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Sharing and Ascribing Goals

PIERRE JACOB

Abstract: This paper assesses the scope and limits of a widely influential model of goal-ascription by human infants: the *shared-intentionality* model. It derives much of its appeal from its ability to integrate behavioral evidence from developmental psychology with cognitive neuroscientific evidence about the role of mirror neuron activity in non-human primates. The central question raised by this model is whether sharing a goal with an agent is necessary and sufficient for ascribing it to that agent. I argue that advocates of the shared-intentionality model underestimate both the distinction between the target and the goal of a goal-directed action and the gap between sharing and ascribing a goal.

Introduction

Much experimental work in developmental psychology over the past fifteen years strongly suggests that before the end of their first year, preverbal human infants are able to represent the actions of a variety of agents as goal-directed. Although the nature of the basic mechanisms at work in human infants' goal-ascription remains controversial, one influential model of goal-ascription by human infants has emerged: I shall call it the *shared-intentionality* model. This model derives much of its appeal from its ability to integrate behavioral evidence from developmental psychology together with cognitive neuroscientific evidence about mirror neuron (MN) activity based on single-cell recording in the brain of non-human primates. It seems to be corroborated by recent developmental evidence showing the role of early motor experience in shaping the ability of human infants to represent the actions of others as goal-directed, which has been interpreted as evidence for the role of MN activity in early goal-ascription by human infants.

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1 In philosophy and cognitive science, there is a stronger and a weaker sense of
 2 the expression ‘shared intentionality’. In the stronger sense, individuals are said to
 3 share collective intentionality (or we-intentions) when they have the capacity to
 4 engage in joint (or collective) actions (e.g. tango dancing, playing chamber music
 5 or playing football).¹ Collective intentionality has recently been highlighted as a
 6 distinctive human cognitive trait.² In the cognitive neuroscience of action, there
 7 is also a weaker sense in which the agent of a transitive action such as grasping a
 8 peanut and an observer of that action are said to share a motor representation of
 9 the agent’s action, on the grounds that many of their brain structures overlap.³ In
 10 this weaker sense, being able to engage in joint action is not a necessary condition
 11 for shared intentionality. Nor is it distinctive of human cognition: mirror neuron
 12 (MN) activity, which was discovered in the ventral premotor cortex of non-human
 13 primates, has been widely interpreted as evidence for the existence of shared motor
 14 representations in the brains of an agent and an observer.⁴ Only the weak sense of
 15 ‘shared intentionality’ will be relevant to this paper, the main goal of which is to
 16 assess the developmental evidence for and against the shared-intentionality model
 17 of goal-ascription by preverbal human infants.

18 While some of the recent behavioral investigation of goal-ascription by human
 19 infants focuses on their early ability to imitate a model’s observed action, most
 20 of it has been conducted within the violation-of-expectation framework. This
 21 framework rests on the assumption that individuals look longer at an unexpected
 22 than an expected event, so that by measuring infants’ looking times, psychologists
 23 can get evidence about the nature and content of their expectations. These
 24 experiments fall into two broad categories: one choice-based, and the other
 25 efficiency-based. In choice-based experiments, infants are induced to expect that
 26 an agent has a preference for one of two toys. In efficiency-based experiments,
 27 infants are induced to expect that an agent will select an action as an efficient means
 28 to achieve a goal in the presence of situational constraints (e.g. obstacles in the
 29 environment) (cf. Figure 1).

