dogs were not using cues such as odour or differences in baiting to guide their choices.

6 GENERAL DISCUSSION

The major goals of the present research were to determine 1) whether dogs could respond accurately in the Knower-Guesser paradigm; and 2) if so, to assess whether such performance was indicative of a theory of mind, or could be explained more simply by other factors such as associative learning. In the Guesser Absent condition of Experiment 1, which was modelled closely on the original Knower-Guesser paradigm developed by Povinelli et al. (1990), the dogs showed a strong preference for the informant that stayed in the room and conducted the baiting (the Knower). Although the dogs also showed a preference for the Knower in the Guesser Present condition of Experiment 1, this preference was significantly less than that in the Guesser Present condition, suggesting that the performance in the Guesser Absent condition could not be attributed entirely to associative cues. To reduce further the possible role of associative cues, in Experiments 2, 3, and 4, a third experimenter conducted the baiting. In Experiment 2 the informants covered their cheeks (Knower) or eyes (Guesser) with their hands during the baiting, while in Experiment 3 they either attended (Knower) or were inattentive (Guesser) to the baiting. In both experiments, dogs showed a significant preference for the Knower. Moreover, the owners did not watch the baiting in Experiment 3, and therefore could not influence the dogs' choices with inadvertent cues. Finally, in Experiment 4, the dogs showed no preference between the informants when they had equal perceptual access to the baiting, and were unsuccessful at selecting any container when the informants did not provide communicative cues, ruling out the possibility that successful performance was based on unintentional cues provided by the experimenters or olfactory cues. Overall, the

results across the four experiments provide strong evidence that dogs responded on the basis of what the informants had or had not seen during the baiting – consistent with the hypothesis that dogs have a functional theory of mind in their interactions with humans.

Comparison of past and present research on theory of mind in dogs

The present results provide the clearest evidence yet for theory of mind in dogs, extending that found in previous studies (e.g., Cooper et al., 2003; Horowitz, 2002; Virányi et al., 2006). Thus an important question is why the results of the present study were positive regarding dogs' capacity for a functional theory of mind, whereas results of previous studies have been mixed. In designing the current experiments, care was taken to avoid some of the methodological problems that may have influenced prior results. The following section provides a comparison between the current experiments and prior research on theory of mind in dogs. Addressing the potential methodological problems of prior studies may have been the primary reason for the positive results obtained in the present research.

A number of previous studies on theory of mind in dogs have found conflicting results. For example, Gácsi et al. (2004), Virányi et al. (2004) and Bishop & Young (in press) as reviewed in Cooper et al. (2003) found that dogs could successfully beg for food from a person who was attending to them, which suggests that dogs may be able to attribute attention states; and on the basis of extensive observations, Horowitz (2002)

suggested that dogs have at least a rudimentary theory of mind. On the other hand, Virányi et al. (2006) found that dogs were unsuccessful in the Ignorant Helper paradigm.

Cooper et al. (2003) reported an additional two unpublished studies with dogs on theory of mind, one with conspecific informants, and one with human informants. In the conspecific version, the subject dogs had to follow another dog, who either had visual access to the baiting or did not. The dogs were indifferent between the conspecific informants, therefore this study did not provide any evidence for theory of mind.

However, the dogs may have been more driven to interact with the dogs in a social context, which may have interfered with their performance in the paradigm. In the version with the human informants, the Knower remained in the room, whereas the Guesser left the room during the baiting. The dogs initially showed a significant preference for the Knower. However, the Knower preference decreased over subsequent trials, although the preference pooled over all trials remained significantly greater than chance. The decrease in performance could perhaps be due to a decrease in motivation, however, this is unlikely in this situation, as performance declined from only the second trial. Alternatively, other factors may have influenced dogs' performance, for instance, they may have responded to the location or person that they last chose. Although unmentioned in the summary of the experiment, it is possible that the dogs were not differentially reinforced, in an effort to suppress associative learning over the course of testing. However, this may be the reason for the decrease in performance. For instance, the dogs may have initially responded on the basis of theory of mind, but did not receive reinforcement, and altered their means of responding on subsequent trials in an effort to receive reinforcement. Additionally, Cooper et al. (2003) examined results on a per trial

