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Article

Reading the Eyes: Evidence for the Role of Perception in the Development of a Theory of Mind

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Efforts at explaining how we understand other minds has thrown up two main rival theories: the theory theory (*e.g.* Perner, this issue) and the simulation theory (*e.g.* Gordon, 1986). The theory theory suggests that we reason what someone else might think, desire or intend (*etc.*) by virtue of our ability to represent their mental representation of the world, and by using our theory of how mental states relate to behaviour. The simulation theory argues that we reason what someone else might think, desire, or intend (*etc.*) by using privileged access to our own mental states as a model for theirs, simply imagining what we would think if we were 'in their shoes'. In this paper, we do not attempt to test these theories against each other. Rather, we present data from young normal children which show how a correct account of how we understand other minds must be constrained in new ways that neither of these two theories has considered. Specifically, we present evidence for the role of *perception* in the use of

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our theory of mind.[1] Perceptual input has been largely ignored in this debate, yet the data to be presented suggest it does play an important role.

1. Eye-direction as Symptoms and Criteria

In what follows, we will focus on perceptual input derived from face-processing. More particularly, we will focus on the role of a special class of information, namely *eye-direction*. Might such information play a role in judging another person's mental states, and if so, how?

These questions can be considered in relation to two broad types of mental state: perceptual and cognitive. How do we succeed in judging someone's visual *perceptual* experience? One highly reliable way seems to be by checking their eye-direction, and then computing what could lie in their line of regard. Lempers, Flavell, and Flavell (1977) showed that young two year old normal children understood this, and Scaife and Bruner (1975) suggested that most 9 month olds were sensitive to such cues and used them meaningfully (see also Butterworth & Jarrett, 1991).[2] This suggests that eye-direction is *criterial* for judging someone else's visual perceptual experience.

In judging someone's *cognitive* mental state it is not usually assumed that we make use of any kind of specific perceptual input.[3] The argument goes something like this: since cognitive mental states (like thoughts) are unobservable, it follows that there can be no outward signs that a person is currently involved in such mental activity. Of course, such an argument contains a simple error: if x is unobservable, this in no way implies that x has no outward manifestation. An example will serve to reject this argument firmly: The heart is unobservable (to all but surgeons), yet has some outward signs (*e.g.* the pulse, or rosy cheeks, after exercise in the gym). Could thinking also have some outward sign? And if so, might we use such perceptual data in reasoning about mental states?

Here we argue that Wittgenstein's (1953) distinction between *symptoms* and *criteria*[4] might be useful. Thus, for perception, eye-direction necessarily specifies a person's visual focus, whereas for thought, it seems implausible that there will be anything as simple as criteria, but there may nevertheless

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1 We use the term 'theory of mind' to refer to the ability to reason about one's own or someone else's mental states. In this article, we do not intend this to be coterminous with the theory theory. Theory of mind has simply become convenient shorthand. Whether our theory of mind really is theory-like is a question that, as this special issue suggests, is up for grabs.

2 In fact, the youngest infants in Scaife and Bruner's (1975) study who showed gaze-following were 3 months, but these were a minority of the sample overall.

3 The exception to this is informational access in the case of attributing knowledge; though this hardly counts as a 'specific perceptual input', given the range of forms this can take.

4 We are grateful to Angel Rivière for drawing our attention to this distinction.

be some outward symptoms that a person is thinking. A far-fetched example of such a symptom in the realm of action would be the 'thinker' pose, made famous by Rodin. Such an example obviously lacks any ecological validity, since in the real world people rarely adopt such poses. A more plausible class of information that we might well use to infer that a person is thinking could, once again, be eye-direction, but this time eye-direction of a very specific kind. When people are asked to solve problems they usually look towards one of the upper quadrants of their visual field, at nothing in particular (Kinsbourne, 1972; Gur, Gur & Harris, 1975). It struck us that such eye behaviour cues might provide important scaffolding for constraining when and to whom a novice 'mentalizer' (Morton, 1989) might apply his or her theory of mind.

We have, then, the possibility that a certain class of perceptual information, namely eye-direction, is used not only to judge what another person can see, but also to judge when another person is thinking. If one thinks of what eye-direction could be taken to cue, it makes good sense that eye-direction should be read as playing this dual role. Thus, if the eyes are taken as indicating a person's focus of attention, then monitoring a person's eye-direction will tell you either that a person's attention is directed *outward* (at an external object or event, *i.e.* that they are *perceiving*) or, in the absence of any particular external object, *inward* (at an intentional object, *i.e.* that they are *thinking*).

