Against simulation: the argument from error

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According to Simulation Theory, to understand what is going on in another person's mind, the observer uses his or her own mind as a model of the other mind. Recently, philosophers and cognitive neuroscientists have proposed that mirror neurones (which fire in response to both executing and observing a goal directed action) provide a plausible neural substrate for simulation, a mechanism for directly perceiving, or 'resonating' with, the contents of other minds. This article makes the case against Simulation Theory, using evidence from cognitive neuroscience, developmental psychology, and social psychology. In particular, the errors that adults and children make when reasoning about other minds are not consistent with the 'resonance' versions of Simulation Theory.

'The fact remains that getting people right is not what living is all about anyway. It's getting them wrong that is living, getting them wrong and wrong and wrong and then, on careful reconsideration, getting them wrong again.'

Philip Roth, American Pastoral

Introduction

Imagine an inner-tube sliding down a spiral waterslide. A foot above the pool, the slide ends. Where will the tube land in the pool? Many people draw a curved path to the water, as if the inner-tube had a curvilinear 'impetus' [1]. To solve this problem, people are using 'a systematic, well-developed conception of motion that is inconsistent with the laws of classical physics' ([1], p.147) – the impetus theory of motion, part of a naïve theory of physics. For the most part, naïve physics serves people well, as in everyday interactions with falling apples and swerving bicycles. But when the naïve theory deviates from the way the world actually works, robust and systematic errors emerge.

An analogy could be drawn between such naïve physics, and reasoning about human actions and thoughts: that is, naïve psychology. In each case, we could construct a theory (or a body of beliefs) about the entities involved, and the rules governing their interactions [2–4]. A lay theory of psychology, just like the theory of physics, could be constructed (possibly over a scaffold of innate concepts) from observation, inference and instruction, and then

deployed to predict or explain another person's inference, decision or action.

Simulation Theory

Although venerable, this analogy between lay physics and lay psychology has an influential rival. Simulation Theory, in its stronger forms, proposes that people need not use a naïve theory of psychology, or indeed any mental state concepts [5], when predicting and explaining actions [6–9]. Instead the observer uses his or her own mind as a model of the other mind, just as one could work out exactly where the inner-tube would land in the pool, without any equations or theory of momentum, by sliding a miniature inner-tube down a scale-model slide. Importantly, the observer does not have to build the model (which would require extensive theoretical knowledge, [10]); the parsimony and appeal of Simulation Theory hinges on the idea that all humans have simply been given a fully functional model of other people's minds that they can use unreflectively: namely, their own minds.

Simulation Theory has recently been embraced with enthusiasm by neuroscientists and cognitive scientists, following the discovery of the 'mirror system': neurones (Box 1) or in fMRI studies in humans, brain regions (Box 2) that are recruited both when performing, and when watching someone else perform, a particular action [11]. The mirror system, its proponents argue, provides a plausible neural substrate for simulation, a mechanism for 'directly understand[ing] the meaning of the actions and emotions of others by internally replicating ('simulating') them without any explicit reflective mediation' ([12], p.396), and might even explain how 'we assign goals, intentions, or beliefs to the inhabitants of our social world' ([13], p.493).

The mirror system does offer powerful insights into the neural representation of simple actions and some basic emotions (most plausibly, disgust and fear [14]). However, both children and adults also attribute to other people contentful, epistemic mental states like thoughts, beliefs and knowledge (see Box 2). I contend that when asked to predict or explain an inference, decision or action, children and adults do not simulate the other person's beliefs in their own mind, but instead deploy an intuitive theory of how the mind works, analogous to the naïve theory of physics described above.

