Chapter 5

Animal reasoning and proto-logic

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Abstract: This chapter addresses a theoretical problem that arises when we treat non-linguistic animals as thinkers in order to explain their behavior in psychological terms. Psychological explanations work because they identify beliefs and desires that show why the action in question *made sense* from the agent's perspective. To say that an action makes sense in the light of an agent's beliefs and desires is to say that it is the rational thing to do (or, at least, *a* rational thing to do) given those beliefs and desires. And that in turn means that, in at least some cases, an agent might *reason* her way from those beliefs and desires to acting in the relevant way. Most models of reasoning, however, treat it in terms of logical operations defined over linguistic structures, which makes it difficult to see how it might be extended to non-linguistic creatures. This paper develops a framework for thinking about the types of reasoning engaged in by non-linguistic creatures. It explores non-linguistic analogs of basic patterns of inference that can be understood at the linguistic level in terms of rules of inference involving elementary logical concepts. The three schemas discussed (reasoning from an excluded alternative and two types of conditional reasoning) are highly relevant to animal practical reasoning, and I show how animals might apply them without deploying any logical concepts.

We find ourselves committed to providing an account of animal reasoning as soon as we grant that forms of animal behavior require psychological explanation – as soon as we grant that in certain situations animals behave the way they do because of their beliefs about their environment and about how best to achieve their goals.[1] Psychological explanations work because they identify beliefs and desires that show why the action in question *made sense* from the agent's perspective – just as psychological predictions work by showing the course of action that *makes sense* in the light of the agent's beliefs and desires. To say that an action makes sense in the light of an agent's beliefs and desires is to say that it is the rational thing to do (or, at least, *a* rational thing to do) given those beliefs and desires. And that in turn means that, in at least some cases, an agent might *reason* her way from those beliefs and desires to acting in the relevant way. Reasoning and rationality are correlative notions, at least where rational behavior is understood to mean more than simply adaptive behavior.

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[1] The practice of applying belief-desire psychology (Kacelnik's 'PP-rationality') to animals (and prelinguistic infants) is well-established in cognitive ethology, comparative psychology, and developmental psychology. In this paper I will be assuming the legitimacy of this practice. I have explored it and defended it against various philosophical objections in Bermúdez 2003. See also and compare Dickinson and Balleine 1993; Heyes and Dickinson 1995; and Kacelnik; Dretske; Millikan; and Hurley, this volume.

Studying animal reasoning is important both for the light it sheds upon animal cognition and animal behavior, and for the way it helps us to understand what is distinctive about the types of reasoning that are made available by language mastery (henceforth: linguistic reasoning) – and hence, by extension, for how we understand the relation between psychological explanations as applied to the behavior of linguistic and non-linguistic creatures respectively. It is clear that an account of animal reasoning will have to strike a delicate balance. On the one hand, there must be sufficient parallels between animal reasoning and linguistic reasoning for comparable models of belief-desire explanation to be applicable in both cases. On the other hand, however, such an account must be sensitive to the significant differences between linguistic and non-linguistic cognition. The acquisition of language makes available types of reasoning that are impossible in the absence of language.

I have argued elsewhere that logic requires language (Bermúdez 2003, Ch. 9). Language offers the possibility of *intentional ascent* – of thinking about thoughts. A thought can only be "held in mind" in such a way that it can be the object of a further thought if it has a linguistic vehicle. Only when it has a linguistic vehicle can the internal structure of a thought be manifest. If this is right, then those types of reasoning that exploit the internal structure of a thought are only available to language-using creatures. Paradigmatic here is the quantificational reasoning typically formalized in the *predicate calculus*. This is the reasoning that allows us to conclude, for example, that *this F* must be *G* because all *F*s are *G* – or that, since *a* is *F* at least one thing is *F*. But the

thesis of language-dependence holds also for types of reasoning that do not exploit the internal structure of thoughts. Consider the types of inference that involve logical concepts such as *disjunction* (. . . or . . .) and *material implication* (if . . . then). The validity of these inferences (typically formalized in the *propositional calculus*) is a function of the truth-values of the thoughts featuring in them (as opposed to the internal structure of those thoughts. The inference-schema of *modus ponens* (that allows one to conclude q from $p \rightarrow q$, and p) is valid just as long as it is not the case that p is true and q false. Making these truth-functional inferences requires understanding the relation between the truth-values of thoughts. But thinking about the truth-value of a thought is a form of intentional ascent. It requires holding the thought in mind and ascribing to it a higher-order property.