basis, so although sensitive to performance in each trial, their analysis may have been insensitive to dogs who individually performed well. However, due to the small number of trials, the dogs would have needed to be correct on six out of six trials to obtain a result significantly different to chance (binomial test, $p < 0.05$) at the individual level. In contrast, in the present research, the dogs were tested in 24 trials per experiment, thus providing greater statistical power to detect significant Knower preferences at the level of individual dogs. Nevertheless, overall Cooper et al.'s findings are suggestive that dogs can behave as if they have a theory of mind. In the present study, the dogs received differential reinforcement in order to maintain high response levels, and to reduce the likelihood of the dogs changing tactics in an attempt to obtain reinforcement. The dogs' performance remained consistent across trials. Aside from the decrease in Knower preference over trials, which could in part be due to a lack of differential reinforcement, the results reported by Cooper et al. are consistent with those of the present study. The dogs immediately showed a preference for the Knower in both Cooper et al.'s study and the present research, suggesting in both cases that the dogs were reasoning with mental states. However, an important criticism of the results found by Cooper et al. is the lack of multiple conditions varying with regard to the cues related to knowledge states (i.e., they only tested dogs when the distinction between Knower and Guesser was that of presence/absence). This allows the results to be explained by learned associations regarding the presence or absence of humans. Dogs may have learned that humans who are present in a feeding context are more reliable sources of food, and thus responded on this distinction. As mentioned above, due to the varied nature of the experiments in the present research, it is unlikely that the dogs were able to succeed in all of the experiments

using associative cues, and thus the present research provides more robust evidence of knowledge state attribution in dogs.

The poor performance of dogs in the Ignorant Helper paradigm (Virányi et al., 2006) could be attributed to the vast difference in salience of the tool (a stick) and goal (toy) objects used in the paradigm. The dogs in Virányi et al.'s (2006) study were selected on the basis of having a high play drive, and thus the dogs may have struggled to inhibit their desire for the toy, resulting in an apparent inability to indicate the location of the stick (required to reach the toy) when the Helper was ignorant to its location. The present research overcame this potential confound by having no inherent difference in salience between the two informants the dogs had to choose from, and thus the only basis for a preference between the two was their expected knowledge states. This meant that there was no *a priori* reason for the dogs to be unsuccessful in the present research, unlike that of Virányi et al. (2006).

Horowitz (2002) investigated dogs' responsiveness to the attention of conspecifics in the context of play. She found that dogs altered their behaviour in relation to the attention of the receiver, suggesting that they could attribute a state of attention to the other dogs. The present research differs from Horowitz' study because dogs were tested in an experimentally-manipulated situation, and used humans rather than conspecifics to interact with the dogs. Although careful observational research contributes greatly to the field of animal social cognition, experiments are able to provide systematic variations to assess the specific effect of different components involved in social interactions. Thus, the present research builds upon Horowitz's observational

study, which indicated that dogs may have at least a rudimentary theory of mind, with strong experimental evidence also suggesting that dogs have a theory of mind.

Finally, the results found by Gácsi et al. (2004) and Virányi et al. (2004) in the begging version of the Knower-Guesser paradigm, although positive, could be explained by learned associations. It is probable that dogs have had experiences in which humans facing them were more likely to supply food than humans facing away. Although it is unlikely that the dogs had experience with people wearing blindfolds or buckets on their heads, they may have been able to use eye visibility cues to make their choices. However, it appears that the dogs initially showed a preference for a person who could see them in all conditions, and thus this preference could also be due to the attribution of attention. The immediacy of this preference also indicates that the dogs had generalized past knowledge to the experimental context, thus supporting the assumption that they were reasoning with mental states, rather than using associations learned during the course of testing. Although the dogs' performance in each individual experiment in the present research could be attributed, in part, to the use of associative cues, when combined, the dogs would require numerous, and sometimes complex, learned associations to solve the Knower-Guesser task successfully in all situations (the issue of associative cues is dealt with, in depth, in the *alternative explanations* section below). Thus, the present results go beyond those of Gácsi et al. (2004) and Virányi et al. (2004), in that performance cannot be attributed to orientation or eye-visibility cues alone, and is therefore consistent with the use of knowledge state attributions to solve the task.

