tion (Initiates Joint Attention, or IJA) bids, and that an attenuation of positive affective sharing plays a role in joint attention impairment in autism (Kasari et al. 1990; Mundy et al. 1992). If positive affect is indicative of motivation, these observations are consistent with the hypotheses that social motivation plays a role in the development of sharing intentions with others (Tomasello et al.'s article) and the neurodevelopmental impairment of joint attention in autism (Mundy 1995). Frontal processes involved in motivation (i.e., associating rewards with goal-directed activity) have also been associated with infant IJA development (Dawson et al. 2002a; Nichols et al., 2005).Moreover, there is a shift from *reactive* affect in IJA (smiling after looking from an object to a social partner) to *anticipatory* affect (smiling at the object and then conveying the affect to the social partner) between 8 and 10 months (Venezia et al. 2004). This may indicate an important change in the integration of affect, cognition, and intentional control in the early development of intention sharing. Thus, current research offers some support for the social-motivation hypothesis of intention sharing. However, the fundamental nature of the motivation processes involved remains to be described.

Tomasello et al. also suggest that the capacity to monitor and regulate goal-directed actions, and to represent the goals of self and other, provides a cognitive foundation for sharing intentions. Neurodevelopmental research and theory ascribe similar cognitive functions to triadic joint attention (Mundy 1995, 2003). The ability to follow gaze and respond to the triadic joint attention bids of others (Responds to Joint Attention, or RJA) is associated with temporal and parietal cortical functions serving attention disengagement, orienting, and social perception (e.g., see Mundy et al. 2000; Vaughan & Mundy, in press). For example, primate studies indicate that the superior temporal sulcus (STS) contributes to the processing of gaze direction versus the processing of the direction and orientation of limb movements (e.g., see Perrett et al. 1992). However, a subset of limb movement cells appears to be modulated by activity of the gaze-following system (Jallema et al. 2000). Thus, the *combined* analysis of direction of visual attention and body movements of others by STS systems provides an important source of information that gives rise to the capacity to detect intentionality in others (Jallema et al. 2000).

IJA may be associated with the dorsal-medial frontal cortex and anterior cingulate complex (DMFC/AC [Caplan et al. 1992; Henderson et al. 2002; Mundy 2003; Mundy et al. 2000]). The DMFC/AC contributes to the planning, self-initiation, and self-monitoring of goal-directed behaviors, including visual orienting (e.g., see Rothbart et al. 1994) and the capacity to share attention across dual tasks, or representations (Stuss et al. 1995). Thus, the DMFC/AC plays a critical role in the maintenance of representations of self, a social partner, and third object/event that is critical to the capacity to share intentions (Mundy 2003; Mundy et al. 2000). The DMFC/AC is also be involved in the motivational mediation of goal-related behavior. The DMFC/AC plays a critical role in the supervisory attention system (SAS) (Norman & Shallice 1986), which functions to guide attention deployment and behavior, depending on the motivational context of the task (e.g., see Buch et al. 2000).

Ultimately, the DMFC/AC is involved in representing the self, and self-monitoring of goal-related behavior, as well switching attention between internal proprioceptive (self information) and exteroceptive information about external events (e.g., see Craik et al. 1999; Faw 2003; Mundy 2003).

Frith and Frith (2001) argue that the DMFC/AC integrates self-monitored information with perceptions processed by the STS about the goal-directed behaviors and emotions of others. This putative facility for integrating proprioceptive "self" information with exteroceptive "other" information has been called a *social executive function* (SEF) of the DMFC/AC (Mundy 2003), and a breakdown of this SEF may play a role in joint attention and social-cognitive impairment in autism (Mundy et al. 1993). Theoretically, the DMFC/AC facility to compare and integrate the actions of self and others contributes to the capacity for simulation (Stich & Nichols 1992) and the ability to infer the intentions of others by matching them with representations of self-initiated actions (Mundy 2003). Once this integration begins, a fully functional, adaptive human social-cognitive system emerges with experience (Frith & Frith 2001). Indeed, there is evidence that DMFC/AC activity is associated with social-cognitive performance on theory-of-mind measures in adults (e.g., see Calarge et al. 2003). Thus, understanding of intentions in others may be an emergent property of the gradual phylogenetic and ontogenetic development of a myriad of integrated functions of the human DMFC/AC and temporal cortical systems.