In this article, I will adapt the 'argument from error' ([15], see Box 3), to show that the errors that human observers make are not consistent with the 'resonance' Simulation Theory embraced by mirror neurone
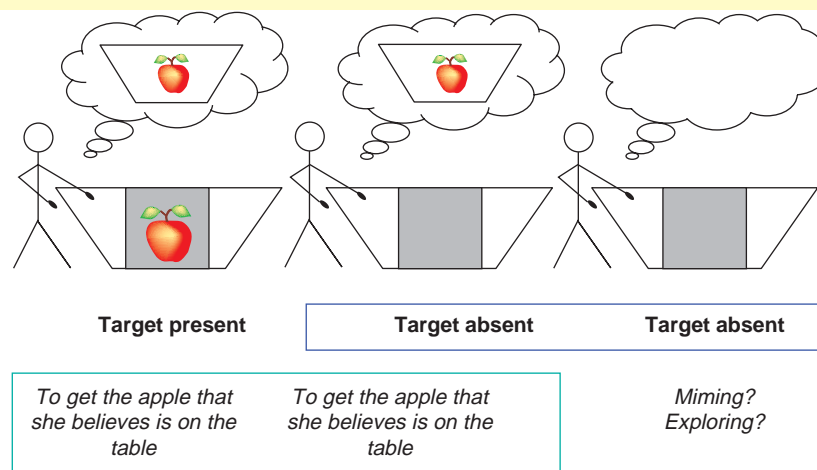
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Box 1. Mirror neurones and false beliefs

Mirror neurones in macaque premotor cortex fire both when the monkey executes a particular goal-directed action (grasping, breaking), and when the monkey observes, or even just hears, the same action being performed. The discoverers of mirror neurones have suggested that the mirror neurone system is a mechanism for the direct perception of the mental causes of behaviour [11–13,44].

However, humans observers predict and explain one another's intentional actions by identifying the *reasons* for the action [39] in the actor's beliefs and desires. The difference between representing the (physically present) target of an action, and the actor's reason for an action, is particularly clear when an action proceeds based on a false belief [45] (see Figure I). A simple empirical test would therefore be: would a mirror neurone respond to a reach towards empty space, if the actor *thought* that there was an apple present (as in Figure I, centre panel)?

Target present

Target absent

Target absent

To get the apple that she believes is on the table

To get the apple that she believes is on the table

Miming?
Exploring?

Figure I. Umilta *et al.* [46] found that mirror neurones distinguish between actually reaching for a target (left), and miming the same reach in the absence of a target (right), even when the end of the action (including the target itself) was occluded. The centre panel shows a 'False Belief' version of Umilta *et al.*'s paradigm: the experimenter looks, and sees an apple on the table, and then his view is blocked. The apple is then removed, with the monkey but not the experimenter watching. Then the experimenter reaches towards the table. Would the monkey's mirror neurones fire to this goal-directed action, when the target is actually absent but the actor believes it is present?

enthusiasts. Rather, observers must rely on a naïve theory of psychology. Also, the argument from error suggests that aspects of the observer's naïve theory of psychology (like over-attributing rationality, and naïve cynicism) play a pervasive role in reasoning about the mind. Along with recent results from neuroimaging (Box 2), this argument suggests that the burgeoning field of the cognitive (neuro)science of reasoning about other minds (for recent reviews, see [16,17]) must focus beyond Simulation and the mirror system, on the mechanisms that subserve the whole range of sophisticated human theorizing about the mind [18–20].

As in the inner-tube example, one symptom of the use of an intuitive theory in making predictions is occasional systematic error. An observer with a scale-model slide might, of course, make errors in marking where the model inner-tube lands, or in starting the inner tube exactly the same way on each trial, but the errors will be distributed evenly around the true answer. By contrast, the errors predicted by the impetus theory of motion are in one direction only. Such systematic errors cannot reflect simple ignorance or agnosticism about momentum: almost no one predicts a path to the water that curves *away* from the direction of the curve of the slide. Rather, the impetus theory is specific, useful (as a heuristic) and wrong.

Children's errors

The same is true of naïve psychological reasoning. Over-simplified ideas about thinking and knowing are easy to identify in children, whose theories of mind are still immature. Four-year-olds, for example, do not yet have differentiated concepts of 'not knowing' and 'getting it wrong', as illustrated elegantly by Ruffman [21]. In one experiment, a child and an adult observer ('A') are seated in front of two dishes of beads. The round dish contains red and green beads, but the square dish contains only yellow beads. Both A and the child watch while a bead from the round dish is moved under cover into an opaque bag. The child, but not A, knows that the chosen bead was green. Then the child is asked '*what colour does A think the bead in the bag is*?' The correct answer is that A doesn't know, or (even better) that A thinks it is red or green (but not yellow), Overwhelmingly, though, the children report that A thinks the bead is *red*. Note that this answer is not simply random: none of the children said A thinks that the bead is yellow. Rather, the actual result is best explained by an inaccurate generalization in the child's developing theory of mind: 'ignorance means you get it wrong'. Because A is ignorant of which bead was chosen from the round dish, A must think that it was the wrong colour, a red one.

