



## Anniversary Essay

## Humans are not alone in computing how others see the world



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It is 35 years since Premack & Woodruff famously asked, 'Does the chimpanzee have a theory of mind?' (1978, *Behavioral and Brain Sciences*, **1**, 515–526). The first wave of experiments designed to tackle this provocative question in the context of cooperative transactions with humans offered largely negative answers. It was not until a landmark *Animal Behaviour* paper by Hare et al. (2000, *Animal Behaviour*, **59**, 771–786) that a different approach based around foraging competition between conspecifics delivered an affirmative (if limited) verdict that, at least, 'Chimpanzees know what conspecifics do and do not see'. This influential paper laid the foundations for a much more productive decade of studies that provided evidence for apes' recognition in others of states corresponding to knowing, intending and inferring. It further stimulated related studies in other mammalian and avian species too. Here I set the Hare et al. paper in its historical, scientific context, provide an overview of the variety of studies that have followed in its wake and address some core questions about the scientific tractability of identifying phenomena in nonverbal creatures that may be akin to human 'theory of mind'.

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Through the first half of the 20th century the subject of psychology was dominated by behaviourism, which eschewed reference to inner states of mind. In the case of animal behaviour research, there was a particular concern that a scientific focus on surface behaviour was the way to avoid anthropomorphic misattributions to animals of internal, human-like, mental phenomena. A broadly similar attitude characterized the development of ethology, and rightly so, insofar as description and quantification of objectively defined categories of behaviour established the rigorous bedrock of our science (Hinde 1970).

However, the dominance of behaviourism in psychology has to be set beside an intriguing fact: that in our everyday lives, we humans are committed mentalists, presumably because this approach to understanding, explaining and predicting the future actions of others has evolved to be the most powerful cognitive approach to optimal social action, whether competitive or cooperative. Our language is rich with hundreds of terms to denote and distinguish such core states of mind as seeing, wanting, intending, thinking and believing, including numerous subtle nuances among

these, such as suppose, expect, doubt, suspect, etc. (for epistemic states) and want, wish, hope, ought, should, etc. (for desires). Even 3-year-old children begin to employ such terms and the folk psychological schemes associated with them (Bartsch & Wellman 1995). They use these to discuss why others are acting as they do, what they are likely to do in future, and so on. Humans develop into sophisticated mentalists rather than merely surface behaviourists, for good reason: it works for us.

Since such attributions of states of mind seem so optimal for us, yet can in principle be made without applying linguistic labels to them (and there is intriguing and mounting evidence that human infants begin to do so before they have any significant language: Baillargeon et al. 2010), might a fruitful null hypothesis be that natural selection has shaped minds in other species to structure their social cognition in significantly similar ways? This was essentially what lay behind Premack & Woodruff's (1978) influential question, 'Does the chimpanzee have a theory of mind?'. However, progress in empirically tackling it was slow and faltering for many years. The contribution of Hare et al. (2000) was pivotal in offering a productive new approach, with exciting results. At the time of writing it has accrued over 300 citations in Web of Knowledge (WoK) and over 550 in Google Scholar. It ushered in a much richer and revealing phase of research, not only in chimpanzees but also in a variety of other primates, other mammals and birds.

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## THE SCIENTIFIC BACKGROUND AND CONTEXT TO HARE ET AL. (2000)

Two main threads, sometimes intertwined, can be discerned in the foundations of the field (Whiten 1991, 1997; Call & Santos 2012). The first thread received its principal boost within ethology, particularly in Humphrey's (1976) influential essay on 'The social function of intellect'. Here Humphrey introduced the hypothesis that primate intelligence was primarily an adaptation not so much to the physical problems experienced, such as foraging and predation, but to the special complexities of social life, such as forging optimal coalitions in an inherently dynamic society. Humphrey compared primate social life to a game of chess, to be won by those socially skilled enough to second-guess their opponent's moves. Shortly after, Premack & Woodruff's seminal 1978 paper initiated the second thread. Here, within comparative, experimental psychology, the focus was not the functional context of primate society, but rather the question of to what extent chimpanzee minds are like ours in the architecture of their social cognition, and how this can be experimentally tested. Do they also attribute to others mental states such as intending, knowing and some of the many others that in humans constitute what has been called a folk 'theory of mind' (henceforth ToM)? Premack & Woodruff remarked that 'a system of inferences of this kind may properly be regarded as a theory because such [mental] states are not directly observable, and the system can be used to make predictions about the behavior of others' (page 515). They explored ways of testing for such inferences in chimpanzees. Other writers, for varied reasons including the rather grandiose sound of 'Theory of Mind' when used to refer to everyday cognition, have preferred such terms as 'mind reading', 'mentalism' and 'natural psychology' to refer to this family of phenomena (Whiten 1994), although ToM later became the most common expression used by developmental psychologists.

