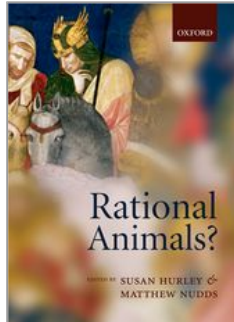


Descartes' two errors: Reason and reflection in the great apes

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Descartes' two errors: Reason and reflection in the great apes

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Abstract and Keywords

This chapter examines reason and reflection in the great apes. It presents a variety of behavioural evidence that is best explained either by causal reasoning or by metacognition and analyses the between capacities for reasoning and for metacognition. It evaluates the results of a study which suggest that apes do not simply associate a cue with the presence of food, but understand that the food is the cause of the cue, and can reason accordingly. This behaviour can be regarded as evidence of a capacity for proto-logical reasoning that relies on pairs of contraries and conditional dependence based on causal dependence.

Keywords: reason, reflection, apes, causal reasoning, metacognition, proto-logical reasoning, conditional dependence, causal dependence

Abstract

Descartes' two errors: Reason and reflection in the great apes

Reasoning and reflection have traditionally been considered uniquely human attributes. Many animals, including the great apes, are often regarded as masters at making associations between arbitrary stimuli while at the same time they are rarely considered capable of reasoning and understanding the causality behind even simple phenomena. In this chapter, I defend a view opposite to this predominant position. Apes (and possibly other animals) are actually quite good at understanding and reasoning about certain physical properties of their world while at the same time they are quite bad at associating arbitrary stimuli and responses. In other words, if two stimuli have a causal connection (as when food inside a shaken cup makes noise) apes perform better than if stimuli hold an arbitrary relation (as when an unrelated noise indicates food), even if the contingencies of reinforcement are the same. Neither a history of reinforcement based on traditional associationism or a biological predisposition to respond differentially to certain stimuli combinations explains these results. Instead, I postulate that subjects reason and use logical operations based on inference by exclusion to locate the hidden food. In addition to the ability to reason about physical phenomena, I argue that apes (and other animals) also have some access to their understanding of the problem. More precisely, they have metacognitive abilities that allow them to know what they know or do not know. Thus reasoning and reflection may not be the bastions of human uniqueness, as Descartes once thought. Rather, these skills may have evolved (or coevolved) in other animals as well because they allowed them to solve problems in the world more efficiently.

10.1 Introduction

When I was growing up, my elementary school teacher taught us that there were two kinds of animals: rational and irrational. Rational animals were those that are able to reason (p.220) and think, capable of moral judgments, and possessing a conscience. Irrational animals not only lacked such high

Descartes' two errors: Reason and reflection in the great apes

qualities, they also lacked feelings, a sense of the future, language, and culture. Put another way, we were taught that human beings are rational animals, and that animals in the rest of the animal kingdom are irrational or non-rational.

This distinction between humans and non-human animals (animals henceforth) has its roots in some of the greatest Western thinkers. Descartes in particular made a sharp distinction between animals and humans. Perhaps partly influenced by the automata activated by the laws of hydraulics that populated the gardens of 16th century France, Descartes maintained that animal behavior could be reduced to a series of automatic reflexes. Human behavior, in contrast, is not purely reflexive but is controlled by rational thought. His famous '*cogito ergo sum*' ('I think, therefore I am') sums up the gist of his message. According to Descartes, humans are rational and conscious whereas animals are non-rational and unconscious; humans can reason and reflect whereas animals can do neither.

This idea of a clear dichotomy between humans and animals has had a pervasive influence, not just on elementary school teachers and philosophers, but also on much of contemporary psychology. Beginning with such illustrious figures as James (1890), Loeb (1918), or Thorndike (1898), the idea that animals can learn to associate stimuli and responses, but possess no understanding and are incapable of reasoning about even simple events in the world is widespread. Animals are often branded as association champions: capable of associating arbitrary stimuli and responses, yet incapable of understanding the causality behind even simple phenomena.

In this paper, I will defend a position that is exactly the opposite of this predominant view. I will argue that apes (and possibly other animals) are actually quite good at understanding and reasoning about certain physical properties of their world, but that they are quite bad at associating arbitrary stimuli and responses. In other words, if two stimuli have a causal connection (for example, shaken food inside a cup makes noise) apes perform better than if stimuli hold an arbitrary relation (for example, noise indicates food), even if the contingencies of reinforcement are maintained equal.