The preceding section illustrates not only the limited number of studies on theory of mind in dogs, but also the restricted conclusions that can be drawn from those studies.

The current research advances upon these studies by examining dogs' performance in the Knower-Guesser paradigm across a series of studies in which systematic attempts were made to eliminate the possible influence of associative cues. Thus, the positive results of the present research provide the strongest evidence yet of a functional theory of mind in dogs.

Comparison with the performance of other nonhuman species in the Knower-Guesser paradigm

Results of the present study also provide stronger evidence for nonhuman social cognition than previous studies which have tested species other than dogs in the Knower-Guesser paradigm. For example, a number of other species have also been tested in the Knower-Guesser paradigm, such as chimpanzees (Povinelli et al., 1990), capuchin and rhesus monkeys (Kuroshima, Fujita, Fuyuki, & Masuda, 2002; Povinelli, Parks, & Novak, 1991), and domestic pigs (Held, Mendl, Devereux, & Byrne, 2001). However, the results from these species are far less conclusive than those found with dogs here. Overall, these studies did not provide conclusive evidence that chimpanzees, rhesus and capuchin monkeys, and domestic pigs could respond as if they had a functional theory of mind.

An important difference between the present study and that of Povinelli et al.'s (1990) original Knower-Guesser paradigm with chimpanzees is that the dogs were not given extensive discrimination training prior to testing. The chimpanzees in Povinelli et

al.'s study required over a hundred trials of training before they showed a significant preference for the Knower in their first phase, which was equivalent to the Guesser Absent condition in Experiment 1. The chimpanzees clearly needed to learn the discrimination, whereas the dogs in the present study spontaneously showed a preference for the Knower, and the majority of individual dogs showed a significant preference over 24 trials. This immediate preference could be paralleled with success in transfer tests in a setting such as Povinelli et al.'s. An important consideration is the lack of an increase in performance by the chimpanzees when the indicative hats were introduced (worn by the Knower and the baiter). This suggests that the chimpanzees were unable to use arbitrarily assigned associative cues to solve the task.

Povinelli & Eddy (1996) tested chimpanzees in a begging paradigm, which had a condition similar to that in Experiment 2 in the present study, in which the humans who the chimpanzees were begging from either had their hands covering their eyes or their ears, and a condition not unlike that of Experiment 3, in which one person was attentive and one was inattentive. Unlike the dogs in the present study, the chimpanzees performed at chance in both of these conditions (as they did in conditions involving blindfolds and buckets occluding the experimenters' vision). They did, however, perform above chance when they had to choose between a person facing them or with their back turned. Miklósi et al. (2004) suggested that the difference between dogs and chimpanzees is due to species specific constraints. For example, if chimpanzees predominantly use body orientation (which is correlated with looking direction) as an attention cue, they may not be sensitive to more subtle cues, such as eye visibility.

Povinelli et al. (1991) applied the Knower-Guesser paradigm as used with chimpanzees (Povinelli et al., 1990) in a study with rhesus monkeys (*Macaca mulatta*). They found that the rhesus monkeys did not have any preference for the Knower when the Knower baited the containers while the Guesser was absent, and they could not learn this discrimination when conspicuous associative cues were introduced. The monkeys were also unsuccessful in the transfer phase in which the Guesser had a paper bag over his head during the baiting.

Kuroshima et al. (2002) tested capuchin monkeys (*Cebus apella*) in a Knower-Guesser paradigm. Initially, the monkeys showed no preference for the Knower or the Guesser, however, after extensive training (hundreds of trials), the monkeys showed a preference for the Knower. Although they tested variations of the methodology (such as the pattern of container handling, and container type in a later study (Kuroshima, Fujita, Adachi, Iwata, & Fuyuki, 2003), the authors did not alter the perceptual access that the informants had to the content of the containers (i.e., they either checked or did not check the contents after the baiting), and thus it is unclear whether the monkeys would be able to generalise to different variations of the Knower-Guesser paradigm.