Humphrey incorporated reference to the Premack & Woodruff initiative in further developments of the ethological perspective (Humphrey 1980), hypothesizing that the most successful individuals in complex primate societies might be those who could discriminate not merely the surface actions of others but could go one step further to discern their underlying states of mind, and thus socially outwit them in the metaphorical games of primate 'chess' being played out. More explicitly, Humphrey (1986) went on to suggest that one way in which primates might do this would be to use their direct access to their own psychological processes (their 'inner eye', as he put it) to model those of their companions, an idea that was later more fully developed by philosophers and psychologists into what came to be called the 'simulation' theory of ToM (Goldman 1989; Stone & Davies 1996; now see Goldman 2006).

A complementary ethological perspective was offered in Krebs & Dawkins's (1984) paper on 'mind reading and manipulation'. Krebs & Dawkins drew on their earlier analysis (Dawkins & Krebs 1978) in which they argued that the existing view of animal communication as functioning to transmit (honest) information was likely to be less revealing in empirical research than the hypothesis that animals are selected more fundamentally to manipulate others to their own ends. In the 1984 paper the authors further argued, in ways that complemented Humphrey's hypotheses, that animals should therefore evolve to best-guess the minds of others to manipulate and outmanoeuvre them better. However, in contrast to Humphrey they did not suggest simulation using an inner eye as the mechanism, but rather that 'experience of the lawfulness of the behaviour of victims becomes internalised in the brain of the mind-reader ... the mind-reader is able to optimize its own behavioural choices in the light of the probable future responses of its victim' (pp. 386–387; for fuller discussion, see Whiten 1996; Shettleworth 2010). This 'statistical' hypothesis about how mind reading might be

achieved anticipates the principal alternative hypothesis later developed in contrast with simulation, sometimes going by the unfortunate title of the 'theory-theory of mind' (i.e. observations, statistical analyses and inferences generate mind-readers' hypotheses about underlying states of mind in others: see Carruthers & Smith 1996, for further discussion).

Remarkably few animal studies built on these early beginnings for 10–15 years. By contrast, developmental psychologists saw the opportunities suggested by these early ideas, and developed experimental tests that began to chart the ontogeny of ToM in children, most notably demonstrating that not until the age of about 4 years were children very competent in recognizing that others' mental representations of the world could be very different to their own and need to be computed to predict their future actions accurately, as seen most revealingly in the context of deception and false beliefs (Wimmer & Perner 1983; see Wellman et al. 2001 for an updating meta-analysis). Just a few years later came the first demonstration that such milestones seen in normally developing children may be absent or drastically delayed in the condition of autistic spectrum disorders (Baron-Cohen et al. 1985). These discoveries, initially sparked by the earlier primate writings described above, became the foundations of a vast research effort addressing numerous questions about the development of ToM in normally and non-normally developing children (see Baron-Cohen et al. 2013 for an updated overview). A WoK search [theory of mind AND child\*] now delivers in excess of 4000 journal paper titles! The best work in this field has enormously enriched our understanding of human social cognition, together with some of the most important consequences of differences between people in its manifestations.

The next developments in animal behaviour again arose within ethology. When Richard Byrne and I began to document what appeared to be episodes of deceptive behaviour perpetrated by baboons in the course of our studies of their behavioural ecology, we recognized that here might be empirical instances of the kinds of social manoeuvres that Humphrey and Premack had theorized about, and that developmental psychologists had started to address in their focus on the recognition of false beliefs in others. Accordingly, and recognizing also that the phenomenon of deception should by its nature be expected to be capricious and thus not easily subject to the usual criteria of scientific replication, we assembled an extensive database of such records contributed by field primatologists and searched it for recurrent patterns (Whiten & Byrne 1988; Byrne & Whiten 1990, 1991). Among our conclusions were that, taken together, the observations suggested that many monkeys and apes appeared able to take into account what others could or could not see, the issue on which Hare et al. (2000) later focused. In a summary of the tactical deception corpus, I concluded (Whiten 1991, page 326) that 'the bulk of the episodes in both monkeys and apes concerned the monitoring and manipulation of others' visual attention'. For example, both monkeys and apes yielded episodes indicating they were able to judge very finely how to hide desirable objects or parts of their body deceptively from the gaze of others (Whiten & Byrne 1988; Byrne & Whiten 1991). Other episodes were interpreted as suggesting a recognition of others' wants and goals.

The contribution of these studies was to indicate the scope and potential adaptive benefits of mind-reading abilities given the challenges and complexities of primate societies. However, compelling conclusions about whether nonhuman primates could truly attribute states such as seeing and knowing required appropriate experimental manipulations of the kind that developmental psychologists had already been pioneering. The form that these might take was suggested in new experimental approaches suggested by Premack (1988). In one of these, after requisite pre-training about the choice they could eventually be allowed to make,

young chimpanzees were allowed to watch while one of two containers was baited behind a screen such that the chimp could not directly see which one was baited. The chimpanzee could also see two human trainers, one of whom could observe which container got baited and the other could not because of a large screen blocking the view. The chimpanzee was then able to request the 'advice' of one of the two trainers, who pointed to a container, followed by the chimpanzee choosing which container to select. Just four young chimpanzees were tested. Two consistently chose the informed individual, implying they recognized that this trainer of the two had been able to see which container was baited, and so was the knowledgeable one from whom preferentially to seek advice. The other two provided more ambiguous results. This experiment thus suffered from a small sample size and results that were at once suggestive and positive (for two individuals) but, overall, somewhat ambiguous and inconclusive. The experiment was also reported in a rather informal manner. It is perhaps best regarded as a pioneering, 'proof of concept' pilot study. It is nevertheless proper to acknowledge and report it here, because its essential logic was applied in the more complete studies that followed, including those of Hare et al. (2000, 2001).