Furthermore, I will argue that in addition to being able to reason about their physical world, apes can reflect on the problems they try to solve, have some access to their own understanding of the problems, and have the capacity to recognize that they make mistakes. These claims go against the positions of some of the most prominent cognitive scientists of our time. For instance, Tulving and Madigan (1970) maintain that 'one of the truly unique characteristics of human memory [is]: knowing about knowing' (p. 477).

This chapter is organized into three parts. First, I will review some recent evidence supporting the idea that apes engage in causal reasoning about physical problems related to finding food. Second, I will review some evidence that suggests that apes have access to their own mental processes. Finally, I will conclude with some reflections on the evolution (perhaps it would be more appropriate to say coevolution) of reasoning and reflection in animals.

(p.221) 10.2 On reasoning

It is widely believed that many animals are extremely good at associating arbitrary cues with responses while at the same time being rather limited in their ability to understand the causal relations between certain physical events. For instance, an animal may learn that a noise predicts the presence of a food, but may not understand that it is the food that causes the noise. Associating such cues is seen as common, while having a causal understanding is seen as exceptional, in many cases unproven. It is true that there are many cases that suggest cue learning, but there are other cases that, although at first sight may appear as cases of cue learning, on closer inspection cannot be so easily explained by conditional associations.

Premack (1995) contrasted what he called natural causes and arbitrary causes. Natural causation is based on an underlying theory that explains the relation between two events; for instance, gravitational theory states that an unsupported object will fall to the ground due to the gravitational force of the earth. Arbitrary causation is based on pairing the two events in time and space; for instance, the color green denotes right of way. Premack argued that chimpanzees were quite

skilful at solving problems depicting natural causes. In one study, Premack and Premack (1994) presented chimpanzees with two boxes and two types of fruit (for example banana and apple). Chimpanzees were allowed to witness the experimenter deposit one kind of fruit in each of the boxes so that both boxes were baited. Later subjects saw the experimenter eating one of the fruits (for example, banana) and the question was whether, given the opportunity to select one of the boxes, they would select the box in which the experimenter had deposited the food that he was not currently eating (that is, apple), presumably because it still contained the fruit. Chimpanzees solved this problem quickly without trial-and-error, showing that they were able to infer that if the experimenter was eating the banana, the box where the banana was deposited would be empty. This is called *inferential reasoning by exclusion* (see also Bermúdez' discussion, Chapter 5, this volume). The alternative to this inferential strategy is a discriminative learning strategy in which subjects learn through multiple trials that the presence of the banana in the experimenter's mouth is a discriminative sign for choosing the other alternative. Premack (1995), however, ruled out this explanation on the grounds that chimpanzees did not learn gradually to select the correct container, but selected it from the beginning. Next I will present some additional studies on this topic in which I further explored great apes' understanding of natural causes, and directly contrasted problems depicting natural and arbitrary causes.

10.2.1 Shaken food inside a cup makes noise

Call (2004) extended this previous work on inferences to include the use of auditory stimuli and to probe more deeply into the understanding that apes (not just chimpanzees) have about such events. The basic idea of this study was to contrast two types of problem that present similar superficial cues and reward contingencies but that (p.222) differ in their causal structure. In one such study, we presented two opaque cups and baited one of them. In the causal problem (a natural cause, in Premack's terminology), we shook both cups, which resulted in the baited one making a noise. In the arbitrary problem (an arbitrary cause, in Premack's terminology), we

tapped both cups but we only produced a noisy tapping for the baited cup. Thus in both problems a sound indicated the presence of the food, but the problems differed in their causal structure: in one case the noise was caused by the food, in the other it wasn't. The results showed that apes selected the baited cup above chance in the causal, but not the arbitrary problem. This is even more striking since we ran the arbitrary test after the apes had succeeded in the causal test; moreover, in the arbitrary test they were actually rewarded every time they selected the cup associated with the tapping noise, something which occurred on approximately 50 per cent (that is, 12) of the trials. Additional tests indicated that substituting the tapping noise with a recorded shaking noise made no difference, and control tests showed that animals were not using cues given inadvertently by the experimenter, or the smell of the reward, to locate the food.