The idea that eye-direction might convey important information about an individual's mental state has been discussed elsewhere (Baron-Cohen, in press a). The notion that perception may be important in the development of a theory of mind can be found in Hobson's (1990) theory, although Hobson restricts his discussion to emotional expression in the face.[5] In this paper, we specifically examine the role of eye-direction information. We report two experiments. In the first, in order to confirm that children do understand the criterial role eye-direction plays in diagnosing someone else's visual perceptual focus, we tested if normal 3 and 4 year olds could make fine discriminations based *solely* on eye-direction in photos of faces, to judge when another child was looking at *them*. In our second experiment, we tested if these children also made use of eye-direction as symptoms of when someone else was thinking.

Before turning to our experiments, it is worth briefly reviewing what is known about the processing of eye-direction. Gaze has been the subject of a long tradition of social psychological research (Argyle, 1972; Rutter, 1984) which has identified various interpersonal functions of eye-contact. Following another's gaze seems to be a very basic and evolutionarily old ability, judging from research in human infancy (Scaife & Bruner, 1975)

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[5] This notion leads Hobson to predict that children with perceptual problems, such as the congenitally blind, should show abnormalities in the development of a theory of mind.

and non-human primates (Whiten, 1991). Animal research has located cells specifically sensitive to this information in the superior temporal sulcus of the cortex (Perrett *et al.*, 1985). Evolution thus appears to have ensured that the brain is able to detect eye-direction, though it is only recently that the adaptive function of this has been explored (Whiten, 1991; Perrett, 1991; Baron-Cohen, in press a). Secondly, neuropsychological studies have demonstrated that some patients with prosopagnosia, as well as monkeys with specific lesions in the temporal cortex, can be selectively impaired in eye-direction detection (Campbell *et al.*, 1990; Cowey & Heywood, 1991; De Haan & Campbell, 1991), whilst being relatively unimpaired in other face-processing tasks. Such dissociation provides tempting evidence for the existence of a specialized eye-direction detector (or EDD) mechanism (Baron-Cohen, in press a). To trace the development of this ability therefore seemed to us to be an important exercise. The current experiments begin such an endeavour.

2. *Experiment 1: Which Child is Looking At You?*

2.1 *Subjects*

We tested two groups of children, 3 year olds (mean chronological age (CA): 3 years 6 months, sd = 0.3) and 4 year olds (mean CA: 4 years 4 months, sd = 0.3). They all attended nursery schools in Inner London. There were 15 children in each of these two age groups. The sex ratio was approximately equal in each age group.

2.2 *Materials*

We used 20 pairs of photographs of children's faces, comprising an equal number of male and female models, of different ethnic groups. The models were all children or teenagers, on the grounds that to young children, faces of other children might be both more interesting and more familiar than faces of adults. In each pair, one of the photographs was of a face looking directly forward. The other in the pair was looking either to the right, or to the left. In these off-centre gazes, in 10 instances (Condition 1) the nose faced directly forward (see Figure 1a), whilst in the remaining 10 instances (Condition 2) the nose faced in the same direction as the eyes, leaving the face as a three-quarter pose (see Figure 1b). This allowed us to test whether children were specifically using eye-direction information, or simply face-direction information. The photos were 3 inches square, black and white, and were reproduced from The Fairburn System of Visual References (1978). The expression of the mouth was either neutral or smiling.

2.3 *Method*

The experimenter placed each pair of photographs down on the table, in front of the subject, randomizing the position of each with respect to left or right. She then asked 'Which child is looking at you?' The subject simply had to point to one or the other.

2.4 *Results*

Table 1 shows the mean score of each group. As is clear, both groups performed significantly above chance (Binomial, $p < 0.02$), the 4 year olds performing significantly better than the 3 year olds ($t = 2.92$, 28df, $p < 0.025$). Errors, when they did occur, tended to occur equally in each condition. Indeed, an Age by Condition ANOVA showed a significant effect of group (F 5.8, df (56,3), $p < 0.02$) but no significant effect of condition.

Table 1 Mean scores of each group on Experiment 1 (maximum = 20).