The basic approach was next taken up by Povinelli, in what grew to be an impressively substantial and rigorously conducted programme of research, generating a large suite of experiments. Povinelli initially used a design similar to that of Premack (1988), in which a chimpanzee subject could choose the advice of one of two humans, and the question was whether the chimpanzee would discriminate between human helpers who had been able to witness food baiting or not, and were thus, respectively, in a state of knowledge or ignorance, able only in the latter case to guess about where the food would be. The first results were reported as positive: 'Inferences about guessing and knowing by chimpanzees' (Povinelli et al. 1990). However, critiques later suggested that through series of trials, the chimpanzees may have learned to make the critical distinctions on the basis of directly observable cues (in these experiments, the ignorant alternative was initially engineered by that person leaving the room, and later, in transfer tests, having a bag over their head, covering their eyes; Heyes 1993). Later multiple and better controlled experiments of this kind delivered a resounding negative verdict on chimpanzees' appreciation of the nature of 'seeing' (Povinelli & Eddy 1996). Although they would prefer to beg from an individual who faced them rather than one facing away, that appeared to be the limit of their sophistication. Some by-now rather famous images of other seeing/not-seeing contrasts, which chimpanzees failed to discriminate, include one in which the trainer either had a large bucket over their head or held it to one side, or had a large black blindfold over their eyes, versus their mouth (but for an update with somewhat different results, see Kaminski et al. 2004).

Variations on these experimental designs by others studying apes and yet other pioneering designs applied to monkeys (Cheney & Seyfarth 1990, 1991) to which we return further below, similarly failed to support the hypothesis that these primates are in any interesting sense mind-readers. When Tomasello & Call (1997) assembled an influential and wide-ranging survey of primate cognition their killjoy conclusion was simply that 'there is no solid evidence that non-human primates understand the intentionality or states of mind of others' (page 340). As we shall see, they later overturned this verdict, consequent on the scientific evidence of the Hare et al. paper and others following in its wake.

#### **HARE ET AL. (2000): A NEW PERSPECTIVE**

The paper this essay celebrates, by Brian Hare and his colleagues Josep Call, Bryan Agnetta and Michael Tomasello, differed in two

main ways from the approaches pioneered by workers such as Premack and Povinelli. First, the subject chimpanzees were tested in interaction with conspecifics, rather than in interaction with humans. Second, the interactions were inherently competitive. In this way the study brought together the two key prior threads in the field: it linked directly with the natural, ethologically inspired earlier research on social interactions such as tactical deception and other aspects of competitive animal games of 'chess' referred to by the likes of Humphrey, Krebs, Dawkins, Whiten and Byrne; and it coupled this with some fundamental logic in the experimental designs that had been evolving in both the comparative and developmental psychology literatures outlined above.

Hare et al. presented five main experiments along with some subsidiary experimental probes, in a series that escalated in the controls imposed in order to rule out alternative hypotheses to that proposing that chimpanzees can compute what others can or cannot see. All of the experiments were based on a core design in which a subordinate and a more dominant chimpanzee were released through doors either side of a central arena in which were placed one or more food items that both chimpanzees would be assured to desire. In the normal course of such a scenario, the dominant chimpanzee would thus take the food, by definition. The experiments asked whether the subordinate chimpanzee was able tactically to take into account what the dominant competitor could or could not see, when this differed from its own view such that it could gain a potential advantage and have a chance at the food item. For example, in the first experiment, one piece of food was directly visible to both protagonists in the centre of the arena, but a second was visible only to the subordinate because it was on the subordinate's side of a wall partition near the middle part of the arena. Once the two chimpanzees were released on either side of the arena, subordinates showed a clear preference to take the food hidden from the dominant's view.

This result was what would be predicted if the subordinate recognized which food item the dominant could see and which one it could not. However, alternative explanations could be that the subordinate recognized it would take longer for the dominant to get to the food on their side of the partition, or even that the subordinate just moved to eat where it could not see the dominant.

A second experiment therefore removed the wall barrier and instead hid the food item from the dominant to one side, or just inside, an obscuring object. Similar results were nevertheless obtained, with the subordinate taking more food items that the dominant had not been able to see from its side of the arena. A further two experiments incorporated additional controls to rule out the possibility that the subordinate was reacting directly to behavioural cues from the dominant (most obviously, seeing which food the dominant headed for and choosing the other) or being intimidated by the dominant. To counter such concerns, experiments were run in which the subordinate expressed its preference by a heading direction before the dominant was released, and similar results were again obtained.