In another test, we further probed the apes' understanding of the relation between movement and noise; in particular, we investigated whether they were able to make inferences regarding the location of food. Again, we presented subjects with two cups. This time, however, we shook the empty cup and lifted the baited one so that no sound was produced from either cup. If subjects know that shaken food produces a noise, they should select the lifted cup because if a shaken cup makes no noise, then the food must be in the other cup. Results indicated that subjects selected the baited cup more than in a control condition in which we lifted both cups. Additional experiments showed that this result could not be explained as a learned avoidance response to the silent shaken cup since they did not avoid the shaken silent cup when it was paired with a cup, which we rotated silently. In a further test, three subjects were able to appreciate that certain movements but not others can produce a noise. We presented a silent shaken cup (moved laterally) paired with a silent stirred cup (that is, moved in a circle). Here, both cups were moved, but food inside the cups would only produce a sound if the cup was shaken and not if the cup was stirred. The subjects who succeeded at this task know that certain movements, but not others, are likely to produce a sound.

In summary, these results show that the apes are better at solving causal as opposed to than arbitrary problems, and that they can make inferences regarding the location of food based on the differential movements of cups in the absence of any sound cue. One interpretation of these results is that apes do not simply associate a sound with the presence of food, but attribute the sound to the food itself, they understand that the food is the cause of the noise.

10.2.2 Solid food under a board occupies space

One possible criticism of the previous paradigm is that it is based on auditory information, and this may be special for some reason. Therefore, it is unclear whether (p.223) these results represent a general understanding of causality about the physical world. We decided to investigate this possibility by using tests that do not involve auditory information but visual information. Some studies with human infants have shown that they are sensitive to certain properties of objects such as solidity. In a classic study, Baillargeon *et al.* (1985) presented infants with an object and a screen located in front of the object, which flipped towards the object. In one condition, the screen flipped over the object until it occluded it and then stopped. In another condition, the screen described the same movement as before, but once it reached the object it continued to move so that it apparently passed through the object.

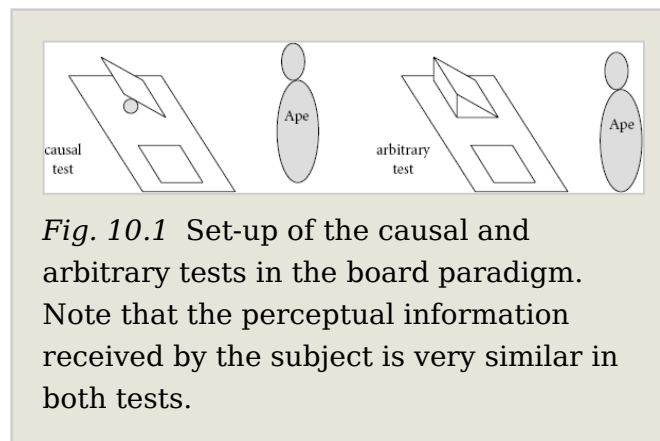
Using this inclined barrier idea, Call (submitted) investigated whether bonobos, gorillas, and orangutans can understand that a piece of food hidden underneath a screen occupies space. Again, we contrasted a causal problem with a matched arbitrary problem. In the causal problem, we presented apes with two small wooden boards (25×9 cm) on a platform and hid a reward under one of them in such a way that the orientation of the boards differed. The empty board remained flat on the surface of the platform while the baited board acquired an inclined orientation due to the presence of the reward under it (Fig. 10.1). Given a choice between the two boards, the apes preferentially selected the inclined board in 80 per cent of the trials. There were no significant differences between species. It's possible that the apes had previously learned that objects with an inclined orientation are often

Descartes' two errors: Reason and reflection in the great apes

rewarded, or that they preferred inclined objects because they look larger: a response acquired before the experiment is often very hard to rule out, particularly with species that have to live in complex and stimulating environments to develop properly. Fortunately, the arbitrary test in this study allowed us to rule out the possibility of a previous association. In this arbitrary test we replaced one of the boards with a solid wooden wedge that produced the same visual effect as a baited board when placed on the platform. Prior to the test, we showed the wedge to the subjects so that they could inspect it. We then paired it with a flat board and measured the subjects' preferences. Results indicated that there was no preference for the wooden wedge over the flat board. Subjects selected the wedge and the flat board in 53 per cent and 47 per cent of the trials, respectively. This result is even more striking if one notes that, as in the noise paradigm, we ran this arbitrary test after the apes had succeeded in the causal test.

(p.224)

Moreover, they were rewarded every time they selected the wedge in this test, which on average they did 50 per cent of the time (that is, on 12 trials).



In summary, subjects only preferred the wooden inclined object in the causal test, not the arbitrary one, presumably because, as in the previous experiment, they understood that the inclined orientation was caused by the presence of food.