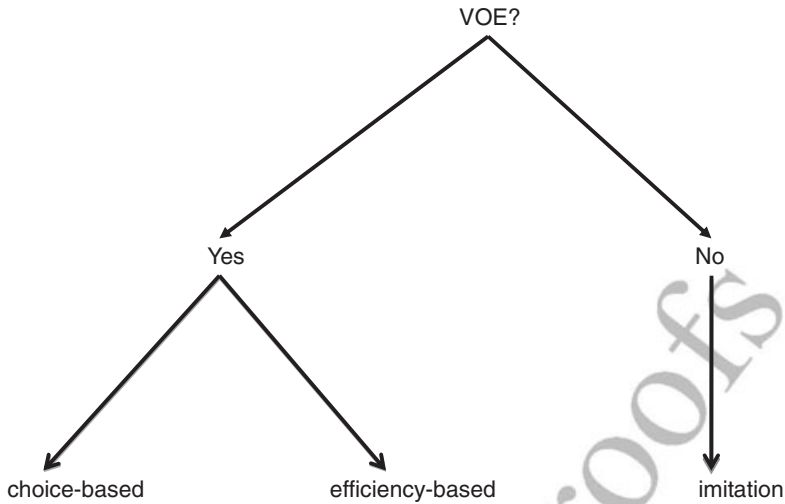
30 The paper falls into five sections. In the first section, I spell out the main
 31 assumptions of the shared-intentionality model and summarize some of the basic
 32 cognitive neuroscientific evidence in its favor from single-cell recording in the
 33 monkey brain. In the second section, I review some of the developmental evidence
 34 for this model from choice-based experiments conducted within both the violation-
 35 of-expectation framework and the so-called ‘imitation’ framework. In the third
 36 section, I review some of the choice-based evidence against the shared-intentionality
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 39 ¹ Cf. Bratman, 1992; Gilbert, 1989; Pacherie and Dokic, 2006; Searle, 1995; Tuomela, 1995.

40 ² Cf. Rakoczy and Tomasello, 2007; Tomasello, 2008; Tomasello *et al.*, 2005; Tomasello and
 41 Carpenter, 2007.

42 ³ Cf. Jeannerod, 1999, 2006; Decety and Grèzes, 2006; Decety and Sommerville, 2003; Jackson
 43 *et al.*, 2006; Singer and Lamm, 2009.

⁴ Cf. Rizzolatti *et al.*, 1996; Gallese, 2001; Gallese *et al.*, 2004; Rizzolatti and Sinigaglia, 2008.



17 **Figure 1** *The investigation of goal-ascription by human infants*

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model. In the fourth section, I review some further developmental evidence against the model, based on the single-target-efficiency paradigm. In the last section, I criticize the claim that some of the recent evidence showing that infants' motor experience enhances their understanding of goal-directed actions performed by others is also evidence for the role of mirroring in human infants, and offer an alternative account of the role of infants' motor experience in goal attribution.

27 1. Mirroring Another's Goal

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At the core of the shared-intentionality model are the two related ideas that a fundamental part of ascribing a goal to another is to share the goal with him or her and that one cannot share goals with every conceivable agent. In accordance with Meltzoff's (2005, 2007) *Like-me* framework, advocates of the shared-intentionality model stress the role of *familiarity* in shaping human infants' early ability to reason about and ascribe goals: the fundamental intuition underlying the model is that the early ability to reason about another's goal is shaped by familiarity with the agent's action. But on the face of it, many different kinds of agents and actions will be perceptually familiar to an infant, depending on her social and cultural environment. The shared-intentionality model tries to spell out the relevant notion of familiarity in terms of a two-step appeal to the notion of *similarity* relative to the observer (i.e. the self). The *perceptual* familiarity of an agent is evaluated in terms of the human-like aspect of her bodily appearance. The *motor* familiarity of an agent's action depends on whether the observer could perform the agent's act, i.e. on the similarity between the agent's performed act and the observer's motor

1 repertoire. The shared-intentionality model can be captured in the five following
 2 assumptions.

- 3 (1) The first assumption is that, in accordance with Meltzoff's (2005, 2007)
 4 *supramodal* hypothesis, the model assumes that preverbal human infants are
 5 equipped with a supramodal code that enables them to represent in a single
 6 format both the observable acts performed by others and their own felt
 7 acts.⁵
- 8 (2) The second assumption is that in virtue of the supramodal code, preverbal
 9 human infants have the ability to single out observable agents that are
 10 *perceptually* like them (or human-like) from other agents.
- 11 (3) The third assumption is that preverbal human infants have the ability to
 12 single out observable actions that fall within their own motor repertoire,
 13 i.e. that are executable, from observable actions that are not executable.
- 14 (4) The fourth assumption is that when a preverbal human infant observes
 15 a *Like me* (i.e. human-like) agent perform an executable action that falls
 16 within the infant's own motor repertoire, the infant mentally rehearses
 17 (i.e. covertly imitates) the agent's action (or maps it onto her own motor
 18 repertoire).⁶
- 19 (5) Finally, the model assumes, along with Rizzolatti *et al.* (2001), that by
 20 mentally rehearsing (or covertly imitating) the agent's action, the infant
 21 comes to share, and thereby to understand, the psychological state (e.g. the
 22 agent's goal) that caused the agent to perform her action in the first place.