A fifth and final experiment replaced the opaque barriers used in the other experiments with transparent barriers, and now the subordinate's preference for food behind barriers disappeared. Accordingly, there is a compelling consistency in the results of the escalating series of experiments (although it would have been yet more compelling if they could have been done with different groups of subjects, to avoid interference effects between experiments); together with various supplementary control tests and observational details of both the subordinates' and dominants' behaviour, they support the conclusion that chimpanzees are able to see such competitive situations not only in terms of their own visual perspective, but instead, and crucially, in terms of the different visual perspective of a competing individual.

Does this mean the chimpanzee does indeed have a theory of mind? Is this 'mind reading' of a kind akin to what is happening when we humans make similar distinctions? I postpone these deeper questions to the next section, because it makes sense to outline here a follow-on paper that appeared in *Animal Behaviour* soon after the one described above, building very directly on the paradigm established there. Hare et al. (2001) now raised the stakes and asked 'Do chimpanzees know what conspecifics know?'

The essential approach was now to test whether chimpanzees could take into account not only what a competitor could or could not see in the here and now, but also the implications for later competition, which would require some encoding of the implications of what the competitor had seen earlier: in everyday terms, what they should 'know' (because of what they had seen) or should 'not know' (because of what they had not seen). In a first experiment a food item was placed on the subordinate's side of one of two small barriers in the competition arena, either while the dominant could watch and become knowledgeable, or not watch (their door was shut) and so remain ignorant. In a further, 'misinformed' condition, the dominant saw where the food was put but then its door was closed and the subordinate watched while the food was shifted behind the other barrier. As before, both chimpanzees were then released into the arena, with the subordinate given a head start to indicate its preference before the dominant could do so. Subordinates took more food items and were less likely to approach the food when the dominant had been uninformed, or even misinformed, compared to control conditions in which the dominant had earlier seen where the food was hidden.

A second experiment began with the same uninformed versus informed scenarios, but then replaced the dominant chimpanzee with another, so that even in the informed condition, the subordinate was now faced with a new and naïve dominant competitor, who was always ignorant because they had not been involved in the original food placement phase. As predicted, subordinates obtained a significantly greater proportion of food items in this 'switched competitor' condition, compared to where there was no switch. Accordingly, chimpanzees in these experiments showed an impressive ability to remember what a competitor had earlier been in a situation to see, or not, and take it into account to shape tactics appropriate to the knowledge state of the competitor. However, in a third and final experiment, when the paradigm was extended to one in which the dominant was able to watch as a piece of food was placed behind one barrier but not allowed to see another piece hid behind a second barrier, subordinates failed to discriminate these scenarios in their later choices. Here, we apparently reach a limit in terms of what chimpanzees will discriminate in this realm. Hare et al. discuss various potential explanations that include a limit on keeping track of the inherent complexities in the sequence of events witnessed in this third and final experiment.

In summary, the new approach of investigating such aspects of social cognition in the context of the kinds of competition between conspecifics that are likely to be more akin to the 'environment of evolutionary adaptedness' that would have shaped such social cognition paid off. Chimpanzees, who had appeared surprisingly 'dumb' in not discriminating the significance of a potential human helper having a bucket over their head rather than at their side, were now experimentally confirmed as rather sophisticated in their social cognition concerning what others may be able to see and subsequently remember, consistent with the earlier evidence based on nonintervening direct observations of wild and captive primates (e.g. Whiten & Byrne 1988). Hare's coauthors, Tomasello and Call, who earlier expressed clear scepticism on the possibility of primate theory of mind as quoted above, accordingly shifted radically to the view that 'Chimpanzees understand psychological states: the question is which ones and to what extent' (Tomasello et al. 2003).

This is an exciting conclusion to draw from these experiments. Is it valid?

### WHEN DOES SMART BEHAVIOUR READING BECOME 'MIND READING'?

In my earlier article with this title (Whiten 1996) I noted that the question of whether any animal discriminates 'states of mind' in others is typically addressed through a contrast with the alternative that it is actually only discriminating observable behaviour patterns (e.g. Cheney & Seyfarth 1990). At first blush this seems a clear distinction: and indeed it seems to be so whenever we agree that as suggested at the outset of this article, evidence from our rich mentalist talk and an array of consistent results from nonverbal forms of testing means we humans are indeed inveterate mentalists rather than mere behaviourists. Yet the contrast becomes less clear, I suggested, insofar as we must recognize that we are not telepathists: we do not see directly into the mind. Like chimpanzees, all we can perceive and react to, to guide adaptive social responses, are observables such as behaviour patterns, and this fact means that distinguishing mind reading from behaviour reading in a nonverbal animal is actually inherently and deeply problematic.