Held et al. (2001) investigated the behaviour of domestic pigs in a Knower-Guesser paradigm with conspecific informants. Informant pigs were trained to go to a set location when released from the starting box, and test pigs were trained to follow a human that was baiting a feeding corridor. In probe trials, the pigs only followed the informant pigs on about half of the trials. If they did follow an informant pig, they showed no preference between Knower and Guesser pigs, except for one pig that had a highly significant Knower preference. Held et al. reported previous research from their

group (Held et al., 2000), which found that pigs will follow a conspecific to a hidden food location. Thus an inability to perform the required behaviour is unlikely to be the reason for the negative results in this study.

The combined results of Kuroshima et al. (2002) and Povinelli et al.'s (1991) studies suggest that rhesus and capuchin monkeys are unable to use knowledge attribution cues to solve the Knower-Guesser paradigm. However, it appears from Povinelli et al. (1990) that chimpanzees are able to learn the discrimination between a present Knower and an absent Guesser, and transfer this knowledge to another situation (namely when the Guesser has a paper bag over his head during baiting). In the begging version of the Knower-Guesser paradigm, however, the chimpanzees did not beg discriminately based on the visual access of two humans, suggesting that there may be limitations to the abilities of chimpanzees to use knowledge state attribution. Domestic pigs were also unsuccessful at solving the Knower-Guesser task. Overall, it appears that species-specific differences may play an important role when assessing theory of mind. First, a theory of mind may have evolved along the primate lineage, and therefore may be present to some extent in other primates. Thus, it is also more likely to be present in chimpanzees, who are the closest extant relative to humans (Pough et al., 2002); and the further away from humans, phylogenetically, that a species lies, the less likely it is that it would have a theory of mind. According to this view, theory of mind may be less advanced in more distantly related species, such as rhesus and capuchin monkeys, when compared to that of chimpanzees. This phylogenetic difference could explain the variation in performance by these different species. However, the homology argument cannot be justified for more distantly related species such as pigs. Instead, other non-

primate species that are group-living may be at an advantage if individuals can attribute mental states to others, as this may be beneficial in social interactions. Pigs are one such example, as they live in social groups, and also forage socially (as reviewed in Held et al., 2001). Thus, pigs may have advanced social cognition skills regarding conspecifics. Additionally, as they have been domesticated, they may also be sensitive to the mental states of humans. However, Held et al. (2001) found pigs to be unsuccessful in the Knower-Guesser paradigm with conspecifics. This suggests that for a non-primate species to possess a theory of mind, they may need to be enculturated (that is, live in human families) to elicit their full potential. Unlike domestic pigs, domestic dogs not only derive from social ancestors, but have also been domesticated for tens of thousands of years, and are heavily enculturated (Hare & Tomasello, 2005). The domestication of dogs has also exceeded that of pigs, as dogs have been bred both to work with humans, and to be companions. This may have meant that dogs possessing advanced social cognition characteristics may have been at an advantage, thus increasing these abilities in the species as a whole. Thus, domestic dogs are very likely to possess a theory of mind.

In general, the social cognitive abilities of dogs may not significantly exceed those of other animals such as chimpanzees. Thus, the apparent failures of other species in the Knower-Guesser paradigm (e.g., Held et al., 2001; Kuroshima et al., 2002; Povinelli et al., 1990; Povinelli et al., 1991) may be due to inadequate ecological validity of the tests, rather than a lack of ability on behalf of the animals. Although novel situations are required to test the generality of animals' abilities, tests must also remain ecologically relevant and valid (Tomasello, Call, & Hare, 2003b). Held et al. (2001) appeared to have considered the ecological validity of their version of the Knower-

Guesser paradigm, which involved domesticated animals obtaining food from humans, and social-foraging animals following conspecifics to food. Additionally, the pigs' vision was occluded by blocking part of the pens, which would likely be a familiar occurrence in their general life on the farm. However, these considerations may not have been made in the case of the chimpanzee and monkey versions of the Knower-Guesser paradigm. First, it is unnatural for these animals as species to have their food provided by humans. However, enculturated individuals are likely to have overcome this potential inhibition, due to their extensive experiences of being provided with food from humans. Second, these species are often competitive regarding food, rather than cooperative, and thus may not perform well in a cooperative situation (Tomasello et al., 2003a). Third, especially in the case of chimpanzees and rhesus monkeys, eye contact tends to be threatening (Kuroshima et al., 2002), and therefore it may be aversive to look a human in the face, thus reducing the animals' abilities to differentiate subtle differences in the humans' behaviour. Fourth, the treatments that are administered are often unusual and would not normally occur in the animal's experience, for example, encountering a human with a paper bag or bucket on her head (Tomasello et al., 2003b), and thus may not only distract the animal, but also may not serve the function intended (to block vision and thus have the animal infer a state of ignorance to the human). Overall, chimpanzees and other primates may therefore not be suitable species to be tested in the Knower-Guesser paradigm, certainly not without major modifications.