Group	mean	sd
3 year olds	15.1*	4.0
4 year olds	18.5	2.0

* 3 × 4 year olds, $p < 0.025$

2.5 *Discussion*

This first experiment confirms earlier findings (Butterworth, 1991) that young children are sensitive to other people's gaze-direction. It also extends these by using a new technique involving photographic stimuli, and by testing if eye-direction is *the* critical information being used. Both 3 and 4 year olds use eye-direction to detect where someone is looking, and it is clear that they do not simply rely on a coarse level of information, such as face-direction. There is some developmental improvement between these ages, but essentially both groups performed well. In this respect they resemble adults in their level of competence at this (Cowey & Heywood, 1991). In the next study we explored if children of the same age also make use of eye-direction (of a slightly different kind) to judge if a person is *thinking*.

Figure 1(a)

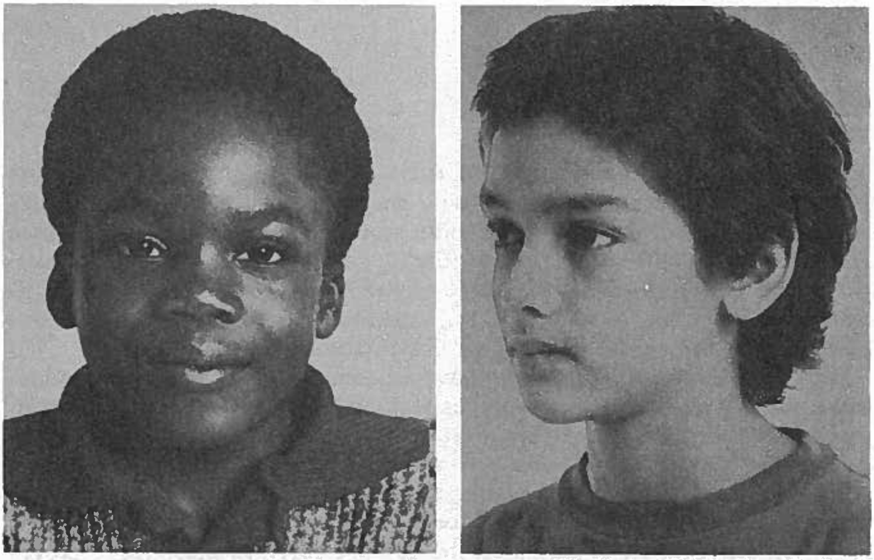

Figure 1(b)

Figure 1 Examples of photographs used in Experiment 1: 'Which one is looking at you?'. (a) Eye-direction cue only; (b) Eye and face-direction cues available.

2. Experiment 2: Which Child is Thinking?

3.1 *Subjects*

The same children took part in this experiment as had participated in Experiment 1.

3.2 *Methods and Materials*

Once again, we used stimuli from the Fairburn System of Visual References, as in Experiment 1. However, this time we used 10 pairs of photographs, one of which was looking to one side and in an *upwards* direction, and the other of which was looking directly forwards, at the camera. The photos in which the child was looking away were all judged (by two independent raters) to depict 'thinking'. An example is shown in Figure 2. Again, the mouth in all photographs was either neutral or smiling. The subject was simply asked 'Which one is thinking?', as the Experimenter laid out each pair of photographs, randomizing which was on the left or right.

3.3 *Results*

Table 2 shows the mean score of each group. Again, the 4 year olds performed significantly better than the 3 year olds ($t = 2.64$, 28df, $p < 0.025$). As a group, the 4 year olds scored significantly above chance (Binomial Test, $p < 0.05$), whilst the 3 year olds did not. However, analysing each subject's score, 30% of the 3 year olds did score significantly above chance (> 8 out of 10), and these were among the oldest 3 year olds in the sample (youngest CA = 3 years 5 months).

Errors in Experiment 2 could have occurred for one of two reasons: either failing to detect that the eyes were directed upward, or failing to understand that this signifies that a person is thinking. In order to isolate the proportion of subjects who were failing on Experiment 2 simply for the first of these reasons, we carried out a correction analysis.[6] This entailed scoring each subject for the number of errors in Experiment 2, minus the number of errors on the 10 nose-forward pairs from Experiment 1. This allowed for a tighter test of group differences on 'thought-

[6] We are very grateful to Paul Harris for suggesting this correction analysis.