The challenge, therefore, in developing an account of animal reasoning is to identify forms of reasoning at the non-linguistic level and then explain them without assuming that the animal is deploying elementary logical concepts or exploiting the internal structure of a thought. I shall discuss three such basic types of reasoning that it would be natural (when thinking about language-using creatures) to characterize in terms of mastery of certain primitive basic logical concepts. As we shall see, there is an alternative way of understanding them at the non-linguistic level – in terms of what we might term *proto-logic*.

The first type of reasoning can be described as reasoning from an excluded alternative. This is the type of inference that takes a creature from recognition that one of an incompatible pair of states of affairs holds to the

recognition that the other does not hold. Here is an example. Imagine a creature that has learnt that the lion and the gazelle will not be at the watering-hole at the same time and, moreover, is in a position to see that the gazelle is drinking happily at the watering-hole. The creature can conclude with confidence that the lion is not in the vicinity. This type of reasoning is one of the ways in which a creature can learn about what is not immediately perceptible. One can see easily, for example, how this sort of inference could be life-preserving for a creature that is just as threatened by the lion as the gazelle is. It is natural to formalize it in the propositional calculus as an instance of disjunctive syllogism (the transition from 'A or B' and 'not-A' to 'B', where 'A' stands for 'The gazelle is not at the water-hole' and 'B' for 'The lion is not at the water-hole').

A second such way of moving beyond the here-and-now comes with straightforward conditional reasoning (typically formalized as *modus ponens*). This is the reasoning that takes one from recognition that there is a conditional dependence between two states of affairs (the second will be the case if the first is the case) and recognition that the first state of affairs is indeed the case to the conclusion that the second state of affairs is the case. Conditional reasoning of this type is deeply implicated in a range of different activities. The detection of patterns of behavior seems closely bound up with the possibility of conditional reasoning. A creature that knows that if the gazelles see the lion they will run away and that recognizes (perhaps on the basis of its understanding of the gazelles' visual perspective) that the lion will

shortly be detected by the gazelles, is in a position to predict that the gazelles will soon take flight.

The third fundamental type of inference is also based upon recognition of a conditional dependence between two states of affairs – but in this case (formalized in terms of *modus tollens*) the reasoning proceeds from recognition that the second state of affairs does not hold to recognition that the first state of affairs is not the case. So, to stick with the gazelles, an observer (perhaps a fellow predator) who is too far away to have a view about the visual perspective of the gazelles can infer from the fact that they are happily feeding where they are that they have not yet seen the lion.

In standard propositional logic these three fundamental forms of inference are understood in terms of the three propositional operators of disjunction, negation, and the material conditional. All three operators are functions from propositions to propositions that take complete thoughts as both arguments and values. Clearly, if we are to find analogues of these three types of reasoning at the non-linguistic level then we will need to find ways of understanding them so that they do not involve propositional operators.

We can begin by simplifying the problem. Reasoning from an excluded alternative can be understood as a form of conditional reasoning. Let 'A' stand for the sentence 'The gazelle is not at the watering-hole' and B for the sentence 'The lion is not at the watering-hole'. The disjunction 'A or B' is truth-functionally equivalent to the conditional 'If not-A, then B' (that is to say, 'If the gazelle is at the watering-hole, then the lion is not at the watering-hole'). Both sentences will be true just if it is not the case that the gazelle and

the lion are both at the watering-hole.[2] The process of reasoning from an excluded alternative will involve a grasp, on the one hand, of the conditional 'If not-A, then B' and, on the other, of the antecedent of that conditional (where that antecedent is in some sense negative). All we need, therefore, is to find a way of understanding analogues for negation and the conditional that do not operate upon complete thoughts.

Let us start with negation. Modern, that is to say post-Fregean, logic is founded on the idea that, as far as the fundamental logical form of sentences is concerned, the linguistic act of negation applies essentially to sentences – and correlatively, at the level of thought, that negation is a logical operation upon propositions. It may seem that, in the sentence 'Socrates is not wise' (and still more so in the sentence 'Socrates is unwise'), a particular property, the property of wisdom, is being held not to apply to Socrates. However, the surface form of natural language sentences is deceptive. The negation operator actually applies at the level of the sentence 'Socrates is wise' rather than at the level of the predicate '– is wise'.[3] The sentence 'Socrates is unwise' is a sentence that is true just if the sentence 'Socrates is wise' is false.