The title above is, however, a bit misleading because it is not only behaviour that may be read to discriminate between states of mind: the environmental context can be crucial too, even sufficient. In fact we see this well in the experiments at stake here. If you put yourself in the position of the subordinate chimpanzee in the experiments of Hare et al. (2000), you would probably be making the judgement of whether the dominant chimpanzee could see the food on your side of one of the barriers largely on the basis of the observable *geometry* of what lies in front of you: assuming the dominant's eyes are open, there need be no difference in the dominant's behaviour at all for you to judge that when there is a line unobstructed by opaque objects between the dominant and the food she can see it, but if there is such an obstruction, she cannot. So really the title I have replicated above is not as apt as it should be: the issue would be more accurately if less neatly expressed as 'when does smart observables reading become mind reading'?

In Whiten (1996) I considered four potential answers. There is not space here to rehearse them fully but a brief summary is necessary.

#### *Deception and the Recognition of Deception (Counterdeception)*

There are numerous reasons for considering both deception and counterdeception in this context. These include relevance to Krebs & Dawkins's (1984) focus on the pressure for animals to distinguish between others' surface behaviour and their true, potentially contrasting underlying intentions; the nature of primate tactical deception and counterdeception cited above (the latter requiring recognition that others' acts may not mean what they seem to, and acting accordingly); and the co-emergence of deception and false-belief attribution in childhood (Sodian et al. 1991). However, I suggested that animals might deceive, or come to recognize, and so counter, deception by others, through a variety of means I distinguished as 'history', 'leakage' and 'contradiction' that can be based rather directly on observables reading and so do not in themselves reliably discriminate mind reading.

#### *Implicit Mind Reading*

Gómez (1991) elegantly described the notion that although nonhuman animals have no language with which to label states of mind explicitly, mind may be seen to be implicit in certain patterns

of observables they discriminate. Thus, in the experiments of Hare et al. (2000), although the subordinates may have been discriminating only the aspects of geometry ('line of sight'), behaviour (eyes opened) and identity (same individual) alluded to above, the subsequent adaptive responses of the subordinates indicates that the mental state of 'seeing' (or not) is implicit in their demonstrable appraisal of the situation they are faced with. Gómez's (2003) analysis now gains additional force in interpreting the new findings with preverbal infants (Baillargeon et al. 2010).

However, one may question whether calling this mind reading adds any explanatory power to the observation that chimpanzees make the critical discriminations between these observables, an issue comprehensively analysed by Penn & Povinelli (2007). This approach thus still does not allow us to decide whether chimpanzees are attributing mental states, as humans do in terms of explicit concepts of mind and mental phenomena. By contrast I argue that the next two approaches to be discussed do this. However, I suspect that the 'implicit' level is that at which the Hare et al. papers of 2000 and 2001 have principally made their ground-breaking contributions in the field of comparative social cognition and I return to this conclusion further below, having discussed the following two alternative approaches.

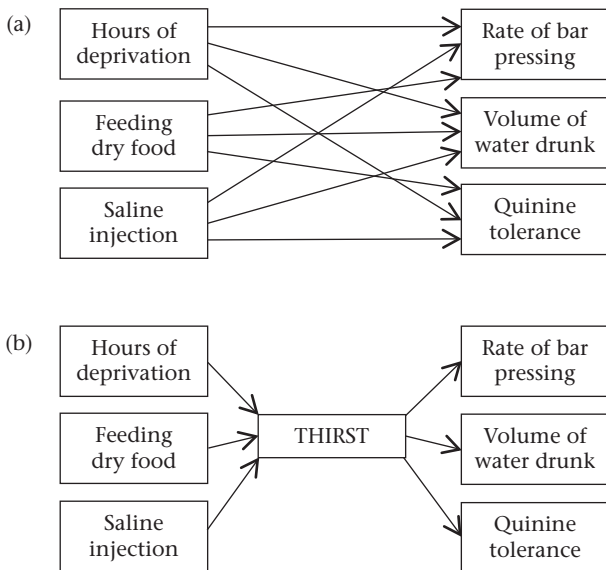
*Mental States As Intervening Variables Predicting Others' Actions*

An example of the concept of intervening variables developed by earlier comparative psychologists is illustrated in Fig. 1. Figure 1a shows nine separate causal relationships concerning rats' drinking behaviour. The recognition that the variant observables on the left can be united by an intervening variable, that here can be reasonably labelled 'thirst' (Fig. 1b) and affects all the observables on the right, provides a more economical analysis, the more so as the number of possible observable conditions on the left, and consequences on the right, multiply. In my 1994 and 1996 papers I suggested (and now, see also Shettleworth 2010) that mind reading follows the same kind of logic, where the brain of either a human or nonhuman mind-reader codes another individual as being in a