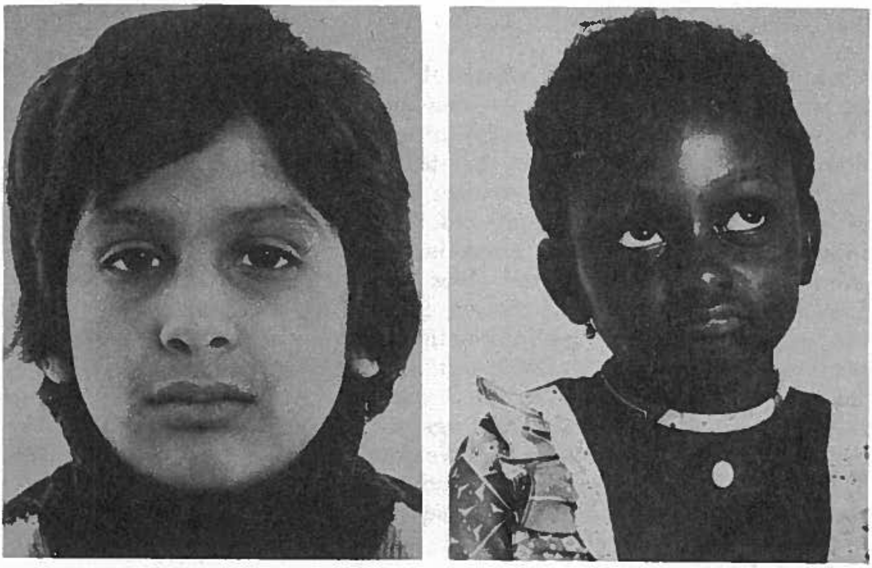

Figure 2 Examples of photographs used in Experiment 2: **'Which one is thinking?'**.

Table 2 Mean scores of each group on Experiment 2 (maximum = 10).

Group	mean	sd
3 year olds	7.4*	1.9
4 year olds	9.0	1.4

* 3 × 4 year olds, $p < 0.025$

detection' ability. Building in this correction factor eliminated the group difference ($t = 0.66$, 28df, $p > 0.05$) on Experiment 2, both groups now performing above chance.

3.4 Discussion

Children in both age groups showed that they judge if a person is thinking by where the eyes are pointing—away and in an upwards direction from the viewer. In terms of mean group scores, only the 4 year olds were significantly above chance on this task, though in terms of individual scores, 30% of 3 year olds were also above chance, these being children older than three and a half years old. After correcting for errors in Experiment 2 that were a result of errors in eye-direction detection rather than thought-detection, most of the older 3 year olds were above chance on Experiment 2. This suggests that for children above 3 years and 5 months old, eye-direction provides information not only about another person's perceptual experience, but also about their cognitive mental state (whether they are thinking). That even the 3 year olds were clearly above chance on this test is consistent with findings from other tasks showing that they possess the concept of thinking (Wellman & Estes, 1981; Baron-Cohen, 1989; Perner, 1991). The present study demonstrates not only that they *possess* this concept, but also that they map eye direction information on to it. In the final section of this paper, we turn to consider the implications of these data.

4. General Discussion

Our experiments show that both 3 and 4 year old normal children used eye-direction to judge a person's visual *perceptual* state and to judge if a person is *thinking* or not. In doing this, 3 and 4 year olds—like adults—reveal that they *do* make use of physical cues in the face in attributing cognitive mental states. As far as we are aware, this is the first such demonstration.[7] Such data provide some ammunition for the notion that the development of a theory of mind may to some extent make use of perceptual input (Hobson, 1990; Baron-Cohen, in press a). In the remainder of this paper we consider some of the different possible roles such perceptual input might play.

First, should this data be taken to support the Gibsonian 'direct perception' theory (Butterworth, 1990; Loveland, 1991) of how we understand mental states? The strong Gibsonian account would presumably insist that the necessary information for reading a person's mental state is specified in the perceptual array. Consider how one proponent of this theory expresses it:

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[7] After we had completed these experiments, George Butterworth drew our attention to a paper by Gibson and Pick (1962). This used a similar technique to ours, to test adult's competence at judging when someone is looking at them. Reading eye-direction to infer when someone is thinking has not been tested before. We are grateful to George Butterworth for guiding us to this.