23
 24 In fact, there are two versions of assumption (5): a stronger and a weaker one.
 25 The question is whether sharing a goal and ascribing a goal are two different
 26 psychological events or one and the same. On the stronger version, they are one
 27 and the same: sharing another's goal is constitutive of ascribing a goal to an agent;
 28 there is simply no difference between instances of the former and instances of the
 29 latter. On the weaker version, there is a difference between the two events: sharing
 30 is not ascribing, but sharing another's goal is a crucial causal step in the process
 31 leading to goal-ascription.⁷

32 The shared-intentionality model of goal ascription seems able to unify results from
 33 developmental psychology and cognitive neuroscience, in particular the activity of
 34 mirror neurons (MNs), first discovered in the early 1990s by single-cell recording
 35 in area F5 of the ventral premotor cortex (and subsequently in the inferior parietal
 36 lobule) of macaque monkeys. On the face of it, MN activity seems to strongly
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 39 ⁵ As Meltzoff (2007) puts it, infants 'can use the self to understand the actions, goals, and
 40 psychological states of others and conversely can learn about their own powers and the
 41 possibilities and consequences of their acts by observing the behavior of others'.

42 ⁶ For some relevant discussion, see Gergely, 2007.

43 ⁷ This distinction between the strong (constitutive) and the weaker (causal) interpretation of the
 contribution of sharing a goal to ascribing it to another is emphasized by Goldman (2009).

1 support assumptions (4) and (5) of the model. MNs are sensorimotor neurons that
2 fire during both the execution and the perception of transitive actions directed
3 towards a physical target (e.g. grasping). Two negative experimental results based
4 on single-cell recording in area F5 of the monkey are worth mentioning at the
5 outset because they seem to have a counterpart in developmental psychology. On
6 the one hand, Rizzolatti *et al.* (1996) report that when a recorded monkey watched
7 a human grasp, not with his own hand, but with pliers, MNs did not fire.⁸ On
8 the other hand, Umiltà *et al.* (2001) report that when a monkey watched a human
9 agent's hand perform a pantomime of a grasping action and the animal knew that
10 there was no target, MNs did not fire either.

11 MNs were so-called because MN activity in an observer's brain was taken to
12 *mirror* (resonate with or simulate) MN activity in the agent's brain (without giving
13 rise to the observer's execution of the observed act). Action-mirroring, which
14 generates a neural similarity between an agent and an observer who comes to *share*
15 a motor representation of the action performed by the agent, was first interpreted
16 in terms of a *direct-matching* model of *action-understanding* (cf. Rizzolatti *et al.*, 2001;
17 Rizzolatti and Craighero, 2004). On this two-step model, the perception of the
18 agent's act first causes the observer to automatically map the agent's act onto
19 her own motor repertoire, i.e. to mentally rehearse the agent's act on her own
20 premotor cortex, in accordance with assumption (4) of the shared-intentionality
21 model of goal-ascription. Secondly, the mental rehearsal of the agent's act enables
22 the observer to understand 'the meaning' or *goal* of the observed act. The direct-
23 matching model of action-understanding has given rise to two kinds of critical
24 discussion, one of which was launched by a dilemma posed by Csibra (2007), while
25 the other concerns the nature of the link between mirroring and understanding an
26 agent's goal.

