

as if in anticipation of prey fleeing in their direction. . . . During such hunts lions integrated their actions solely by observing each other's posture and movement; no sounds were used nor were facial expressions employed which, at any rate, would not have been useful at night. *Encircling implies that lions are aware of the consequences of their actions in relation both to other group members and to the prey.* (pp. 250–51, italics mine)

The same behavior was observed by Griffin (1984, pp. 85–87) and studied in detail by Stander (1992).

The hypothesis of SI would be strengthened if animals spontaneously assemble into groups whose size is related to differences in the prey that are going to be hunted and *before the prey have been spotted*. In lions, for example, the larger males are more likely to participate in hunts when the prey is also large, for example, buffalo *Syncerus caffer* or zebra *Equus burchelli* (Schaller 1972). Kruuk (1972) explicitly noted this evidence for group intentionality in the spotted hyena:

[T]he differences in numbers of hyenas setting out are often apparent long before the hyenas have sighted a quarry; when hyenas are seen in a pack, even if there are no herbivores near, one can predict with a fair degree of certainty that they will eventually hunt zebra, even if this means walking for miles through herds of wildebeest. *This means that hyenas set out to hunt a certain kind of prey to the exclusion of others.* . . . the hyena's hunting methods are very well adapted to the requirements of catching different kinds of prey; the antipredator mechanisms of wildebeest and zebra are so unlike each other that they call for very different hunting action. If the hunting formation has to be taken up before meeting the adversary this would have the consequence of causing hyenas to concentrate on one kind of prey only. (pp. 201–2, italics mine)

It may not be coincidental that behaviors consistent with SI are shown by hyenas, lions, and chimpanzees when engaging in group hunting and aggression that, like so many human behaviors, are structured around individuals using one another to coordinate behaviors for shared outcomes. SI may be more obvious in humans because its widespread use – in culture-based activities such as science, art, music, and religion – was facilitated by language and culture by a process of *exaptation*. In sensu Rozin (1976) and Mithen (1996), it is only in modern humans that SI becomes conspicuous because it can be applied to activities for which it was not originally designed. The flip side is that animals exhibit only minimal SI because it is *not* an open and accessible program but one that is restricted only to task-specific contexts such as group hunting and group territoriality for which it evolved. But the possibility for a limited expression of context-specific SI in animals is an alternative worth considering, and one that may shed some light on its origins.

## Baby steps on the path to understanding intentions

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**Abstract:** Tomasello et al. lay out a three-step ontogenetic pathway for infants' understanding of intentional action. By this account, before 9 months, infants do not understand actions as being goal directed. However, we caution against drawing strong conclusions from negative findings, and, based on recent findings, propose that a key aspect of goal knowledge is present well before 9 months.

To describe the development of infants' understanding of intentions, Tomasello et al. lay out a three-step ontogenetic pathway. Step 1: Early in the first year, infants understand that others' actions are spontaneously produced. Step 2: Beginning around 9

months, infants understand others' actions as driven by internally represented goals. According to Tomasello et al.'s definition of *goal*, this means that infants know that agents monitor the outcomes of their attempts and persist in their efforts when unsuccessful. Step 3: By 12 to 14 months, infants understand others' choice of plans in order to achieve goals. Frameworks like this one are invaluable to the field because they provide the foundation for understanding developmental change. For this reason, it is critical that the framework be right. We suggest one caveat and one revision to Tomasello et al.'s framework.

We take issue with the evidence used to argue that infants do not understand the persistent nature of goal-directed activity before 9 months. To support this claim, Tomasello et al. cite two studies. One is the habituation work by Csibra et al. (1999), in which 9- and 12-month-olds, but not 6-month-olds, responded with longer looks when a computer-animated dot moved in an "irrational" way. The other is work by Behne et al. (2005), which revealed that 9- and 12-month-olds, but not 6-month-olds, communicated more impatience when an experimenter was unwilling to give them a toy than when she was unable to do so.