Another example of young children's incomplete theory of beliefs concerns the sources of knowledge [22,23]. One early notion of the relationship between mind and world is of a direct unmediated connection [4]; on this conception, all features of an object are equally accessible to any mind that contacts that object. Thus, three-year-olds do not realize that people can distinguish between a red and a green ball by looking but not by touching, and between a hard stuffed cat and a

Box 2. Brain regions for thinking about thoughts?

Thinking and reasoning about thinking and reasoning develops in a distinct, and well-documented sequence [2,4,41]. The concept of 'believing' emerges around the end of a child's third year, well after children have mastered other mental state concepts like 'seeing', 'feeling' and 'wanting'. Thinking about beliefs is also subserved by distinct regions in the human brain, including the right and left temporo-parietal junctions, and the posterior cingulate [16–18,42,43] (Figure II, top). All three of these regions are recruited when subjects read stories about a character's true and false beliefs, but not for stories about physical causes, false physical representations (i.e. out-dated photographs), a person's appearance, a person's social background, or even a person's subjective bodily sensations, like thirst, hunger, and tiredness (which, unlike epistemic states, young toddlers do understand) [18,43,44]. Consistent with the developmental trajectory, the brain regions involved in the attribution of epistemic states also seem to be distinct from brain regions involved in representing direction of gaze, emotional expressions, and goal-directed actions [18]. Also importantly, these brain regions for thinking about beliefs are *not* the same brain regions as the ones implicated in the mirror system (Figure II, bottom) (see also [20]).

(a) Mental states
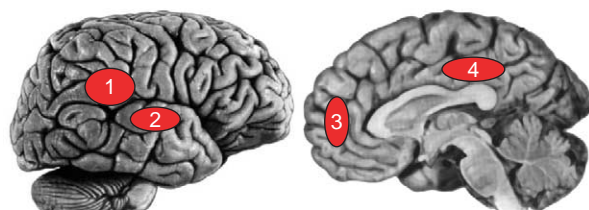
(b) Mirror system
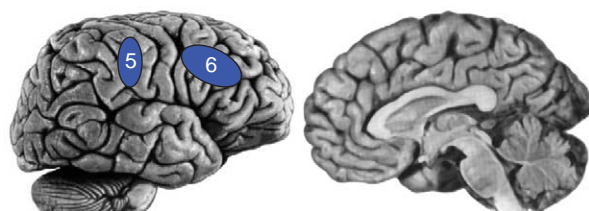
Figure II. Lateral (left) and medial (right) views of the human brain, with schematic activation. **(a)** Brain regions implicated in the attribution of epistemic mental states (such as thinking or believing). These include (1) bilateral temporo-parietal junction, (2) right anterior superior temporal sulcus, (3) medial prefrontal cortex, and (4) posterior cingulate. **(b)** A distinct set of brain regions make up the 'human mirror system' including (5) right inferior parietal cortex and (6) inferior frontal gyrus. Not shown are regions implicated in the experience and observation of emotion: the amygdala for fear, and the insula for disgust.

(visually identical) soft stuffed cat by touching but not by looking (see also Box 4; [22]).

Finally, the developmental time course of the errors that children make is itself revealing. Young children stop making egocentric errors earlier for some mental states than for others [2–4]. Even two-year-old children reason accurately about another person's desires and perceptions that differ from the children's own. However, it is not until at least a year later that the same children understand that other people can have beliefs that are different from their own. As the children have had both beliefs and desires themselves all along, the explanation of this differential time course must refer to a difference in children's command of the *concepts* of beliefs versus desires.

Box 3. The history of the argument from error

Psychologists have long recognized the power of systematic errors in perception and reasoning to reveal the structure of the perceiving and reasoning mind. Hermann von Helmholtz wrote about perceptual illusions that, 'it is just those cases that are not in accordance with reality which are particularly instructive for discovering the laws of the processes by which normal perception originates' [47].