10.2.3 Arbitrary cues are hard to learn

One could argue that the arbitrary tests that we used are too hard for the apes and that is why they scored higher in the causal tests than the arbitrary ones. On this suggestion, differences are detected not because offering a causal

Descartes' two errors: Reason and reflection in the great apes

structure helps, but because the specific arbitrary tests that we used to compare with causal tests are particularly difficult. This argument, however, is disproved by the results of various color and shape discrimination learning tests. As part of other studies, we tested discrimination learning in the same apes that we used for the causality tests and found that these results resembled those obtained in the arbitrary tests presented here, not those in the causal tests. Figure 10.2 presents a comparison between causal, arbitrary, and simple discrimination tests after 24 trials. Only causal tests were above chance ($p < 0.001$ in both cases). Moreover, a much higher proportion of subjects obtained individual scores above chance in the causal than in the arbitrary or discrimination tests; and none was above chance after the first 12 trials in the arbitrary or discrimination tests, whereas several apes were above chance in the causal tests.

In summary, subjects performed better in causal than in arbitrary tests, both in auditory and visual modalities. Moreover, there was no evidence of learning during the testing sessions: subjects either performed well from the beginning of the session

(p.225) or poorly throughout. Finally, the performance on arbitrary tests closely resembled that found in basic discrimination tests, which suggests that the arbitrary tests that we used were not particularly difficult. Taken together, these results suggest that apes do not simply associate a cue with the presence of food, but rather understand that the food is the cause of the cue.

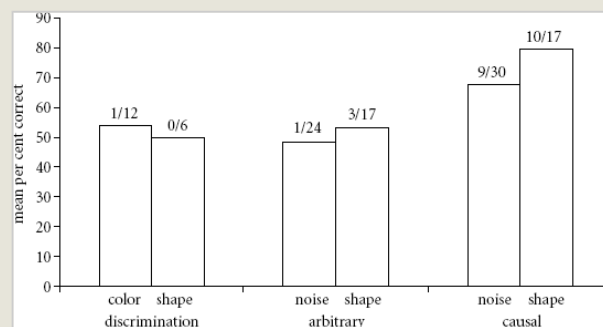


Fig. 10.2 A comparison of the mean percentage of correct trials in the discrimination, arbitrary, and causal tests. Also shown is the number of subjects that obtained individual scores above chance in each of the tests.

10.3 Rationality by association, biological predisposition, or logic

A common response to evidence such as that presented here for rationality and causal understanding in apes is to seek alternative mechanisms that could also explain the evidence but which do not attribute rationality or causal understanding to apes. Two mechanisms, in particular, have historically played a prominent role in comparative research. Some authors have appealed to associative learning and a history of reinforcement; others have appealed to innate preprogrammed dispositions to behave in certain ways in response to certain stimuli. I next consider whether either of these two mechanisms can account for the different results, described in this chapter, between causal and arbitrary tests. After rejecting each of these explanations, I offer a third explanation based on logical thinking and knowledge about physical phenomena.

10.3.1 History of reinforcement

Learning theorists like to think that previous associations or a generalizations of previous associations are all that is needed to explain phenomena like those presented in this chapter. Thus acquired aversions or preferences for certain stimuli may be postulated to explain such results, as opposed to an understanding of the causal structure of the problem. However, such accounts do not explain some of the results in the literature, including those in this chapter.

For example, it might be argued, that the preference for the cup associated with a noise in the shaken food experiment is the result of a previously learned history of reinforcement. However, leaving aside for the moment those cases in which subjects solved the problem satisfactorily when there was no noise, an explanation in terms of association cannot explain why subjects responded to shaken food and noise, but not to the tapping noise or to the tape recording of the noise.

It could be argued that the noise is not exactly the same across these cases. However, this causal test provided the subjects' first experience of this particular noise associated with the particular cup and particular movements. So if a

specific noise is critical, they should not have passed the causal test; but they did. If one abandons the idea of noise specificity and argues instead that all that is shown is that animals can generalize from past experience, one then faces the difficulty of explaining why they failed the arbitrary tests whose perceptual structure closely mirrored that of the causal test. Moreover, when given the opportunity within our testing session to learn to use the noise as a cue (p.226) for the location of the reward, subjects failed to do so, even though they were rewarded on an average of 50 per cent of the trials due to their chance responding.