By contrast, dogs are a highly suitable candidate to be successfully tested in the Knower-Guesser paradigm. Dogs naturally receive food from humans, and have evolved doing so; they are typically cooperative foragers with regard to humans, and they have

also been shown to look at humans for assistance in a number of situations (e.g., Miklósi et al., 2003). Their suitability is underscored by the results of the present research, which found that dogs performed quantitatively better in the Knower-Guesser paradigm than any other nonhuman species thus far.

Alternative explanations and factors that may affect dogs' performance in the Knower-Guesser paradigm

Performance in social cognition tasks can often be explained by other factors, such as the use of associative cues, rather than mentalistic explanations such as theory of mind. The following section reviews other factors that may have influenced dogs' performance in the present study, such as age and experimental design. The results expected, should the performance of the dogs be due to associative factors, are discussed, and these predictions are compared to the results actually obtained. However, because the associative cues related to each experiment differed, it is unlikely that the dogs were using a different set of cues in each experiment. Additionally, the fact that there was no change in performance within experiments, and no evidence of pro-active interference across experiments also reduces the likelihood that the dogs were using associative cues.

If performance in a novel experimental task is spontaneous and stable across repeated trials, then it is unlikely to be due to associative rules learned over the course of the experiment (Povinelli et al., 1990). Thus, performance in each of the present experiments was examined for any variation across trials. There was no linear trend

evident in any of the experiments, that is, the performance of the dogs did not systematically increase or decrease over the course of each treatment. Additionally, performance was stable in all experiments, except for in Experiment 1, in which performance decreased in the second and third block of trials, and rebounded in the fourth block. This pattern can likely be attributed to motivational aspects. As the number of trials went on, the dogs' attention levels decreased until they had a break, after which attention and responses returned to previous levels. In subsequent experiments, the dogs were more experienced in the testing situation, and this pattern was not as marked. Because there was no evidence for learning over trials, it appears that the dogs were reasoning with knowledge states, rather than using discriminative cues to guide their choices.

Within each experiment, there were individual differences between the dogs. In part, these could be due to motivational differences, as some dogs were easily distracted by outside noises. Additionally, the attention span of the dogs varied considerably, with the attention of some dogs apparently waning towards the end of testing sessions. On any given trial, if the dog did not pay attention during the baiting, then it had to guess which informant to choose, thus potentially reducing the dog's performance.

Miklósi et al. (1998) suggested that age may affect performance if attention is needed from the dog (i.e., in experiments with subtle cues/distinctions). Their youngest dog (1.5 years old) in an object choice task – investigating the components of communicative gestures that dogs could use – could not initially use glancing as a cue, nor did he learn over the course of the experiment. However, previous studies have shown no difference in the performance of adult and juvenile dogs in social cognition

tasks (e.g., Agnetta et al., 2000; Hare et al., 2002). The discrepancy between these results is probably due to the subtleness (the head did not move) and briefness (approximately 1-2 seconds) of the glancing cue used by Miklósi et al. (1998), compared to the cues used by Agnetta et al. (2000) and Hare et al. (2002), which were of longer duration (about 5 seconds) and involved head movements as well. Similar to results of Agnetta et al. (2000) and Hare et al. (2002), there was no significant relationship between age and performance of dogs in the present study. Because these dogs ranged in age from 10 weeks to 13 years, this suggests that dogs from a young age have ample experience with humans to succeed at the Knower-Guesser task. This supports previous findings that age did not affect social cognition skills, and the supposition that dogs may have a rapid ontogenetic process regarding these faculties as young puppies (Agnetta et al., 2000).