27 Csibra (2007) raises the following dilemma for advocates of the direct-matching
28 model: what is being mirrored by MN activity must be either the agent's movements
29 or the agent's goal, but it cannot be both at the same time. As recognized by
30 Rizzolatti and Sinigaglia (2010), at least among humans, an agent's movements do
31 not stand in a one-to-one relation to her goal: not only can an agent recruit different
32 movements in the service of a single goal, but she can also recruit one and the
33 same movement in the service of different goals. So, if what is being mapped onto
34 the observer's motor repertoire by MN activity is the agent's overt motor act (or
35 bodily movements), then it is unlikely that mirroring could deliver a representation
36 (or understanding) of the agent's goal. Conversely, if the output of mirroring is
37 a representation (or understanding) of the agent's goal, then it is unlikely to be
38 generated by the mapping of the agent's observed movements onto the observer's
39 motor repertoire.

41 ⁸ Later results showed that after active and/or observational training of the monkey, MNs in
42 area F5 do fire when either the animal performs a grasping action with pliers or observes a
43 human perform such an action (cf. Umiltà *et al.*, 2008 and Ferrari *et al.*, 2005).

1 In response, Rizzolatti and Sinigaglia (2010) choose the second horn of Csibra's
 2 dilemma: on the basis of experimental results reported by Umiltà *et al.* (2008), they
 3 argue that in the monkey brain, MN activity encodes *goals*. Umiltà *et al.* (2008)
 4 trained monkeys to grasp objects using both normal pliers and so-called 'reverse'
 5 pliers: grasping an object with normal pliers involves closing the fingers, but grasping
 6 with reverse pliers involves opening the fingers. Single cell recordings in area F5 in
 7 executive tasks by Umiltà *et al.* (2008) show that F5 neurons discharged during the
 8 same phase of grasping 'regardless of whether this involved opening or closing of
 9 the hand' (Rizzolatti and Sinigaglia, 2010, p. 266).⁹ In other words, what seems to
 10 matter to the firing of F5 neurons is the agent's goal (grasping) irrespective of the
 11 difference between the agent's closing and opening his fingers.

12 Furthermore, Rizzolatti and Sinigaglia (2010) go on to endorse a dual view of
 13 MN activity in human and non-human primates: whereas in non-human primates,
 14 only an agent's goal can be mirrored, they argue that in humans, both an agent's
 15 goal and her movements can be mirrored by MN activity in an observer's brain. As
 16 they put it, 'in the earlier studies on the mirror mechanism, it was indeed not clearly
 17 specified that the parieto-frontal mirror mechanism in humans is involved in two
 18 kinds of sensory-motor transformation—one mapping the observed movements
 19 onto the observer's own motor representation of those movements (movement
 20 mirroring), the other mapping the goal of the observed motor act onto the
 21 observer's own motor representation of that motor act (goal mirroring).'¹⁰

22 The second set of issues raised by the direct-matching model of action-
 23 understanding concerns the link between mirroring and understanding an agent's
 24 goal, which is crucial to assumptions (4) and (5) of the shared-intentionality model.
 25 In a classic paper, Rizzolatti *et al.* (2001, p. 661) drew a contrast between the
 26 direct-matching model and a purely visual analysis of an agent's action. They
 27 argued that whereas 'the results of the visual analysis of an observed action [...]'
 28 are devoid of meaning', an observer's understanding of an agent's action generated
 29 by mirroring derives its meaning from the observer's own 'motor knowledge'
 30 (about how to perform the observed action) 'because the motor representation
 31 of that action is activated in our brain'. Advocates of the direct-matching model
 32 have stressed the immediate (or non-mediated), experiential and non-conceptual
 33 (i.e. presumably non-inferential) character of the understanding of another's action
 34 provided by MN activity (cf. Gallese *et al.*, 2004). According to the latest advocacy
 35 of the direct-matching model, "although there are several mechanisms through
 36

37 ⁹ Umiltà *et al.* (2008) report the results of single-cell recordings in area F5 mostly for *executive*
 38 tasks of grasping with normal and reverse pliers, but on p. 2112 they also refer to 'an example
 39 of F5 mirror neuron recorded during grasping with tools and during the observation of the
 40 same motor act', thereby offering evidence for *mirroring* of goals.