Now let's go back to the test in which subjects selected above chance the baited cup in the absence of auditory cues. Recall that subjects preferred to choose a noiseless lifted cup over a noiseless shaken cup. This finding cannot be explained by invoking the perception of auditory cues because there were none. Yet, due to the fact that this experiment took place after subjects had experienced the pairing of a noiseless shaken cup with a noisy shaken cup, one could argue that subjects had developed an aversion to the noiseless shaken cup. However, the follow-up test revealed that subjects did not avoid the noiseless shaken cup when paired with a noiseless rotated cup. This means that learned cup aversion cannot satisfactorily explain these results.

Another example of the limitations of a history of reinforcement to account for these results is the arbitrary task with the wedge. In study described above, the apes performed well in the causal task in which the food under a board produced an inclined orientation but did poorly in the arbitrary task in which the objects presented closely resembled those of the causal task. No doubt other *post hoc* explanations in terms of a hypothetical history of reinforcement could be put forward to account for the differences between the results on the causal task and the arbitrary task. Unfortunately, these hypotheses are rarely tested, and so far the ones that have been suggested to us and tested failed to account for our results. Therefore, an explanation of the differences between causal and arbitrary tests presented in this chapter in terms of some learned association does not seem plausible.¹

10.3.2 Biological predispositions

The second alternative explains differences in learning as a result of innate aversions or preferences. The phenomenon of differences in learning is not new. Learning theorists have traditionally appealed to some biological predisposition of certain species to explain differences in learning across tasks. Seligman (1972) coined the term 'preparedness' to indicate that animals may be prepared to learn some things faster and better than others, particularly those with great biological significance or importance for their survival. This would typically apply to things like taste aversion and to predator detection and avoidance, both of which may channel learning in very constrained ways. Bolles (1970) referred to species-specific defense reactions to explain why rats and pigeons learn different behaviors with different degrees of ease. Another case of specialized learning can be seen in bees that show a greater facility for learning certain colors and odors over others (Menzel 1985), something which has obvious relevance for bees' survival.

(p.227) It is hard to see, however, how that same biological urgency would apply to the problems presented in this chapter. Clearly, solving these problems does not have the same urgency as defensive reactions to predators or the avoidance of poisonous food. Besides, apes do not experience the artifacts used in the tests in their natural environment and, more importantly, detecting food items by the shape of objects over them or by the noise they make does not form part of the natural feeding habits of the great apes. These animals find their fruit in trees or as part of the vegetation that surrounds them. Moreover, if subjects are predisposed to select the inclined board or objects that produce auditory cues, we would still have to explain why they did not select those alternatives in the arbitrary tasks whose reinforcement contingencies and perceptual arrangements closely resembled those of the causal tasks. Therefore, a biological predisposition does not seem a plausible explanation for the differences between causal and arbitrary tasks presented in this chapter.

10.3.3 Knowledge, logic, and inference

If the difference between causal and arbitrary problems cannot be satisfactorily accounted for by appealing to a biological predisposition or to a learned association, one must find another alternative. I propose that the differential success in these two kinds of problems resides in the ability of individuals to grasp the causal structure of the problem. This ability exists because subjects have developed a system of knowledge and inference about observable phenomena. It is important to emphasize that this system of knowledge is not totally incompatible with the other two mechanisms. It is very likely that experience or a core knowledge system may be important in developing the knowledge about the world that allows individuals to make inferences and solve novel problems. However, I argue that this knowledge system cannot be simply equated with biological predispositions or learned associations. Rather, it is an emergent system that goes beyond perceptual generalizations or biological predispositions (Call 2001). It represents knowledge about the causality of certain physical events, and supports the use of logical inference in choosing among alternatives so as to maximize food intake.²

10.4 On reflection

The ability of animals to reflect on their own knowledge states has, until now, received little attention. While we know a great deal about cognition in animals, we know much less about metacognition. In other words, although it is clear that many animals know how to solve problems, it is unclear whether they also know that they possess this knowledge and, more importantly, whether they know when they do not know. If animals are capable of metacognition, this would open up the possibility that they (p.228) understand that they can make mistakes when they lack appropriate knowledge (see also Shettleworth and Sutton, Chapter 11, this volume).