The claim that these failures of 6-month-olds indicate a lack of goal understanding is problematic because it relies on negative evidence. Both studies required infants to interpret complex or abstract physical constraints and their implications for the agent's ability to attain a goal. As Csibra et al. (1999) pointed out, 6-month-olds may understand goal-directed action, but be unable to infer the physical constraints that make an action rational or a goal unattainable in these experiments. A further concern regarding Behne et al.'s study is that even if the 6-month-olds understood the physical constraints involved, they probably lacked the communicative competence to express their frustration.

Given these concerns, we are left with three possibilities for what 6-month-olds understand about agents' pursuit of goals. One possibility, consistent with Tomasello et al., is that these infants entirely lack this understanding. A second possibility is that this understanding is fully developed by 6 months. Neither possibility can be supported until the appropriate studies have been conducted.

A third possibility, and the one we think most likely, is that 6-month-olds have some basic understanding of goal-directed action that is less developed than at 9 months, but more developed than is suggested by Tomasello et al.'s first step. Well before 9 months, infants understand agents' actions as organized by the agent's relation to an external object. This conclusion is supported by habituation experiments showing that infants display selective and robust novelty responses to changes in the relation between a person and the object at which her actions are directed (Sommerville et al. 2005; Woodward 1998, 1999, 2003, 2005).

Tomasello et al. gloss these findings as evidence that infants expect people to reach for the same object again and again. We do not believe this is the correct interpretation. For one, it is not clear that such an expectation could be derived from experience: people do not normally reach for the same object repeatedly. Moreover, our habituation method is a measure of infants' novelty detection rather than a violation-of-expectation paradigm. Rather than viewing apparently impossible events, infants in these studies saw events that differed on one of two conceptually important dimensions, and their novelty responses indicated which dimension was central to their event representation.

Infants represent meaningful human actions as object directed. They do not represent the motions of inanimate objects (Jovanovic et al. 2002; Woodward 1998) or other human movements in this way (Woodward 1999). Thus these findings do not reflect a general tendency to encode spatial relations, but rather a specific propensity to encode people's actions in terms of agent–object relations. Infants do this for concrete actions, like grasping, early in the first year (Sommerville et al., in press; Woodward 1998), and for abstract ones, like looking, by the end of the first year (Phillips et al. 2002; Sodian & Thoermer 2004; Woodward 2003). Moreover, consistent with Tomasello et al.'s suggestion that infants' own actions structure their emerging concepts of intention, infants'

own experiences as intentional agents correlate with and affect their propensity to represent others' actions as object directed (Sommerville & Woodward, 2005; Sommerville et al., in press; Woodward, in press; Woodward & Guajardo 2002).

Therefore, we propose a step intermediate to Tomasello et al.'s steps 1 and 2: early in the first year, infants represent some actions as being object directed. They can then recruit these representations to make more complex inferences, including predictions about what an agent will do in future situations; that is, infants might begin by realizing that certain actions are organized with respect to external objects and then learn about the relations between actions like looking, opening, and reaching. These relations in turn could support Tomasello et al.'s second step, the insight that agents persist to attain goals while monitoring the success of their efforts.

It is extremely useful to lay out an ontogenetic map of cognitive development, as Tomasello et al. have done. However, it is important to be cautious in drawing conclusions about where infants of a given age are on this ontogenetic path and to consider possible intermediary steps along the way. It is a big jump from Tomasello et al.'s step 1 (nothing in the head) to step 2 (internally represented goals and monitoring systems) – such a big jump, in fact, that it might be tempting to conclude that step 2 emerges of whole cloth from innate specifications. Like Tomasello et al., we believe it is important to go beyond labeling cognitive skills as *innate*. Their ontogenetic pathway positions us to investigate how an understanding of goal-directed action could be built in the course of early conceptual development. Our findings elucidate a baby step on the way to this foundational insight.

### Lack of motivation to share intentions: Primary deficit in autism?

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**Abstract:** We review evidence regarding Tomasello et al.'s proposal that individuals with autism understand intentions but fail socially because of a lack of motivation to share intentions. We argue that they are often motivated to understand others but fail because they lack the perceptual integration skills that are needed to apply their basically intact theory of mind skills in complex social situations.