It is possible that there are breed differences in dogs' ability to behave as if they have a theory of mind. For example, breeds that were selectively bred to respond to human cues, such as gundogs, may have a greater ability to discriminate humans' referential cues, and therefore may be more skilful at attributing mental states. McKinley & Sambrook (2000) found differences in the responsiveness to human cues between gundog and non-gundog groups. However, breed or breed group analysis was not possible in the present study due to the large number of crossbred dogs which could not be classified into groups.

Unlike in begging experiments (e.g., Gácsi et al., 2004; Povinelli & Eddy, 1996; Virányi et al., 2004), the Knower and Guesser in the present research were equally attentive to the dogs during the choice phase. In contrast, in the begging experiments the animals had to choose between a person who, for instance, could see them, versus a

person who could not, whereas in the present study there was no such discrimination during the choice phase. This means that the dogs not only had to observe and understand a difference between the two informants during baiting, but they also had to retain a memory of this difference and apply it when making their choice when the Knower and Guesser were equivalent.

In the present study, due to the experimental setting where the informants were approximately at eye level with the dogs during the experiments, it is possible that the dogs may have made fleeting eye contact with the informants, due to the fluid nature of the informants' eye movements (e.g., watching baiting), and based their choice decision on this. Importantly, this never occurred during the choice phase, as the informants had their gaze fixed upon the container they were indicating. However, in both the Guesser Absent and Guesser Present conditions of Experiment 1, it was inevitable that both informants looked at the dog at some stage during a given trial. In both conditions, the Knower looked at the dog whilst obtaining its attention before commencing baiting. In the Guesser Absent condition, the Guesser tended to look at the dog upon re-entering the room, and the Guesser could also look at the dog at the start of the baiting (as with the Knower). This suggests that if the dogs were using the cue of 'choose the person that looked at me', their performance would have been at chance levels in both of these conditions.

Animals have been shown to be sensitive to inadvertent cues provided by experimenters ("Clever Hans effect", Miklósi et al., 1998; Rilling, 1993), thus, it is possible that the dogs in the present study were responding on such cues. If this were the case, when the potential for cues to be provided was systematically varied, the dogs'

performance should have changed accordingly (i.e., decreased when the cues being used were removed). Experiment 3 eliminated the possibility for owner-given cues, resulting in no change in the dogs' performance relative to the other experiments. Experiment 4 isolated the influence of experimenter-given cues, and found that the dogs were not using any cues inadvertently provided by the experimenters. The possibility that the dogs were using physical cues such as odour was also eliminated, as the dogs could not locate the food without the informants intentionally communicating a container location.

It has been suggested that performance on Knower-Guesser tasks can be attributed to the use of discriminative cues (Heyes, 1998). At the most basic level, the Knower preference in the Guesser Absent condition of Experiment 1 could be due solely to the discriminative cues of presence versus absence during the baiting. Dogs may have learned that people who are present at feeding time are more consistent sources of food than people who are only intermittently present (i.e., the Guesser). This could result in a preference for the Knower. In the Guesser Present condition, however, the dogs could not use presence/absence as a discriminative cue. Alternatively though, they may have learned in their past experiences that those who handle food are more reliable sources of food than those who do not handle food, thus explaining the Knower preference.

In their past experiences, the dogs may have also learned that people with visible eyes are attentive to a situation or the dog, whereas people whose eyes are not visible are less likely to be responsive to the dog. Therefore, in Experiment 2, the Knower preference could potentially be explained by the discriminative cue of eye visibility. However, it is unlikely that the dogs had previously encountered a situation like that of Experiment 2, specifically concerning humans covering their eyes or cheeks with their

hands in a context related to food. This suggests that the dogs needed to generalise from their experiences in another context to show a Knower preference in Experiment 2.