10.4.1 Monkeys and dolphins know when they are uncertain

Recently, several authors have investigated this area with two basic paradigms. In one paradigm, investigators produce uncertainty in their subjects by presenting stimuli that are hard to discriminate; subjects' escape responses are then

measured. The question addressed is whether subjects tend to escape hard-to-discriminate trials when given the opportunity to press an escape key. In one example, Smith *et al.* (1995) presented a discrimination task in which a dolphin and human subjects had to decide whether the stimulus was high or low pitch. (In another version of this task (Smith *et al.* 1997), rhesus monkeys had to distinguish between stimuli with low and high pixel densities.) If the stimulus had the highest pitch (2100 Hz) subjects had to press the HIGH key whereas if the stimulus fell between 1200 and 2099 Hz, they had to press the LOW key. The closer the stimuli drew to the 2100 Hz pitch, the harder it became to decide whether it was either low or high pitch. Subjects were only rewarded for correct responses and incurred a time-out period without reward for incorrect choices. In addition to the LOW or HIGH key choice, subjects had a third option: the escape key. Subjects could press this key to skip the current trial and go to the next one; pressing escape was always reinforced with the limitation that its excessive use gradually delayed the presentation of the next trial, thus becoming aversive. The results showed that dolphins and humans (and rhesus monkeys in the visual version of this task) increased the use of the escape key as the discrimination became increasingly difficult. They rarely used the escape key for low pitch stimuli and the percentage of escape responses also decreased for the highest pitch stimulus.

10.4.2 Monkeys know when they have forgotten

Hampton (2001) also used the uncertainty/escape paradigm and tested two rhesus monkeys with a delayed matching to sample task presented on a computer screen. In a third of the trials, the subjects experienced the presentation of a sample stimulus followed by four alternative stimuli after a delay of approximately 30 seconds. In the remaining two-thirds of the trials, subjects were offered the possibility to decline or take a trial. Declining a trial invariably resulted in the delivery of a not-so-preferred reward (monkey chow). Subjects could attempt to get a highly preferred reward (a peanut) by choosing to take the test (and answering correctly). Incorrect choices resulted in a rewardless time-out period. Hampton (2001) found that subjects performed better in those trials in

Descartes' two errors: Reason and reflection in the great apes

which they were free to decline a test compared with the compulsory test. This suggests that the monkeys may have known when they had forgotten the correct answer.

Two additional tests reinforced this conclusion. In a second experiment, Hampton (2001) increased the delay interval between the presentation of the sample and the (p.229) alternatives in an attempt to foster forgetting in the monkeys. As expected, results showed that monkeys' performance declined proportionally to the amount of delay between the sample and the alternative stimuli. More importantly, monkeys chose to decline a higher proportion of trials in those trials with longer delays between the sample and the alternatives. Hampton (2001) also presented some trials without a sample. As expected, one of the monkeys declined tests more often when no sample had been offered. Hampton (2001) concluded that rhesus monkeys know when they have forgotten and they can respond to this lack of information by escaping the situation, that is, declining to take the test.³

10.4.3 Apes know what they have not seen

A second paradigm has investigated the metacognitive abilities of animals by investigating whether subjects seek additional information before making a choice between two alternatives when presented with incomplete information. Call and Carpenter (2001) presented 2-year-old children, orangutans, and chimpanzees with the following situation. Food was placed inside one of two hollow tubes perpendicularly oriented toward the subjects. In order to get a reward, subjects had to touch the baited tube. There were two baiting conditions. In the visible condition, the experimenter placed the food inside the tube in full view of the subject. In the hidden condition, the experimenter baited one of the tubes but prevented the subjects from witnessing the baiting so although they knew there was food in one tube they did not know which. The question was whether subjects would preferentially look inside the tubes before choosing in those tests in which they had not witnessed the baiting.

The results showed that subjects looked into the tubes before choosing more often when they had not seen the baiting. In addition, in 20–30 per cent of the trials subjects made a

selection immediately after encountering an empty tube, indicating that they could succeed at the task without seeing the food. Subjects were not, in other words, simply searching until finding the food. Interestingly, this result combines the metacognitive and cognitive dimensions in the same problem. After being prevented from witnessing the baiting, subjects sought information to resolve their lack of knowledge (metacognitive dimension) and upon finding the empty tube they inferred that the food was in the other tube (cognitive dimension). Recall that this type of inference is analogous to the ones described in the previous section when, upon finding an empty cup (or a noiseless shaken cup), subjects selected the other cup. Also note that, because the shaken silent tube is not aversive, it is likely that the empty tube is not aversive either. Therefore it is likely that, when they choose the baited tube after finding the empty one, they are not simply avoiding the empty tube, but are actually inferring that the food is in the non-inspected tube.