There is also a long history of using errors to study naïve psychology. The social psychologist Daryl Bem, in the late 1960s, observed that subjects who were asked to explain their own actions often made the same errors as observers who only read about the actions, and used this observation to argue against Cartesian first-person privilege: 'If the reports of the observers are identical to those of the subjects themselves, then it is unnecessary to assume that the latter are drawing on "a font of private knowledge"' [35]. Bem concluded instead that everyone uses a causal theory (i.e. a naïve theory of psychology) to explain behaviour – both their own and other people's (see also [34]).

Stich and Nichols [15] were the first to use the argument from error against the Simulation Theory, but in their most recent book Nichols and Stich [38] have partially recanted. Instead, the authors observe that errors are more common in some kinds of psychological reasoning (e.g. predicting perceptual illusions or biased decisions) and less common in other circumstances (e.g. predicting inductive inference). They conclude that 'the argument [from error] justifies a strong initial presumption that accurate mindreading processes are subserved by simulation and inaccurate ones are not'. I disagree.

Systematic errors may be symptoms of a theory, but the errors are the exception, not the rule. Naïve theories incorporate heuristics and simplifications precisely because (and only when) the short cuts usually generate accurate predictions and explanations, and do so efficiently.

Adults' errors

Adults, too, have systematically inaccurate and oversimplified beliefs about beliefs that are often self-flattering. 'We are convinced of the rationality of [human] reasoning, highly adept at constructing plausible explanations for our decision behaviour, […] and so on' (p.106 [24]). That is, we share the conviction that, in general, beliefs follow from relatively dispassionate assessment of facts-of-the-matter and logical reasoning. As a consequence, people's expectations of how they and others should reason and behave correspond more closely to normative theories of logic, probability and utility, than to their actual subsequent behaviour [25].

Box 4. Sources of knowledge

An experiment to investigate young children's 'source of knowledge' was carried out by Burr and Hofer ([23], Study 3). On each trial a pair of objects was introduced that differed in appearance but not feel (e.g. a clean versus a dirty sock), or in feel but not in appearance (e.g. a plastic cup of warm versus cold water). The child was allowed to see without touching the two objects, and to touch without seeing the two objects (in this case covered by a cloth). The child then picked one of the objects for the puppets, Ernie and Bert, to investigate. One of the puppets could see but not touch the object, because his hands were stuck in his back pockets. The other puppet wore a blindfold, so he could feel but not see the objects. The child was encouraged to do each action along with the puppet. Then the child was asked a knowledge question (e.g. '*Can Ernie tell that the water is warm just by feeling it?*') and a 'Best-Way' question (e.g. '*So what's the best way to find out if the water is warm or cold: to feel it or to look at it?*'). Three-year-old children performed at chance, apparently believing that any kind of contact with an object was sufficient to get all kinds of knowledge about that object [4].

Historically, proposals for when observers use simulation tend to be somewhat ad hoc (see Box 3). In fact, if we could accurately simulate other minds, half a century of social psychology would lose much of its power to shock and thrill. The charisma of many famous experiments in social psychology and decision-making derives from the fact that they challenge our too-rosy theories of mind [26]. The experiments of Milgram [27], and Asch [28], and Tversky and Kahneman [29], are famous because there is a specific, and vivid, mismatch between what we confidently expect, and what the subjects actually do.

Even so, lay epistemology is not universally charitable. Most adults believe that beliefs are sometimes false, that reasoning can sometimes be distorted – both inevitably, by the limitations of the mind, and wilfully, as in wishful thinking and self-deception – and that all of these are more likely to be true of other people's thinking than of their own [30]. As a consequence, observers sometimes *overestimate* the prevalence of self-serving reasoning in others [31–33].

In one study, Kruger and Gilovich [31] asked each member of a married couple, separately, to rate how often he or she was responsible for common desirable and undesirable events in the marriage. Then, each was asked to predict how their spouse would assign responsibility on the same scale. Although everyone actually tended to take credit equally for good and bad events, each *predicted* that their spouse would be self-serving, that is, take more responsibility for good events, and less responsibility for bad ones. Undergraduate observers who didn't know the couples predicted an even stronger self-serving bias, departing even further from the actual ratings. Thus whereas reasoning about reasoning is usually characterized by overly optimistic expectations about people's rationality, in specific circumstances (e.g. the culturally acknowledged self-serving bias) observers are overly pessimistic, an effect dubbed 'naïve cynicism' [31].