In Experiment 3, there was no difference between the informants in terms of eye visibility. If the dogs were using eye visibility as an associative cue, there would have been no difference in preference between the Knower and Guesser. There was, however, a slight difference in eye-gaze angle, in that the Knower looked down towards the baiting, whereas the Guesser gazed upwards, away from the baiting. It could therefore be a possibility that the dogs had generated a rule sometime in their past that people whose eye gaze was directed towards a source of food were more reliable sources from which to obtain the food than from someone whose eye gaze was not directed towards the food. However, this explanation is very specific, and does not fully explain the fact that at the time of choice, when there was no difference between the Knower and Guesser, the dogs were able to choose the Knower. Bräuer et al. (2004) suggested from results regarding visual perspective taking in the presence of barriers, that the dogs were not using open eyes per se as the stimuli, as the human's eyes were not visible to the subjects at all times in some conditions, but the dogs still responded as if the human was attentive to them. Considering the findings of Bräuer et al. (2004), it would thus appear that the dogs in the present study were using the informants' attention states as cues from which to base their behaviour.

Although the performance of the dogs in Experiment 1 can be explained by the use of associative cues, performance in Experiments 2 and 3 would have required a number of complex associative rules to be successful. Particularly when the combination of experiments is considered, and coupled with the lack of improvement within

experiments, and the lack of pro-active interference across experiments, it is highly unlikely that the dogs were relying on associative cues to solve the Knower-Guesser task. In sum, it appears as though the dogs were responding on the basis of a functional theory of mind.

Future research

Due to the lack of published research on theory of mind in dogs, there are a number of avenues that remain unexplored. Thus, potential research ideas are proposed below. Although much of the published research on theory of mind in dogs has been inconclusive, with modification, many of the existing paradigms have the potential to expose a functional theory of mind ability in dogs. There are two main paradigms that may be able to provide evidence of theory of mind in nonverbal animals, the Knower-Guesser paradigm and false-belief tasks.

A number of variations of the present Knower-Guesser methodology could increase the knowledge in the area of theory of mind in dogs. For example, whether there is a difference in dogs' perception of humans' perception could be tested, with a condition where both informants have the same perceptual knowledge, such as one informant having their hands covering their eyes, while the other informant is inattentive. In this condition, while neither informant can observe the baiting, one provides the dog with eye-visibility cues, whereas the other does not. If the dogs showed no difference in this condition, then it would suggest they are reasoning with mental states during

conditions in which the informants have differential knowledge. However, if for instance, they prefer the informant that is inattentive, then they may be using eye visibility cues to guide their choices.

Pongrácz, Miklósi, Dóka, & Csányi, (2003) found that dogs responded to a projected video image of a person in much the same way as if the person was actually in the room with the dog. This could provide a valuable tool for theory of mind studies, as the people involved would be unable to supply the dog with inadvertent cues. For example, in a Knower-Guesser paradigm, a number of baitings could be pre-recorded, with the informants in each of the possible combinations. The indicating/choice phase could then be recorded separately, so that neither informant knew the correct location (the correct location would be determined randomly for each trial, post-recording). The dogs would then need basic training to make a response, for instance to approach or paw a bowl corresponding with the bowls on the video. During testing, the dogs would be manually reinforced by an experimenter conducting the test. This methodology would enable a viable study eliminating both inadvertent informant cues and extraneous cues.

In general, to make the Knower-Guesser paradigm more 'realistic' the Guesser should indicate the correct location at chance levels. For example, if there are four locations, then the Guesser should be correct on 25% of trials (and therefore point to the same location as the Knower on these trials). Additionally, to minimise the potential for learning over trials, a small number of probe trials could be administered amongst trials that do not require any discrimination by the dog (i.e., only one informant would point). Additionally, future research should involve an analysis of response latencies. If the dogs are distracted and forget or are unsure which informant is the Knower on any given trial,

then response latencies may be increased. Incorrect trials should therefore have longer latencies than correct trials. Examining the pattern of response latencies may provide insight into the mechanisms responsible for the performance of dogs in these tasks.

Another potential method also stems from the Knower-Guesser paradigm, but combines design elements from studies on metacognition, such as Bräuer et al. (2004). While one experimenter conducts a baiting, another experimenter can either observe the baiting, or be unable to observe the baiting, for example, have their eyes closed. The dog can then choose whether to complete the trial, in which the observing experimenter would indicate the container that they believe is baited. If they had observed the baiting, they would indicate the baited container and if the dog chose that container, it would receive the reward. However, if the experimenter had not observed the baiting, they would select a container at random, and thus the dog would only receive the reward at chance levels. The other alternative would be for the dog to pass on the trial, in which case a lesser reward would be obtained. Thus, if the observer had witnessed the baiting, and the dog attributed a state of knowledge to the observer, then it should select to complete the trial. However, if the observer had not witnessed the baiting, the dog should attribute a state of ignorance to the observer, and thus opt to pass the trial.