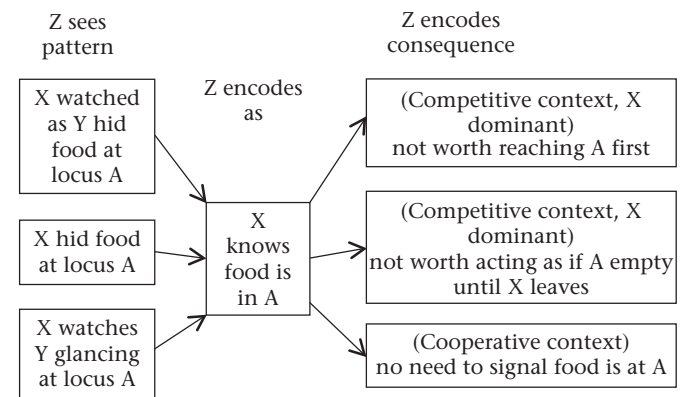
certain state such as 'fearing', 'wanting' or 'knowing' on the basis of a host of alternative indicator variables, and uses that information more efficiently to take actions that are apt for different adaptive outcomes in different circumstances (analogously to Fig. 1b), than would be possible if the vast number of alternative pairwise links had to be learned (analogously to Fig. 1a). Figure 2 offers just one hypothetical illustration applying these principles to the recognition of 'knowing': Whiten (1996) offers other examples for 'fearing' and 'wanting' and a much extended theoretical analysis than can be sketched here.

I propose that this formulation (1) makes sense of what could be entailed in being a nonverbal mentalist; (2) indicates why this represents a powerful cognitive structure, preferentially utilized by humans, at least; and (3) suggests that it may be cognitively demanding to recognize (insightfully?) the existence of such intervening variables in the mass of observable contingencies that make up social life, yet this then provides a more efficient and manageable system once the system is established (Whiten 1996).

Evidence that an animal was processing others' perceptual or knowledge states as intervening variables of the kind illustrated in Fig. 2 would be that novel alternative inputs on the left-hand side could readily be substituted for others and drive the same adaptive outputs; and conversely that on the basis of inputs such as these, novel adaptive outputs could readily be generated. That is what we see in the case of a young child's grasp of the states of seeing and knowing. Gaining such evidence for nonverbal animals is a tall order and evidence for it in the experimental configurations developed by Hare et al. appears minimal at best. On the output side of a web such as that shown in Fig. 2 there is really just one essential prediction to be made in all the experiments: what locus the dominant chimpanzee will head for. However, on the input side there is evidence of a slightly greater range of observables being treated as equivalent: variation in barriers included walls, bags and tyres in different experiments and these were treated as similar in significance to the dominant's door being shut or being replaced by a new, naïve individual; and conversely, variation in the conditions for the dominant being able to see objects included transparent barriers, as well as no barriers. In these ways the results could be seen to go some way towards the conception of discriminating states of mind as intervening variables.



**Figure 1.** A simple example of comparative psychologists' recognition of an intervening variable. (a) Nine causal links between three independent and three dependent variables concerning rats' drinking behaviour. (b) Recognizing an intervening variable ('thirst') permits a more economical representation of causal linkages (after Hinde 1970; Whiten 1994, 1996).



**Figure 2.** Recognizing another individual's state of knowledge as an intervening variable. Here, a hypothetical primate Z reads the mental state of 'knowledge' in an individual X, coding this state as an intervening variable generated on different occasions by a variety of circumstances such as those shown on the left, and in turn giving rise to various predictions appropriate to different circumstances such as those shown on the right. This gains the same benefits of economy indicated in the transition from Fig. 1a to Fig. 1b. (after Whiten 1994, 1996).

### Experience Projection

A very different approach to recognizing nonverbal mentalism rests on models of mind reading that would involve projecting information about one's own mental states onto others: what I labelled 'experience projection' (Whiten 1996). Cheney & Seyfarth (1990, 1991) could be credited with an early application of this approach in a study with macaque monkeys, which tested whether after experience on both sides of one-way 'mirror' glass (i.e. where one can see through the glass one way, but not the other) monkeys would behave differently in situations in which they would then expect that another monkey on the other side of the glass either could see what they were doing (plain glass) or not (one-way glass). In fact no difference was found, leading the authors to conclude they had no evidence for mind reading, over behaviour reading. However, it was asking a lot that the monkeys could, and would, learn by experience the strange optical characteristics of one-way mirrors.

A neater test suggested, although not implemented, by Heyes (1998) was simply to have subjects try out pairs of goggles, with those of one colour being transparent and those of another colour being opaque. The research question would then be whether they then attribute seeing, or inability to see, appropriately to another person wearing one or other of the glasses. For example, Penn & Povinelli (2007) suggest this could be tested by seeing whether a chimpanzee, having had the goggles experience itself, would project this onto humans and so beg from one wearing the goggles they had been able to see through themselves, rather than those that had interfered with their own vision. Given the idea has been in print for so long, it is perhaps rather surprising that a version of this experiment (probably in a different manifestation to goggles) with nonhuman animals has yet to be published (Penn & Povinelli (2007) mention negative results for chimpanzees but such remain unpublished). By contrast, the essential idea has been applied to testing 18-month-old human infants, who did provide significant evidence for experience projection, implying understanding of the state of the mental experience of 'seeing' (versus not seeing) in oneself being projected onto others in similar conditions (Meltzoff 2007).

This approach has perhaps the clearest potential to identify mentalism, at least of this character, in a nonverbal animal, but it is a different approach to that implemented by Hare et al.