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[2] I am taking 'or' in its inclusive sense, according to which a disjunction remains true if both its disjuncts are true. The exclusive sense of 'or' can be defined by adding to the inclusive sense the further requirement that the two disjuncts not both be true. This requirement can itself be given a conditional reading. 'Not-(P and Q)' is equivalent to 'If P, then not-Q'.

[3] For an extended discussion of this view of negation see Frege 1918-1919.

Many philosophers have thought that this claim obscures an important distinction. The sentence 'Socrates is wise' can be false in circumstances in which Socrates does not exist – such as now, for example. Yet these are not, many have thought, circumstances in which it would be appropriate to say that Socrates is unwise. One way of putting the point would be to say that, whereas the two sentences 'Socrates is wise' and 'Socrates is unwise' are contraries (that is, they cannot both simultaneously be true), the two sentences 'Socrates is wise' and 'It is not the case that Socrates is wise' are contradictories (that is, one or other of them must be true). This, in fact, is how the distinction between predicate negation and sentential negation was originally put by Aristotle in the *Prior Analytics* (I.46). Aristotle insisted, and in this he was followed by almost all logicians until Frege, that there is a fundamental logical difference between negating a sentence and negating a predicate.

There is no need to go into the question of whether the distinction between predicate negation and sentential negation is a genuine logical distinction (as opposed, for example, to a distinction in the pragmatics of ordinary language best accommodated at the level of conversational implicature) – or the related question of whether a Fregean or an Aristotelian account of negation is a better way to understand how negation operates in ordinary language.[4] For present purposes the important point is that the

[4] For extended discussion of these and related matters see Sommers 1982, and Grice 1989. Bochvar 1981 provides a formal development of the idea that there are two fundamentally different types of negation.

distinction between predicate negation and sentential negation gives us a way of understanding negation (or rather, *proto-negation*) at the non-linguistic level as involving a thought with a negative predicate (subject to the qualifications to be noted in the next paragraph) – as opposed to the truth-functional construction of a complex thought. In terms of understanding animal reasoning, the problem of understanding how a creature without language can be capable of negation becomes the problem of how a creature without language can think thoughts in which the predicate component is one rather than the other of a pair of contraries. The task becomes one of understanding how the non-linguistic creature can grasp pairs of concepts that are contraries – the concepts of presence and absence, for example, or of safety and danger, or of visibility and invisibility.[5] To return to our observer at the water-hole, we should understand the thought that the gazelle is not at the water-hole as the thought that the gazelle is absent from the water-hole – rather than as the denial of the thought that the gazelle is at the water-hole. Such a thought would be the contrary of the thought that the gazelle is at the water-hole – but it would not be constructed from that thought in a truth-functional manner.

This line of thought opens up a possibility that is not recognized in Millikan's contribution to this volume. Millikan is exploring the thesis that that the representations of non-linguistic creatures are all what she terms

[5] I am assuming, for the sake of simplicity, that the mental representations of animals should be described as concepts. I have argued elsewhere that concept possession requires language (Bermúdez 1998). Those who agree can translate the claims in the text about concepts into their chosen vocabulary.

pushmi-pullyu representations (that is, representations exclusively from the animal's point of view of the affordances that the distal environment presents for action and reaction). She draws a sharp distinction between such *pushmi-pullyu* representations and those types of thinking that move beyond the practical sphere into the realm of the theoretical. Theoretical reasoning, according to Millikan, is thought about objectively existing, independent, and reidentifiable particulars and properties. Thinking of this type requires subject-predicate structure and a negation operator. Millikan comments:

> . . . the capacity to learn, out of the context of practical activity, to recognize what is objectively the same object, kind or property again rests on the capacity to form representations with subject-predicate structure, where certain predicates are understood as contrary to one another[6] so that contradiction is possible. Notice that simple representational systems do not contain contrary representations. Signals used to alert conspecifics to danger, for example, do not have contraries. A dozen danger signals at a dozen times and places do not contradict one another. (This volume, p.XXX)

According to Millikan, then, contrariety cannot be perceived – and nor does it manifest itself in successive perceptual representations (even if these are incompatible with each other, this is evidence only of change not of contrariety).