> . . . it is crucial to question whether the capacity to imagine other people's mental states is ultimately derived from the direct perception of the expression of such mental states . . . According to Gibson (1966), knowing is an extension of perceiving—acquiring knowledge of mental states is therefore to be understood as a natural extension of the process of perception . . . Can the mind be read from behaviour? Is there information available which is consistent with there being other minds in the world?
> (Butterworth, 1990, pp. 136–7)

Gibsonians will certainly find our data consistent with their claim, but insofar as eye-direction is only a symptom (and not criterial) for indicating that a person is thinking—that is, it is possible for a person to be thinking whilst manifesting *any* pose they care to choose—the notion that perceptual information is all you need in order to read minds is not supported.[8]

Secondly, should our data be taken to refute the notion that attribution of mental states is all theory-driven (Premack & Woodruff, 1978), or 'top-down'? Clearly, insofar as both children and adults can attribute mental states to objects that lack anything even remotely resembling eye-direction information, such as the wind (Piaget, 1930), thermostats, or computers (Dennett, 1978), a theory of mind is unlikely to *require* perceptual input for its functioning.[9] Rather, a theory of mind is likely to be theory-driven.

However, it may still be the case that objects which manifest certain kinds of eye-direction information are more likely to be seen as perceiving and thinking objects. Such a possibility is testable. If supported, it would suggest that eye-direction may function as a perceptual *constraint* guiding the toddler to attribute mental states to a particular class of objects (those with eyes) under particular conditions. Such a constraint might be expressed as follows: *a system with eyes is thinking when its eyes are looking away, but not at any external object in particular.*[10] We assume that cartoonists exploit such psychological truths in succeeding at conveying Disney-type fantasy characters as intentional systems.[11]

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[8] Gibson himself did not make such a strong claim. Our data will hopefully sound a cautionary note to those Gibsonians who do.

[9] Inagaki and Hatano (1987) suggests that young children ascribe mental states to a range of phenomena they do not understand, as a strategy for rendering them understandable. Such personification suggests that the child's theory plays a more crucial role than perception.

[10] Dave Perrett (personal communication) pointed out that a further test of this idea would come from an experiment in which the child observes a person in an environment of objects. The person could then either looks directly at an obejct, or at no object in particular. The child would then be asked to judge when the person was thinking.

[11] Clearly, there may be other such constraints (such as motion) that guide children in the application of their newly acquired theory of mind (Mandler, 1991).

Thirdly, given that children seem to use different kinds of eye-direction in both tasks, might it be that their understanding of cognitive mental states such as thoughts is developmentally related to their understanding of simple perception? This possibility is both attractive and plausible, for two reasons: Given that thinking is an abstract activity, if children initially recognize this through concrete symptoms, this might greatly facilitate the acquisition process.[12] Furthermore, the idea that children use eye-direction for understanding perception and thought may help account for how toddlers acquire the notion of mental states with *intentionality* (Brentano, 1874). To clarify, visual perception possesses intentionality: it is always *about* something. Eye-direction signals this intentionality by specifying the *target* of visual perception: what perception is about. This might serve as the toddler's first lesson in intentionality, making it only a small (but important step) to extend this to mental states such as thoughts.

It remains possible that there might be other external, observable symptoms of mental states. Certainly, adults (cross-culturally) appear to use facial information to distinguish such mental states as *regret*, *scheme*, and *worry* (Baron-Cohen, Rivière & Cross, 1992), and toddlers from as young as 9–18 months use eye-information (probably eye-direction) to identify a person's *goal* behind an ambiguous action (Philips, Baron-Cohen & Rutter, 1992; Baron-Cohen, in press b). The search for the facial symptoms of mental states is likely to reveal the complexity of information we use in employing our theory of mind.

Let us now turn to the question running through the papers in this Special Issue. If we do use perceptual input in employing a theory of mind, what bearing does this have on the theory theory *versus* the simulation theory? At the outset of this paper we suggested that both camps might