### What Character of Social Cognition Did the Hare et al. Approach Demonstrate?

Given the above considerations about alternative approaches to identifying the attribution of mental states, going beyond observables reading only, what is the appropriate interpretation of the results of the Hare et al. studies? I think it follows from the above that only the third and fourth approaches can really hope to address this distinction, and Hare et al. did not apply the fourth approach. Their study goes some way towards indicating the kind of multiple-condition series of experiments that may support the third, 'intervening variables' approach. In my opinion a later study tackling the recognition of intent approached this more closely (Call et al. 2004). However, it remains the case that the results of the 2000 and 2001 studies can all be interpreted in terms of the subordinate chimpanzees' discrimination of the critical observables, largely concerning the geometry of what makes for an unobstructed (or not) line between the dominant chimpanzee and food items.

I think this means that as far as the fascinating question 'are chimpanzees truly mentalists, as we are?' we can still not answer that in either the affirmative or negative. Like the sternest critiques

of the claims for nonhuman mentalism to date, Penn & Povinelli (2007), I believe the question is not entirely intractable, but it is an enormously challenging hypothesis to test and it's still not been cracked in a compelling way.

However, I suggest that saying this neglects the true and considerable value of the Hare et al. 2000 and 2001 studies and all that has followed in their wake. What they showed us, was that (1) contrary to the prior picture we had, chimpanzee subjects *do* recognize distinctions between the conditions under which others can see or cannot see things that are perfectly visible to themselves; (2) accordingly, they register the fundamental bases on which we humans make the distinctions we call 'seeing' versus 'not seeing'; and (3) they can use this to guide their social manoeuvring adaptively. Note that 3-year-old children typically fail to predict correctly where a person acting under a false belief will search for an object moved in their absence to a new location; they instead predict the person will search according to their *own* perspective, that is, where they themselves know the object to be. Unlike older children who make the correct predictions, they are thus egocentric in this respect. The chimpanzees in the Hare et al. study, impressively, were not: they could see the food themselves, but they computed the perspective of the dominant and successfully made use of that in their actions. I conclude that if we set aside the preoccupation 'Do chimpanzees *really* have a *theory of mind*', we can recognize the real strides in our understanding achieved through these difficult-to-arrange experiments. And insofar as 'seeing' and 'knowing' are implicit in complex discriminations the chimpanzee performs, it makes some sense to describe these as 'mind reading' or 'natural psychology', provided the limited sense in which these terms are applied is recognized. The same is true for many related studies that have built on the Hare et al. 2000 and 2001 studies.

### DEVELOPMENTS IN THE WAKE OF HARE ET AL. (2000, 2001)

Research since 2000 has focused on a variety of counterparts of states of mind recognized by humans (Call & Santos 2012) and has also diversified taxonomically. In the latter respect it has nevertheless remained extremely biased. Of the ca. 300 WoK citations of Hare et al. (2000), just over 100 are in primate articles, many of them on apes; about 15 concern dogs, even fewer for other mammals (including elephants, pigs and horses); and about 15 are from avian studies. The rest include reviews, general papers and others focused on children and other human foci, including the evolution of human mind reading from the origins implied by the primate work (Hare 2011; Whiten & Erdal 2012) and relationships with other dimensions of social and nonsocial cognition (Suddendorf & Whiten 2001; Whiten 2013).

### *In the Vanguard: Chimpanzee Social Cognition*

As the most numerous of the two species of *Pan* with whom we share our most recent common ancestor, chimpanzees have continued to be the most studied in relation to questions such as those posed by Hare et al. On the one hand we are fortunate that the industry and ingenuity of the Leipzig research group has been coupled with the requisite statistically robust sample sizes and experimental facilities available to them to achieve this; more unfortunate is that we largely lack the scientific checks that come from replication tests by other research groups.

Research building on the 2000 and 2001 papers has included both negative and confirmatory, positive results from variants of the basic design, indicating that visual perspective taking is conditional with respect to environmental configurations (Karin-D'Arcy & Povinelli 2002; Bräuer et al. 2007). More elaborate designs have gone beyond tests of knowledge attribution to provide

evidence for the recognition of intent (where chimpanzees were shown to distinguish an unwillingness to help them from a clumsy inability to help: Call et al. 2004; see Behne et al. 2005 for a child comparison; Buttelmann et al. 2012) and of inference making (Schmeltz et al. 2011). By contrast, tests for the attribution of false beliefs have consistently produced a negative verdict (Kaminski et al. 2008). Related tests have come full circle from the ethological analyses of tactical deception to demonstrate experimentally chimpanzees' capacity, when stealing food, to choose preferentially an option that provides visual cover where a human is in the role of 'dominant' (Hare et al. 2006), or to minimize the sounds such a human victim might hear (Melis et al. 2006), an effect puzzlingly not observed in testing between conspecifics (Bräuer et al. 2008).