(p.230) Recently, we replicated our original results with a different group of orangutans and chimpanzees, and extended them to gorillas and bonobos (Call, in press). The positive results with the gorillas were particularly interesting because, unlike other ape species, gorillas seem to have great difficulty with the mirror-self-recognition test (Suarez and Gallup 1981). In contrast with the positive results with apes, dogs failed this test despite being able to retrieve food with high accuracy when they saw where the food was located (Bräer *et al.*, 2004). Thus the main finding was that, when presented with a situation with incomplete information about the location of food, apes, including gorillas (but not dogs), seek additional information to make a correct choice.

These results indicate that subjects have access to what they have seen or not seen, they know when they are uncertain, and whether or not they remember a past event. In other words, subjects know what they know and do not know, and can respond appropriately in order to remedy their lack of knowledge, either by escaping the situation or seeking additional information.

10.5 Arbitrary, causal, and symbolic connections

Throughout this chapter a distinction has been made between tasks involving causal connections and tasks involving arbitrary associations. The evidence suggests that apes find the former easier to solve than the latter; I have argued that this is because they can understand the underlying causal structure of the former tasks. Of course, this does not mean that apes cannot learn to solve problems that involve arbitrary associations; with enough trials, they certainly can. However, it is not clear whether the capacities that result from acquiring such arbitrary associations have the same properties as those that result from acquiring information about causal connections. Although there is no data directly on this point, I venture that once data is available, it will still show that the capacities enabled by acquiring information about causal connections differ from those enabled by acquiring information about arbitrary associations. One may predict that extinction or contingency reversals may be harder for causal connections than for arbitrary connections. Likewise, the acquisition curves may also differ. Information about arbitrary connections may be acquired gradually, in accord with traditional associative accounts, information about causal connections may be acquired more suddenly, as in insightful learning. These questions and predictions await further research.

The nature of the capacities provided by learning arbitrary associations has important implications for debates on symbol acquisition in animals, since symbols, by definition, are arbitrarily connected with the referent they represent. Although it is clear that apes can acquire and use symbols effectively, it remains unclear whether those symbols have the same connotations that they have for humans.⁴ Unlike apes, (p.231) human beings have an uncanny ability for quickly making sense of and learning arbitrary connections. It is tempting to think that the special meaning of symbols for human beings and the ease with which we learn and use symbols is facilitated by our capacities to reason and reflect.

10.6 The evolution of reasoning and reflection

The evolution of reasoning and reflection has allowed some species and individuals to become more efficient foragers when faced with certain problems. This cognitive adaptation is akin to other behavioral and morphological adaptations. I will use an example from feeding adaptations to illustrate this point. Some animals have evolved digestive systems that allow them to exploit low-quality resources that other animals cannot use effectively. For example howler monkeys feed on leaves and have a larger gut than spider monkeys of equal body-size that feed on fruits. It is this morphological adaptation that allows howler monkeys to feed almost exclusively on leaves. Similarly, cognitive adaptations such as the ability to reason and reflect have evolved to take advantage of properties of the external world. This cognitive adaptation allows individuals to perceive the causal structure of the world, not just statistical regularities.

Acquiring the capacities to reason and reflect does not mean that subjects would lose their capacity to use associative processes to detect statistical regularities. Just as howler monkeys can still feed on fruits despite being folivores, apes can still solve problems in ways that depend on association and reinforcement, despite having developed a degree of causal understanding and some capacity for reason and reflection. Associative mechanisms probably represent a safe fall-back when the reason and reflection system cannot be engaged. Likewise, certain animals may be restricted to traditional learning or have evolved fixed strategies such as preference for certain colors or odors. These animals may not engage in the same inferential processes as apes. Recently we tested dogs in some of the inferential problems presented in this chapter and found that although they can use sound to detect food, they do not infer that the food must be in the other container when the shaken one remains noiseless (Bräuer *et al.*, submitted). Similarly, Watson *et al.* (2001) found that dogs, unlike children, seem to use association-based system rather than a logic-based system in an object permanence task. In particular, upon finding empty containers in their search, dogs gradually decelerated their search responses, which is consistent with an extinction mechanism.

Descartes' two errors: Reason and reflection in the great apes

In contrast children accelerated their searches or remained unaltered, which is consistent with the expectation of finding the target object in the next search.