41 ¹⁰ One crucial issue that I will not address here is whether understanding an agent's goal is
 42 generated by MN activity (i.e. mirroring of goal) or whether MN activity is itself generated
 43 and enhanced by a prior and independent process of goal understanding based on contextual
 cues, as argued by Csibra (2007) and Jacob (2008, 2009).

1 which one can understand the behavior of other individuals, the parieto-frontal
 2 mechanism is the only one that allows an individual to understand the action of
 3 others ‘from the inside’ and gives the observer a first-person grasp of the motor
 4 goals and intentions of other individuals” (Rizzolatti and Sinigaglia, 2010, p. 264).

5 Thus, on the latest version of the direct-matching model, MN activity in the
 6 monkey brain *codes* the agent’s goal. If so, then MN activity in an observer’s brain
 7 enables the observer to mirror the agent’s goal (as a result of the former’s perception
 8 of the latter’s action) and the observer forms a goal with the same content as the
 9 agent’s. Both the agent and the observer entertain the same goal, but only the agent
 10 executes an action that will achieve the goal. In accordance with the strong version
 11 of assumption (5) of the shared-intentionality model of goal-ascription, sharing the
 12 agent’s goal is sufficient for the observer to understand and thereby to ascribe it to
 13 the agent.¹¹

14 What advocates of the mirroring view of goal-understanding (i.e. the strong
 15 version of assumption (5) of the shared-intentionality model) seem to overlook,
 16 however, is the gap between *having* a goal and *ascribing* a goal. Mirroring an agent’s
 17 goal could at best causally enhance an observer’s ascription of a goal to the agent,
 18 but it could not constitute such an ascription.¹² To mirror another’s goal is *to have*
 19 a goal. As stressed by Jeannerod (1999, 2006), not all individuals who form goals
 20 become agents: many of an individual’s goals may remain unfulfilled. But whether
 21 or not an individual’s goal is fulfilled, sharing a goal is having a goal and having
 22 a goal is not ascribing a goal to another. Ascribing a goal to an agent consists
 23 in forming a *belief* (or *judgment*) about an agent that he or she has a goal or is
 24 performing some goal-directed action.¹³ There is a crucial difference between the
 25 psychological *attitude* of forming a goal and that of ascribing a goal: to form a goal
 26 is to mentally represent an act that will bring about a change from one state of
 27 affairs to another. Having a goal is to be directly motivated to act: goals have a
 28 *world-to-mind* direction of fit (they can be satisfied or frustrated, but neither true or
 29 false).¹⁴ By contrast, by ascribing a goal, one is not directly motivated to act: to
 30 ascribe a goal to an agent is to form a *belief* (or *judgment*) whose content is that the
 31 agent has a determinate goal. Like other beliefs and judgments, goal-ascriptions have
 32 a *mind-to-world* direction of fit (they can be true or false).¹⁵ Furthermore, a creature
 33 can arguably form a goal, perform goal-directed actions and be an agent, whether
 34 or not she possesses the *concept* GOAL.¹⁶ However, I assume that one could not
 35

36
 37 ¹¹ If, as recognized by advocates of the direct-matching model, there are other ways of
 38 understanding an agent’s goal, then sharing another’s goal might not be necessary.

39 ¹² This is the weak version of assumption (5) of the shared-intentionality model.

40 ¹³ This distinction is clearly drawn by Goldman (2009).

41 ¹⁴ See Section 2 for a further discussion of what it takes to form a goal.

42 ¹⁵ On the distinction between the mind-to-world and the world-to-mind directions of fit, cf.
 43 Anscombe, 1957; Searle, 1983; and Jacob and Jeannerod, 2003.

¹⁶ Words in capital letters refer to the concepts of the psychological states whose meanings they
 express.

	necessary to possess concept GOAL?	motivating	truth- conditional	world- to-mind direction of fit	mind- to-world direction of fit
having/sharing a goal	–	+	–	+	–
ascribing a goal	+	–	+	–	+

Table 1 *Difference between the psychological attitude of forming a goal and that of ascribing a goal.*

ascribe a goal to some agent, i.e. form a *belief* or *judgment* that an agent has some goal or other, unless one possessed and deployed (or used) the concept GOAL. (These distinctions are summarized in Table 1.) Having outlined the main assumptions of the shared-intentionality model and some of the issues it raises, I now turn to developmental evidence for assumptions (1)–(3) of the shared-intentionality model of goal-ascription.