The argument from error hinges on this kind of systematicity. When the errors that observers make in predicting another person's action, judgment or inference – or in explaining their own past actions or thoughts [34,35] –
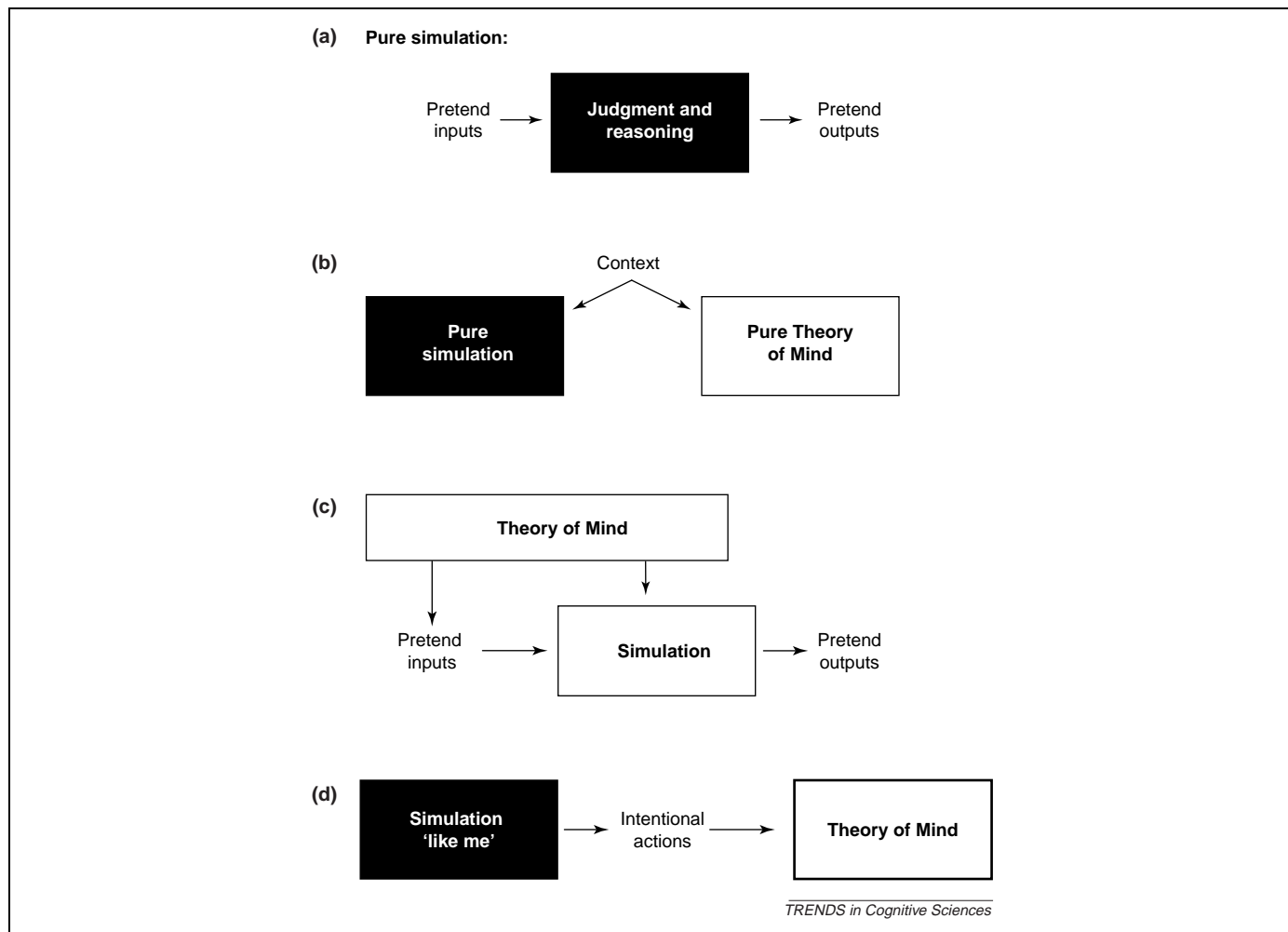
Figure 1. Reconciling Simulation and errors **(a)** The argument from error is directed against pure Simulation Theory, according to which the observer's mind is a 'resonating' black box, a working model that can be fed inputs and produces outputs, although the observer herself has no idea how the model works [5]. This version of Simulation is still current among neuroscientists and cognitive scientists (e.g. [11–13]), because of the apparent parsimony of 'direct perception'. **(b)** One possible compromise is that observers have two separate strategies for reasoning about other minds. In some contexts, the observer is a pure simulator, whereas in other contexts the observer uses pure theory [10]. **(c)** A better option is to conclude that a naïve theory of mind, and some capacity to simulate, interact [19,40]. The naïve theory of mind is necessary to set up a simulation correctly, to know what adjustments to make from the defaults, such as the observer's own beliefs, and to constrain the observer's model of judgment and reasoning (which is therefore not a black box). **(d)** In addition, an automatic mechanism that identifies the similarity between the observer's own body and body motions, and those of other people, may be necessary in development as part of the input to later theory-building.