A modified version of the false-belief paradigm may also provide evidence of theory of mind, much like that used by Tschudin (2006) and Call & Tomasello (1999) (reviewed in section 1.1.5.3). However, because dogs may follow the cues provided by a human rather than what they themselves have observed (Szetei et al., 2003), careful pilot testing would be required to ensure that dogs were actually completing the task to their

best abilities (i.e., they must be able to inhibit the response to the location indicated by the Communicator should the dog's own knowledge be contradictory).

Summary & Conclusion

The present research extends the previous theory of mind research on dogs by providing a systematic set of experiments that incrementally assessed the components necessary for dogs to solve the Knower-Guesser paradigm. Soproni et al. (2001) suggested that although associative processes cannot be completely ruled out when testing for cognitive abilities, they would require far more complex systems to operate than would functionally 'equivalent' cognitive processes, and additionally, they do not explain the immediacy of the dogs' performances. Although one study cannot provide conclusive evidence for knowledge state attribution abilities, the present research does offer evidence in that direction. However, convergent evidence is necessary to establish definitively that dogs possess a functional theory of mind (Povinelli et al., 1990), and there are also many dimensions to such a complicated mechanism as theory of mind that need investigating (Povinelli et al., 1990). Purdy & Domjan (1998) indicated that to make progress, incremental empirical evidence needs to isolate theory of mind systematically from other alternatives.

The present research successfully used a 'triangulation' technique (Heyes, 1993; Heyes, 1998) to provide evidence in support of mental state attribution by dogs. The paradigm was also ecologically relevant to dogs, because of the dogs' pre-existing

sensitivity to human cues, likely due to their extensive history with humans, and importantly because of their willingness to accept food from humans in a cooperative foraging situation.

The goal of the present research was to determine whether dogs could solve the Knower-Guesser task, and do so in a manner consistent with having a theory of mind. When the informants had equivalent perceptual access, the dogs showed no preference between them. However, when one informant had perceptual access to the location of food, whereas the other did not, the dogs chose the knowledgeable informant. Although associative cues appear to have played a role in the first experiment, their effect was minimised in the later experiments, with no detrimental effect on the dogs' performance. The present study provided the most conclusive evidence for theory of mind yet, using the Knower-Guesser paradigm in nonhuman animals. The dogs' performance in this paradigm far exceeded that of dogs in previous theory of mind studies, and also was quantitatively superior to performance of other species in the Knower-Guesser paradigm. Therefore, it appears that domestic dogs were using knowledge state attribution to solve the task, and thus, domestic dogs may have a theory of mind.

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9 APPENDIX

Table 9.1. Name, breed and training history of subjects used in the Experiments 1-4.

Dog	Breed	Training History
AJ	Pug	Retired show dog
Asha †	Labrador Retriever & Staffordshire Bull Terrier cross	General obedience (professional)
Bonnie †	Golden Retriever cross	General obedience (professional - beginners class)
Boss	Bullmastiff & Labrador Retriever cross	General obedience (at home) and trained for pig hunting
Daphne	Fox Terrier & Jack Russell cross	None
Fluff Fluff	Fox Terrier & Jack Russell cross	General obedience (at home)
Jasmine	German Shepherd Dog	General obedience (at home)
Libby	Staffordshire Bull Terrier cross	General obedience (at home)
Lucy	mixed breed	General obedience (at home)
Max 1	Border Collie & Huntaway cross	General obedience (at home)
Max 2	German Shepherd Dog	General obedience (professional)
Ronin †	Labrador Retriever & Samoyed cross	General obedience (at home)
Rouke	Whippet, Staffordshire Bull Terrier & Huntaway cross	General obedience (at home) and in training for pig hunting
Saffie	Siberian Husky	General obedience (professional)
Zeb	Staffordshire Bull Terrier cross	General obedience (at home)
Zoe †	Bichon Frise	Puppy School

† indicates dogs that only participated in Experiment 1 and Experiment 2