It seems to me, however, that Millikan does not recognize the possibility of exploiting and acting upon contrariety without explicitly

[6] On certain grounds. See Millikan 1984 Chapter 16.

understanding and representing contrariety. I am fully in agreement with Millikan's claim that non-linguistic animals cannot understand the notion of contrariety.[7] An understanding of contrariety is a highly complex cognitive achievement, simply because understanding that two propositions are contraries involves understanding that it is not possible for them both to be true at the same time, and hence requires not simply being able to think about truth-values but also about time and modality. However, a creature can master pairs of contrary concepts (such as the concepts of presence and absence) and deploy those concepts in inferences using proto-negation without a full understanding of the notion of contrariety. It is no more plausible to think that the effective deployment of contrary concepts requires a theoretical grasp of the concept of contrariety than it is to demand that the effective deployment of number concepts requires a theoretical grasp of the concept of number.

Proto-negation, understood in terms of contrariety, permits primitive versions of the two basic types of inference involving negation that I

[7] Our grounds, however, are not the same. Chapter 3 of Bermúdez 2003 argues against what I term the minimalist conception of non-linguistic thought (roughly, the thesis that the thoughts of non-linguistic creatures should be understood in perceptual terms). It is true that much of animal cognition can be understood in terms of Millikan's "pushmi-pullyu" representations, but there are very significant forms of animal cognition that cannot be understood in those terms.

identified earlier. The first type of inference involves reasoning from an excluded alternative. Let us consider the earlier example. We are trying to characterize how a creature might reason from the thought that the gazelle is at the watering-hole to the thought that the lion is not at the watering hole. The reasoning here can be assimilated to standard conditional reasoning by treating the central premise as a conditional – namely, the conditional that if the gazelle is at the watering-hole then the lion is not at the watering-hole. The notion of proto-negation shows how this can be understood without deploying propositional negation. The conditional in question becomes 'If the gazelle is present (at the watering-hole) then the lion is absent (at the watering-hole)'. Deploying this thought (apart from the need, to be explored further below, to develop a non-linguistic analogue of the truth-functional conditional operator) is a matter of reasoning practically in accordance with the fact that presence and absence are contrary concepts. Any creature that reasons in this way will also be able (again subject to a satisfactory account being given at the non-linguistic level of conditional reasoning) to undertake reasoning approximating to *modus tollens*. Starting with the conditional 'If the gazelle is present (at the watering-hole), then the lion is absent (at the watering hole)' such a creature will be able to proto-negate the consequent by forming the thought that the lion is present and hence to arrive at the proto-negation of the antecedent (namely, 'The gazelle is absent').

This inference is not valid in virtue of its form in the way that an instance of *modus tollens* is valid in virtue of its form. There is no formal rule that will take one from the premises of the argument to the conclusion – since

the transition from premises to conclusion works only because of the particular pair of contrary concepts involved. It is, moreover, a highly specialized form of practical reasoning, applicable only where the creature in question has the appropriate pairs of contrary concepts. Nonetheless, instances of this inference-schema are of course valid in the semantic sense – that is to say, their premises cannot be true and their conclusion false.

This discussion of proto-negation still leaves us with an important challenge. We need an analogous way of understanding how some precursor of the conditional operator can operate at the non-linguistic level. The conditional operator is a truth-functional propositional operator forming a complex thought from two thoughts in such a way that the complex thought is true in all circumstances except those in which the first component thought is true and the second component thought is false. This requires intentional ascent and hence is unavailable at the non-linguistic level. Conditional thought clearly links two different things. But if those things cannot be complete thoughts, then what can they be?

The proposal I would like to explore is that we look for the sources of conditional reasoning in a primitive form of causal reasoning. Whereas conditional reasoning involves a propositional operator establishing a truth-functional relation between complete thoughts, causal reasoning works on the basis of a causal condition holding between one state of affairs and another. Since causal relationships do not hold between complete thoughts, an understanding of causality presupposes no intentional ascent, and hence does not require language. Causal reasoning, in the sense in which I understand it,

should be distinguished from the type of cognition involved in instrumental conditioning. Instrumental conditionining (as discussed, for example, in the papers by Allen and Papineau and Heyes in this volume) depends upon a creature's "registering" a contingency between its own behavior and changes in the environment (the contingency between pecking and food delivery, for example). In cases where this contingency is causal (as it is in most cases of instrumental conditioning), exploiting the contingency involves a form of causal reasoning. The converse does not hold, however. The causal relations exploited in causal reasoning need not be in any sense related to the agent's own causal powers (which is why the representations involved in causal reasoning will not always count as pushmi-pullyu representations in Millikan's sense).