Tomasello et al. state that all individuals with autism have clear deficits in the development of collaborative engagements with others, although at least some understand actions as goal directed if not fully intentional. This discrepancy between intact intentional understanding and defective social performance holds true also at higher levels of theory of mind (TOM): A subgroup of high-functioning individuals with autism show no deficits in complex TOM skills, as assessed by second-order belief tasks (Ellis & Hunter 1999), and in recognizing basic emotions in other people's faces (Baron-Cohen et al. 1997; Roeyers et al. 2001). However, in their everyday functioning, they seem unable to use these mind-reading abilities satisfactorily. Hence, a distinction must be made between TOM functioning in a test setting and in everyday life. In test situations, individuals with autism spectrum disorder (ASD) have time to use compensatory strategies that they cannot use in everyday-life situations. This may also explain why general intelli-

gence strongly affects task performance and why different studies comparing individuals with ASD and control groups have obtained conflicting results (see also Brent et al. 2004).

Tomasello et al. propose that a lack of motivation to share intentions with others is the main cause of the observed discrepancy between test situations and everyday life. Further analysis of the basic mechanisms behind this motivational theory of ASD is necessary, otherwise it remains descriptive instead of explanatory. So, what is the underlying nature of this deficit? Tomasello et al. acknowledge that our knowledge of the putatively basic human motivation to share intentions with others is limited. The inability to make appropriate social judgments about faces in both individuals with ASD and individuals with bilateral amygdala damage suggests that amygdala dysfunction impairs the ability to link social stimuli with their social meaning and may explain a lack of social interest (Adolphs et al. 2001; Grelotti et al. 2002; Schultz et al. 2000).

However, most children with high-functioning ASD have an intact social interest and initiate social contact as frequently as other children do (Frith 1989, 2003). So, if the core deficit lies in the area of social motivation, it cannot be a lack of social interest in general, but a more specific aspect, for example, lack of interest in other people's mental states. One such form of social interest is joint attention (or joint perception in Tomasello et al.'s terminology), the coordination or sharing of attentive activities such as gaze following and looking where someone is pointing – all essential activities for so-called triadic engagement. Several studies have shown that children with ASD show deficits in the development of joint attention, especially in spontaneously initiating joint attention with a social partner (Mundy et al. 1994; Sigman & Ruskin 1999). There is some evidence that the degree of joint attention earlier in development correlates with the degree of TOM later in development in control children but not in children with ASD (Warreyn et al. 2004). In autistic children, the degree of joint attention correlates negatively with the severity of all the core symptoms of autism (Charman 2003) and with language ability (Dawson et al. 2004), but this correlation does not establish a causal link between deficient joint attention and ASD, nor with its hypothesized deficient motivation to share intentions.

Going one step further, we raise doubts about the existence of this deficiency in social motivation itself. Clinical experience shows that at least some high-functioning adults with ASD have a strong – sometimes even fanatical – interest in what other people feel or think: They spend a great deal of time trying to infer what a certain behavior or utterance means. Often they describe this uncertainty about what is going on in other people's minds as the greatest stressor in their lives. These adults clearly do not suffer from a lack of motivation to share things psychologically with others, but rather from the conflict between their desire to understand others and their inability to do so adequately. Of course, this argument does not exclude that children with ASD lack the motivation to share intentions at a developmentally earlier stage, but the key question remains: Why do adults with ASD who have the skills to read other people's minds in a test situation, and are motivated to do so in daily life, still fail to mind read in natural social interactions? In other words, if motivation is not (or no longer) the problem, what is?

One hypothesis is that individuals with ASD lack the perceptual prerequisites to apply their TOM in complex social situations. A certain level of perceptual integration is necessary to infer correctly what another person is feeling. For example, a smile taken in isolation could mean anything: Only by integrating perceptions of how the person is looking, what he is doing, what his voice sounds like, and the social context, with knowledge about previous experiences with this person, does it become clear whether this person is just greeting you kindly or making fun of you. Even at the basic level of sharing intentions, representations of the intention of the subject need to be integrated with representations of the intention of the other person. Uta Frith (1989) was the first to draw attention to this deficient integration in children with ASD