are suspiciously congruent with their beliefs about how minds work [32], it seems likely that the observers are deploying those beliefs (or theory) in the process of making the predictions and forming the explanations.

Strong versions of Simulation Theory are therefore, in my view, in trouble. Crucially, a simulator uses the facts of *how* a person's mind functions, without explicitly representing *that* all minds function in that way [5]. The pattern of errors described above is not consistent with this kind of Simulation. And, as we shall now see, the most common defence of Simulation Theory against the argument from error also fails: the claim that errors arise from inaccurate *inputs* to the simulation [36].

Errors in the inputs?

An observer never has exactly the same perspective, or information, as the actor does. Could differences in the inputs (such as what features of the context are represented and how) lead to differences between the real, and the simulated, outputs of decision-making and reasoning? One class of errors in naïve psychological reasoning that can clearly be explained this way is the 'curse of knowledge' [37]. Both adults and children over-attribute their own knowledge to (ignorant) others. Simulation Theory can easily explain these errors, in terms of incorrect or insufficient manipulation of the inputs to simulation.

The 'incorrect inputs' defence does not work, though, for the systematic errors described above, such as young children's conflation of ignorance and 'being wrong' [21]. Remember that children who know that the selected bead is green reported that the ignorant adult observer, 'A', thinks the bead is red. If the child were simulating A, she might accurately express A's ignorance, or else she might assimilate A to the self and judge that A thinks the bead is green. Simulation Theory offers no account of children's actual, systematic error. It is not enough to say that they used incorrect inputs: the theory must explain why the inputs were wrong in just this way.

Similarly, adult observers are sometimes over-charitable and sometimes over-cynical in attributions of rationality. Again, Simulation Theory cannot simply argue that the observers were using the wrong inputs: why are the inputs wrong in this particular pattern?

Some alterations would let Simulation Theory accommodate such systematic errors of attribution (Figure 1). For example, the process that generates the inputs to the simulation might include, or be influenced by, the observer's beliefs about beliefs or naïve theory of psychology. The resulting hybrid model can explain all of the errors, but loses the parsimony of a pure Simulation Theory: the 'direct understanding' without 'explicit reflective mediation' (see also Box 5).

Conclusion

In summary, the 'argument from error' is a powerful argument for the existence of a naïve theory of psychology, and against a Simulation account of epistemic mental state attribution. These substantial limitations on Simulation Theory, and therefore on the explanatory power of

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> **Box 5. Questions for future research**
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> - How do Simulation- and Theory-like mechanisms interact over development? And in a mature adult brain?
> - What are the similarities and differences between the mirror systems (and capacities for simulation) of humans, who benefit from the guidance of a naïve theory of mind, and macaques, who presumably do not?
> - If illusions reveal the mechanism, what specific principles of the naïve theory of mind, like over-attribution of rationality and naïve cynicism, can be revealed by a careful analysis of observer's errors in predicting and explaining actions and inferences?

the mirror system, should be kept in mind when studying the neural bases of thinking about other minds (Box 2).

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