Of particular importance here may be the development of the comprehensive DMFC/AC capacity for self-monitoring and self-regulation of goal states. From a constructivist perspective, infants need to self-monitor and self-regulate (*exercise* control of) their own goal-directed behaviors and emotions *in order* to understand goal-directed, intentional action in others (Mundy 2003; Tomsello et al.). Thus, in addition to motivation and representational ability, the constructs of self-awareness and self-regulation may be important to consider in theory on triadic joint attention and the capacity to understand intentions in others. Supporting this conjecture, self-recognition (self-awareness) has been associated with infant IJA development (Nichols et al., 2005), and 6-month RJA predicts self-regulation during delay of gratification in 2-year-olds (Morales et al., 2005). Infant IJA and RJA are also associated with behavior and emotion regulation among 30- to 36-month-olds (Sheinkopf et al. 2004; Vaughan et al., submitted), and infants exposed to less optimal caregiving associated with dysregulated behavior display attenuated IJA development (e.g., see Claussen et al. 2002).

These observations are quite consistent with the insights of Tomasello et al. and point to a persuasive convergence of perspectives on the human capacity to share experience with others. They also suggest that self-awareness and self-regulatory processes may be neurodevelopmentally bundled with social-motivation and social-cognitive processes in both the phyologenetic and ontogenetic development of the capacity to share experience, as well as in the resultant human capacity for cultural cognition.

Do infants understand that external goals are internally represented?

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Abstract: Evidence for infants' sensitivity to behavior being goal oriented leaves it open as to whether they see such behavior as being designed to lead to an external goal or whether they see it, in addition, as being directed by an internal representation of the goal. We point out the difficulty of finding possible criteria for how infants or children view this matter.

Organisms can be described as having goals even when they do not have an explicit representation of the goal-to-be-achieved that directs behavior. For example, some plants turn towards light, which McFarland (1989) described, therefore, as *goal-seeking*. Tomasello et al.'s exemplary thermostat can recognize a goal when it obtains, so can be described as *goal-achieving*.

Tomasello et al. recognize the importance of such distinctions by pointing out that much confusion resulted from failure to clearly distinguish the *external goal* (a potential future state of the environment) and the *internal goal* (a behavior-guiding mental representation of the external goal). Instead, Tomasello et al. decide to use "goal" *simpliciter* for internal goal and "desired result" for external goal. Unfortunately, this decision can only aggravate

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conceptual confusion. When technical definitions go against natural meaning, as in this case, readers tend to fall back into natural language meaning. Even the authors appear to do so. For example, in section 2.2 they write, "[I]nfants understand . . . actors routinely go around obstacles to get to *goals*" (our emphasis). This certainly can't mean according to their definition that "infants understand actors go around obstacles to get to *their internal representations of their desired results*."

Tomasello et al.'s definition of *goal* is, however, not just an unfortunate technical use of language but misleads in substance by suggesting without argument or evidence that infants understand purposive behavior as guided by internal representations of goals. When reviewing infants' understanding of the pursuit of goals in section 2.2, the authors routinely describe infants as seeing observed behavior as "goal-directed action," which, according to their definition would be phrased "action directed by the internal representation of a goal." Their descriptions thus entail that infants understand goals as internally represented without giving any reason or evidence for such a claim.

Such reasons would be particularly valuable because of the importance of the distinction in question. We know of no obvious way of determining whether children see behavior as *goal-directed* (directed by an internal representation of a goal) in distinction to seeing behavior as *goal-oriented*, without assuming an internal representation of the goal.

The relevant contrast is between *teleological* explanations and *intentional* or *mentalistic* explanations. A completely *externalist* (no internal states involved) teleological explanation sees behavior as a function of the present state of the world (circumstances), some future state (goal) and rudimentary rationality – that is, that behavior will occur that transforms reality into the goal state. This externalist view also applies to inanimate objects without internal, behavior-directing states, like a pendulum whose goal is to come to rest at the lowest possible point (according to Aristotle [Kuhn 1977]).