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[12] It may be, then, that Hobson is correct to predict that blind children will be delayed in the acquisition of a theory of mind (ToM), though we will have to wait for the critical experiments to be done. If blind children were found to be delayed in the development of ToM, we would suggest the explanation for this lay not principally in being unable to see facial expressions of *emotion*, as Hobson (1990) argues, but rather in their inability to see and make use of eye-direction. Such a handicap would, we predict, at worst only *slow down* the acquisition of a ToM, but not prevent its emergence at all. We make this latter claim on the grounds that whilst perception of information like eye-direction may facilitate the acquisition of a ToM, ToM is likely to be a central process which can function independently of perceptual input (Leslie & Sellars, 1990; Baron-Cohen, in press a). And certain, the normal social skills and social understanding of blind *adults* suggests that even if there are delays in ToM development during childhood, these have no long-term effect on their eventual attainment of a ToM.
Similarly we would predict that children with prosopagnosia—even prosopagnosia involving impairments in eye-direction detection—would at worst be slowed down in their acquisition of a theory of mind, but not prevented from acquiring one. Young and Ellis (1989) report what we think is the only data relevant to this, of an 8 year old girl with prosopagnosia who passed a false belief test. The critical test would be to assess such cases at 4 years old.

incorporate such findings without undue concern. Consider, for example, this suggestion from simulation theory:

> One interesting possibility is that the readiness for practical simulation is a prepackaged 'module' called upon automatically in the *perception* of other human beings. One might even speculate that such a module makes its first appearance in the useful tendency many mammals have of turning their eyes towards the target of another's *gaze*. Thus, the very *sight of human eyes* might *require* us to simulate at least their spatial perspective and to this extent, at least, to put ourselves in the other's shoes.
> (Gordon, 1986, p. 170; some italics added)

This quotation stands as a virtual prediction of the results presented in this paper. On the other hand, the theory theory scores some points too, in that while such observable features as eye-direction may serve as cues to what a person is perceiving, at best such cues can only index *that* a person is thinking—not *what* that person is thinking *about*. To go 'the extra mile' and reason about the *content* of someone's thoughts is likely to require the use of a *theory* about the relationships between perception, cognitive mental states, and action (Wellman, 1990; Perner, 1991). In this paper, we inject new data into the white heat of this debate not in order to refute either the simulation theory or the theory theory, but rather to draw attention to one possible meeting point of these two theories—in the role of face-processing in mental state understanding.

In closing, we would like to touch on the relevance of this approach for understanding children with autism. Our earlier studies have revealed significant impairments in such children's development of a theory of mind (Baron-Cohen, Leslie & Frith; see Baron-Cohen, in press b, for a review). Other studies show that, whilst older children with autism can judge a person's perceptual experience under controlled laboratory conditions and when specifically instructed to do so (Baron-Cohen, 1989), they do not engage in joint-attention behaviours spontaneously (Mundy, Sigman & Kasari, in press). In addition, younger children with autism are relatively insensitive to the significance of another person's gaze direction (Mundy *et al.*, in press), and also appear not to monitor eye-direction to clarify an actor's *goal* (Phillips *et al.*, 1992). It therefore seemed logical to test them on the 'Which one is thinking?' task described here. In a recent study of this (Baron-Cohen, Campbell & Walker, 1992), children with autism, as predicted, showed severe impairments on this task, and this was dissociated from performance on other face-processing tasks. Further studies are needed in order to throw light not only on the development of autism, but also on the development of a theory of mind, and on the nature of what Magnus (1885) called 'eye language'.[13]

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[13] In this paper we have not explored the role of *learning* in the acquisition of 'eye-language'. There are of course several interesting possibilities here. First, toddlers may learn that gaze directed away from themselves is associated with the person attending to something else ('not-me') and that that something else may be external (a percept, if something is indeed present) or internal (a thought). Such learning could proceed without any teaching, though this would assume prior possession of the concept of thinking.

On the other hand, some eye-language may be 'taught' through some non-verbal form of motherese. The skyward look in order to convey scepticism about someone's sanity, or the wink in order to convey being a co-conspirator, are clear instances of eye-language that might well be taught explicitly. We would argue for a distinction between the parts of eye-language that are explicitly taught and are culture-specific, versus other parts of eye-language that are not taught and are universals. Our testable prediction is that eye-direction detection of the sort described in both experiments in this paper will fall into the universal category.

We end this paper with an invitation to play a game. Sit opposite a friend. Now, without vocalizing or moving any other part of your body except your eyes, try 'catching' your friend's eye to get him or her to look at a particular spot in the room. We expect that you will have done the following: (a) Made pronounced eye-contact; (b) rolled your eyes sideways until you are looking at the spot in question; (c) returned your gaze to remake eye-contact; (d) finally, repeated this sequence, perhaps with a small embellishment of eye-widening or eye-brow raising. Furthermore, we expect that this is what you would do irrespective of either your or your friend's culture. And that it works. That's what we mean by the universality claim.

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