Setting aside their earlier scepticism of 1997, Call & Tomasello (2008; see also Call & Tomasello 2005) declare that on the basis of this suite of experiments, their 'conclusion for the moment' is that 'chimpanzees understand others in terms of a perception-goal psychology, as opposed to a full-fledged, human-like belief-desire psychology' (page 187).

#### *Social Cognition in Other Primates and Other Mammals*

As in these experimental studies of deception, Santos and colleagues have utilized the basic logic of the 2000 and 2001 studies but have done so among free-ranging macaque monkeys. In these studies on Cayo Santiago, given two food sources the monkeys demonstrated a preference to steal food from the one that either provided more visual cover from the human victim's point of view (Flombaum & Santos 2005) or minimized the noise involved (Santos et al. 2006). This research group has also used a very different approach developed in human infant studies that relies on changes in inspection time to indicate what subjects find surprising, and applying this method to macaques led to the conclusion that, paralleling the results with chimpanzees noted above, these monkeys discriminate the conditions of others having knowledge, but not their false beliefs (Marticorena et al. 2011). Hare et al. (2003) more directly repeated the approach of the 2000 chimpanzee study with brown capuchins, finding some ability to discriminate between the seeing versus not-seeing conditions, although it was not so clearly established that this was not simply due to the direct cues from the behaviour of the dominant participant. Other positive results have since been reported for capuchin monkeys (Kuroshima et al. 2002, 2003; Hattori et al. 2010) as well as for goats (Kaminski et al. 2006) and dogs (Kaminski et al. 2009).

#### *Social Cognition in Birds*

Experiments following the design of Hare et al. have to my knowledge not been completed with birds, but the findings of the chimpanzee studies reinforced interest in the cognitive complexities underlying the natural food-caching behaviour of corvids. For example, scrub-jays have been shown not only to recache their food later if another jay was present to see the initial caching, but to do so taking into account which particular competitor had been present (Dally et al. 2006).

As in the case of the suite of chimpanzee experiments developed over the last decade, a substantial corpus of studies has demonstrated considerable cognitive sophistication in various corvid species in these scenarios (Bugnyar & Henrich 2005; Clayton et al. 2007); indeed, the latter article uses Humphrey's original expression for an animal mind-reader, 'natural psychologist' in its title. However, as in the chimpanzee study, it is possible to describe what the birds are discriminating in terms of direct observables and appropriate behavioural rules, such as that given by Penn &

Povinelli (2007, page 736) as 're-cache food in a site different from the one where it was cached when the competitor was present'. Van der Vaart et al. (2012) have developed a theoretical model in which a 'virtual jay' is guided only by simpler processes such as stress and its effects on memory, which largely replicates the behaviour of real jays in the experiments. However, Thom & Clayton (2013) have run additional experiments that counter the stress hypothesis.

There is, however, one particularly intriguing result in this corpus that relates directly to the 'experience projection' model of mind reading outlined above, yet is not considered in the model of van der Vaart et al.: it is only scrub-jays that themselves have a history of pilfering caches that adopt the strategy of recaching when others may have seen their caching (Emery & Clayton 2001). This is clearly consistent with the hypothesis that they project onto others the pilfering intent they have themselves experienced and take appropriate action. I have yet to see a compelling alternative account of this effect. Penn & Povinelli (2007) dismiss it along with all other candidate evidence for nonhuman mentalism, but they fail to explain why it should occur.

#### THE FUTURE

Having shifted my own research programme to what I saw as more tractable issues of social learning and cultural transmission, it is not for me to declaim where those now most active in the field should take it next! However, a few modest comments would seem in order in relation to some obvious biases and gaps. I will mention three of these.

First, for those who wish to focus on the question of 'true mentalism', some versions of the 'goggles' experiments, now done with human infants (Meltzoff 2007), would seem eminently worth completing. With subjects such as apes, this clearly presents great practical difficulties, but many in the field agree that, scientifically, it could in principle deliver important answers on this issue.

However, if as I advocate above, one focuses instead on just what discriminations animals make that correspond to those that form the bases of our human psychological categories, then there remains much unexplored territory. One aspect of this is that there are hardly any studies of wild animals. This is of course for the good reason that the experimental configurations needed (as in the Hare et al. studies) are difficult to engineer in captivity and even more so in the wild. However, impressive attempts have begun (Crockford et al. 2012) with exciting, if still controversial, results. Note that the latter study did not focus on competition but on altruistic warning calls among chimpanzees: although Hare et al. have argued that it is the competitive element that helped their breakthrough, this has yet to be compellingly demonstrated and I for one remain sceptical on that issue.

Finally, the taxonomic biases are all too evident in the numbers of recent studies cited above. Studies of nonprimates and non-caching birds remain rare. Even chimpanzees' sister species, the bonobo, is only now beginning to be included in the corpus of studies (MacLean & Hare 2012). Future studies could benefit from starting from the natural problems of social manoeuvring that the animals in question negotiate in their natural lives. Contexts other than competition for food could be explored, such as complexities within pair bonds, and perhaps even the mutual perceptions that predator and prey have of each other.

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