An externalist view also provides limited understanding of "intelligent" mechanisms like temperature-regulating systems. Knowing the external temperature and the system's target temperature (external goal) enables prediction of whether the system will switch the furnace off (behavior). Ways of manipulating the system intelligently remain limited to changing the external circumstances (e.g., to heat up the room). Other intelligent means of intervention become possible only if we understand more of the internal workings.

According to an *internalist* view of intelligent behavior, the system/organism's behavior does not depend directly on the state of the world and some future goal state but on internal representations of these states. Here we need to distinguish two levels of understanding. In the case of the thermostat, we have full *physiological* understanding of the internal parts of the thermostat (bimetallic strip that bends when heated and touches a contact point, etc.) and their functional role (bimetallic strip curvature represents external temperature, contact-point setting represents goal, etc.). At the level of folk psychology (theory of mind, mentalism), however, we have no understanding of the actual internal parts; we only surmise that there must be some part registering the external temperature (belief), another part representing the goal value (desire), and a comparison mechanism that takes action when the two values coincide (practical reasoning mechanism).

Nevertheless, we gain an advantage over the purely externalist approach in two ways:

1. *Intentionality*. We can understand that the system represents the external circumstance in a particular way, which depends among other things on the information the system has. Given misinformation it will misrepresent the circumstances (false belief). Its subsequent behavior can then be predicted or explained, in a way not possible with a purely externalist account.

2. *Manipulability*. Understanding that the internal representation of external circumstances depends on information enables a novel means of manipulating the system's behavior. We can make it delay switching on the furnace by deception – that is, by heating up its sensors to make it "believe" the room is still hot.

Children's understanding that beliefs are internally represented has been assessed by their ability to predict, explain, or induce false beliefs. Can similar techniques be used for testing understanding goals as internally represented? Curiously, there is no straightforward analogy to false belief, because goal representations do not depend on manipulable ingoing information, and goals cannot be misrepresented. If the thermostat represents the goal as 31°C, then that *is* the system's goal, even though people might prefer 21°C. In other words, the (external) goal is determined by its internal representation (direction of fit [Anscombe 1957; Searle 1983]), whereas, for beliefs, the external circumstance is not determined by what the system believes it to be.

A tempting line of thought is that understanding subjective preference requires an understanding of internal representation of goals, because subjectivity smacks of *Intentionality*. Indeed, infants in their second year (Repacholi and Gopnik 1997) understand that someone else can want broccoli, which the children themselves find revolting. However, a difference in goals can be understood without understanding goals as internally represented (see Perner et al., 2005). The infants simply understand that one of this (admittedly strange) person's *external* goals is to eat broccoli.

In conclusion, seductive choice of terminology can suggest that infants take an internalist, mental view of goals, but we find it difficult to specify hard criteria for determining when they actually do take such a view.

From action to interaction: Apes, infants, and the last Rubicon

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Abstract: Tomasello et al. have presented a position that is grounded in a conservative perspective of cultural learning, as well as in a rich interpretation of recent findings in early social cognition. Although I applaud their theoretical framework, I argue that data from studies of human infants are not necessarily consistent with the developmental picture that they describe.

Approximately one decade ago, Tomasello et al. (1993) brought forth the argument that human beings' understanding of conspecifics as intentional or mental agents is a species-unique ability that renders humans capable of participating in cumulative cultural evolution. In their present thought-provoking article, Tomasello et al. draw on a wealth of recent research regarding the cognitive capacities of nonhuman primates and human infants as a means of revisiting the issue of cultural cognition. The authors conclude that nonhuman primates have a greater understanding of intentional agents than was previously believed. Furthermore, they maintain that the crucial difference between human cognition and that of other species centers on the ability to participate in activities involving joint intentions and attention or what they refer to as *shared intentionality*. They propose that the ontogeny of the ability for collaborative engagement occurs in three stages over the first year of human life as a joint product of the understanding of intentional action (also found in other apes) and the motivation to share psychological states (species specific). It is evident that Tomasello et al. are well placed to provide an evolutionary account of human cognition, seeing as they occupy a unique niche in the field of cognitive science. Indeed, a substantial portion of the published research on social cognition in human and nonhuman primates over the last decade can be attributed to them. In the following commentary, I address three principle is-

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