Philosophers frequently reflect upon the relations between causation and conditionals, and it is often suggested that a proper understanding of conditionals will be an ingredient of an adequate account of causation.[8] At the very least, a causal explanation of a particular event entails certain conditional

[8] The most radical proposal in this area is that singular causal claims of the form 'event c caused even e' can be analysed in terms of counterfactual conditional claims of the type 'had event c not occurred, even e would not have occurred'. A counterfactual theory of causation is proposed in Lewis 1973.

predictions about what would happen in suitably similar situations.[9] It is clear that, in the order of analysis, thought and talk about conditionals is more fundamental than thought and talk about causation. No one has ever proposed that we understand conditionals in terms of causation. Conditional sentences and conditional thoughts assert the existence of dependence relations and causation is just one of a range of possible dependence relations. Nonetheless, the order of acquisition frequently fails to duplicate the order of analysis. It is highly plausible on experimental and observational grounds that the capacity for causal cognition is very widespread in the animal kingdom and available at a very early stage in human development (Leslie 1982, and the essays in Sperber 1995) – which is exactly what one would predict on evolutionary grounds. The ability to detect certain types of causal regularity and to distinguish genuine causal relations from accidental conjunctions has obvious survival value. Causal dependence relations (which may hold between the agent's behavior and changes in the environment, or between agent-independent states of affairs in the environment) are directly observable, highly salient, and pragmatically significant in a way that no other dependence relations are. It seems plausible both that causal relations should be more primitive than conditional relations and that a creature arrives at an understanding of conditional dependence by abstracting away

[9] These predictions are most frequently viewed as involving (non-truth-functional) subjunctive conditionals (about what would or would not happen), rather than truth-functional indicative conditionals. There is a useful discussion of causation and conditionals in the first chapter of Mellor 1995.

from the more familiar and everyday relation of causal dependence. Perhaps the child's first step towards an understanding of conditional dependence is observing that a certain relation holds between the truth-values of two separate thoughts when a causal relation holds between the states of affairs that those thoughts characterize. Once this first step (which of course involves intentional ascent and hence requires language) has been taken, it is a relatively straightforward matter to notice that there are other types of situation (and correlatively other types of dependence relation) that share that same feature. And thus the abstract concept of conditional dependence is grasped.

How might causality be understood by non-linguistic animals? Certain aspects of the full-fledged concept of causation are clearly unavailable at the non-linguistic level. The full-fledged understanding of causation has a modal dimension that comes with the thought that a cause is sufficient for the effect it brings about, and this is, in effect, the thought that it is not possible for the cause to occur without the effect occurring. On the assumption that modal thinking involves a type of intentional ascent and hence requires semantic ascent,[10] the notion of sufficiency is not available at the non-linguistic level. Different theorists will view this with different degrees of concern. Some analyses of causation take the idea that a cause is sufficient for its effect as central (e.g. Mackie 1965). Other accounts do not. If we follow Mellor (Mellor 1995) in holding that what makes it the case that one fact c causes another fact e is that the conditional probability of e given c is greater than the conditional

[10] For an argument for this assumption see section 9.4 of Bermúdez 2003.

probability of e given not-c, then cases in which causes really are sufficient for their effects cease to be central to the understanding of causation. But there is no suggestion that non-linguistic creatures can have a full understanding of causation. The proposal is simply that (at least some) non-linguistic creatures have a basic capacity to track causal relationships holding between events or facts and that this basic capacity allows them to engage in a primitive form of conditional reasoning.

All accounts of causation, from David Hume's pioneering account onwards, are agreed that certain forms of regularity are at the heart of the notion. And it seems overwhelmingly plausible that the core of the understanding of causation at the non-linguistic level will be based on the registering of regularities in the distal environment. It is easy to see where this type of understanding might originate. On the one hand, it seems plausible to take a sensitivity to environmental regularities to be a basic part of the innate endowment of any creature capable of learning about the environment. On the other, one might expect any creature to be peculiarly sensitive to regularities between its own actions and ensuing changes in its immediate environment. Of course, as regularity theories of causation have been forced to acknowledge, there are many regularities that are not causal, and it is in the capacity to distinguish genuinely causal regularities from accidental regularities that one might expect differences between different species of non-linguistic creature and, for that matter, different stages of development

within any given species[11]We know from dishabituation studies of infant perceptual expectations about object behavior that even when they are only a few months old show surprise at examples of "action at a distance" and many developmental psychologists have suggested that their understanding of the physical world is governed by the principle that objects can only interact causally when they are in physical contact (Spelke 1990). If correct, this suggestion indicates that the simple association of two events cannot be sufficient for registering causal dependence. At a minumum the associated events must be spatio-temporally contiguous.