The evolution of cognitive and metacognitive processes (which includes reflection and consciousness) is a topic that has recently received considerable attention. Some view metacognitive processes as an epiphenomenon consequent on other changes in cognitive processes, such as the development of language (for example, Macphail 2000), (p.232) while others view metacognition as an evolved mechanism with a specific function. Humphrey (1993) has championed a version of this latter view and coined the term 'inner eye' to refer to a system that evolved to read the minds and predict the behavior of other people. Dickinson and Balleine (2000) suggest that non-reflexive consciousness represents the interface between the motivational and cognitive systems and it is probably present in several vertebrates such as corvids, rats, and primates. Finally, the research reviewed in this chapter (see also Smith *et al.*, in press; Terrace and Metcalfe, in press) suggests that dolphins, apes, and rhesus macaques are capable of monitoring their own internal representations and perceptions and suggests that reflective abilities may be more widely distributed among animals than previously thought (Macphail 2000; Humphrey 1986). If so, the ability to reflect may be better characterized as a continuum rather than a discrete variable. It is conceivable that different species have evolved different versions of reflective abilities tailored to the cognitive mechanisms that they support or enable.

What view should be taken of the relationship between reasoning and reflection? Is it possible to have 'clever brains and blank minds', as Humphrey (1986) put it, or are clever brains associated with non-blank minds? It is clear that some cognitive processes can occur without metacognitive monitoring; in blindsight and related phenomena there is a clear dissociation between cognitive and metacognitive processing. On the other hand, certain forms of reasoning may have arisen only with the participation of reflective processes. Frye *et al.* (1998) have postulated that different levels of metacognitive processing result in different levels of

knowledge in children. They use a stepwise approach to explain the changes in both metacognition and knowledge level that occur during children's cognitive development. It is conceivable that a similar approach can be successfully applied to different animals that have evolved different levels of cognitive and metacognitive processes. For example, in contrast with the great apes, there is no evidence that dogs are capable of engaging on certain inferential operations (Watson *et al.* 2001; Brauer *et al.* submitted) or that dogs know what they have or have not seen (Bräuer *et al.*, 2004; Call, in press). Similarly, pigeons, in contrast with rhesus monkeys, seem to solve transitivity and ordinality problems without a scalar representation of stimuli and show little evidence of internal monitoring (Inman and Shettleworth 1999).

It is tempting to speculate that the ability to engage in certain inferential abilities is tied to the ability to monitor internal states of knowledge. Future studies should be devoted to investigating the relationship between cognitive and metacognitive processes. It would be particularly interesting to investigate metacognition in those species that have shown certain inferential abilities such as parrots and corvids (Pepperberg 1999; Bond *et al.* 2003). Contrary to what some authors have argued (Macphail 2000), reflection may not be a consequence of the evolution of cognitive skills such as language; rather, it may be the other way around. Indeed, a certain level of reflection may have enabled the development of certain reasoning and cognitive skills.

(p.233) 10.7 Conclusion

Reasoning and reflection have traditionally been considered uniquely human attributes. Many animals, including the great apes, are often regarded as expert at associating arbitrary stimuli while at the same time they are rarely thought capable of reasoning and understanding the causality behind even simple phenomena. In this chapter, I have defended the opposite view. Apes (and possibly other animals) are actually quite good at understanding and reasoning about certain physical properties of their world while at the same time they are quite bad at associating arbitrary stimuli and responses. In other words, if two stimuli have a causal connection (as when

Descartes' two errors: Reason and reflection in the great apes

food inside a shaken cup makes noise) apes perform better than if stimuli hold an arbitrary relation (as when unrelated noise indicates food), even if the contingencies of reinforcement are the same. In addition to the ability to reason about physical phenomena, I have argued that apes (and other animals) can also reflect on a problem at hand and have some access to their own understanding of a problem. Thus, reasoning and reflection may not be as unique to human beings as Descartes thought; they may have evolved (or coevolved) in other animals also because they allowed them to solve problems in the world more efficiently.

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Notes:

(1) Editors' note: Cf. Papineau and Heyes, this volume, for skepticism about the empirical tractability of issues between associative and rational explanations of animal behavior.

(2) Editors' note: See also Bermúdez' hypothesis (this volume) that understanding of causal relations may underwrite proto-conditional inference in non-linguistic animals.

(3) Editors' note: See and cf. Shettleworth and Sutton, this volume, for further details and a methodological assessment of these tests of metacognition.

(4) Editors' note: see and cf. Boysen; Savage-Rumbaugh *et al*, this volume, on the way acquiring (arbitrary) symbolic associations can enhance the capacities of apes.



Descartes' two errors: Reason and reflection in the great apes

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