The regularities to which non-linguistic creatures are sensitive (unlike those usually stressed in regularity analyses of causation) need not be exceptionless. Indeed, there are very good evolutionary reasons why one would expect causal cognition to be sensitive to probabilistic regularities (Brunswik 1943). Decision-making in the wild is decision-making under uncertainty and no creature that waited for an exceptionless regularity would fare well in evading predators and obtaining food. This is another reason not to be concerned about the unavailability at the non-linguistic level of the idea that causes are sufficient for their effects. It may well be the case that every apparent example of probabilistic (or indeterministic) causation at the macro-level can be explained in terms of hidden variables, so that what looks like a probabilistic regularity is really a manifestation of a deeper underlying exceptionless regularity. If this were the case then the only reasons for adopting a probabilistic understanding of causation would be apparent

[11] See Call's contribution to this volume for empirical evidence on how non-arbitrary causal relations enhance learning in great apes.

examples of indeterministic causation at the micro-physical level. But the emphasis is very different when it comes to non-linguistic creatures' understanding of causation. As far as the practicalities of foraging and reproducing are concerned the apparent probabilistic regularities are paramount. [Might you work in a comparative reference to Call's piece in the volume around here, on causal understanding in animals and how non-arbitrary/causal relations enhance learning/performance, perhaps in a note? This would seem to be relevant to and supportive of your position, and would help with unifying volume.]

Proto-causal understanding tracks relationships, which can be either deterministic or probabilistic, between states of affairs. This is why an understanding of causation is available at the non-linguistic level. It also explains why primitive versions of certain fundamental inference forms are available at the non-linguistic level. We can term this proto-conditional reasoning. Let us return to our three basic inference forms. We are looking for analogues at the non-linguistic level of the basic inference forms of disjunctive syllogism, *modus ponens* and *modus tollens*. The basic logical operations involved here are negation and the conditional. If negation at the non-linguistic level is understood in terms of the mastery of pairs of contrary predicates as suggested in the earlier discussion of proto-negation, and if we view the relevant conditionals as proto-conditionals tracking the causal relations between states of affairs, then we have all we need for non-linguistic analogues of our three basic forms of inference. *Modus ponens* can be understood straightforwardly in terms of a proto-conditional together with an

understanding, which may take the form of a perception or a memory, that the antecedent holds. The consequent will straightforwardly be detached. We can view *modus tollens* in terms of the combination of a proto-conditional with the proto-negation of the consequent of that conditional resulting in the detachment of the proto-negation of the antecedent. As we saw earlier, the disjunctive syllogism "A or B, not-A, therefore B" can be understood in terms of a causal conditional with not-A as its antecedent and B as its consequent.

We began with two thoughts. The first is that, since psychological explanations of the behavior of nonlinguistic creatures are rationalizing explanations and since the notions of rationality and reasoning are correlative notions, the application of belief-desire psychology to animals (in the manner widespread in cognitive ethology and comparative psychology) stands or falls with the possibility of explaining how animals might engage in practical reasoning. The second is that, although animal reasoning must have sufficient commonalities with linguistic reasoning for it to be plausible to apply similar explanatory models of belief-desire explanation in the linguistic and non-linguistic cases, we cannot view non-linguistic reasoning as involving logical concepts and logical rules of inference. The suggestions about proto-logic sketched out in this paper try to do justice to both these thoughts by proposing analogues at the non-linguistic level for schemes of practical inference that can be understood at the linguistic level in terms of rules of inference involving elementary logical concepts. The three schemas discussed (reasoning from an excluded alternative and the two types of conditional reasoning) are highly relevant to animal practical reasoning, and I have

shown how animals might apply them without deploying any logical concepts. The ability to deploy pairs of contrary concepts (without an explicit understanding of the notion of contrariety) and to be sensitive to causal regularities in the distal environment can provide animals with the tools for relatively complex forms of practical reasoning – and certainly for forms of practical reasoning that are sufficiently complex to underwrite the extension of belief-desire psychology to non-linguistic creatures.

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