2. Choice-Based and Imitation-Based Evidence for the Shared-Intentionality Model

The shared-intentionality model derives much empirical support from experiments conducted within both the violation-of-expectation framework and the so-called ‘imitation’ framework. I start with the former. What I call the choice-based paradigm derives from a series of experiments reported by Woodward (1998, 1999). In an initial phase of the experiments, after being presented with two toys (e.g. a teddy bear on the left and a ball on the right), 9-, 6- and 5-month-old infants were habituated to seeing a human hand in a grasping posture repeatedly reach for, and rest on, one of the two toys (e.g. the teddy bear). During the test trials, the toys’ spatial positions were switched and the infants saw the human hand reach for and rest on either the same toy as before (i.e. the teddy bear) or the other toy (i.e. the ball). The aim was to test whether preverbal human infants were more surprised by the agent’s changing her target (new toy event) or her path (new side event). Woodward (1998) reports that 9-, 6- and even 5-month-olds looked reliably longer at the new target (old side) event than at the old target (new side) event, indicating that they expected the target to remain the same.

However, when the human hand was replaced by either an inanimate rod topped with a sponge or a mechanical claw, infants did not look longer at the new rather than the old target (Woodward, 1998).¹⁷ Similarly, the asymmetry between looking

¹⁷ On the face of it, these negative results are reminiscent of early reports of single cell recording in the monkey showing that MNs in area F5 do not fire in response to a grasping action performed by a human with pliers (cf. Rizzolatti *et al.*, 1996).

1 longer at the new than the old target also broke down when instead of a human
 2 hand in a grasping posture, infants saw the back of a human hand in a non-grasping
 3 posture repeatedly drop on the same toy (Woodward, 1999).¹⁸ In accordance
 4 with assumptions (1)–(3) of the shared-intentionality model, these results strongly
 5 suggest that preverbal human infants' early goal-ascriptions are biased in favor of
 6 human-like agents who perform executable actions (that the observer can map onto
 7 her own motor repertoire).

8 Choice-based experiments conducted within the so-called 'imitation' paradigm
 9 yield similar results.¹⁹ *Covert* imitation is at the heart of the shared-intentionality
 10 model of goal-ascription: according to assumptions (4) and (5) of the model,
 11 seeing an agent perform a goal-directed action causes the observer to mentally
 12 rehearse (or *covertly imitate*) the agent's action, which in turn causes the observer
 13 to *share* the agent's goal and thereby to ascribe the goal to the agent. Now
 14 from *covert* imitation to *overt* imitation, there is only a small step.²⁰ In a pair
 15 of so-called 'imitation' studies reported by Hamlin *et al.* (2008), after being pre-
 16 sented with twelve toys, 7-month-olds saw a human agent sitting in front of a
 17 pair of the toys. In the first study, the infants saw the agent either contralater-
 18 ally reach-and-grasp one of the two toys or ipsilaterally place the back of her
 19 hand onto one of them. Then the infants were invited to choose one of the
 20 toys. Infants systematically selected the toy that had been the target of a grasp-
 21 ing action, not a back-of-the-hand action. In a second study, infants saw the
 22 agent either perform an unfulfilled reach-and-grasp action directed towards one
 23 of the two toys or point to one of them. When invited to choose one of the
 24 two toys, the infants were reliably more likely to select the toy that had been
 25 the target of the failed reach-and-grasp action rather than of the pointing act.
 26 These 'imitation' studies seem to corroborate both the positive and the nega-
 27 tive results reported by Woodward (1998, 1999) in the violation-of-expectation
 28 framework.

29 In the first of another pair of so-called 'imitation' studies reported by Mahajan
 30 and Woodward (2009), after being familiarized with sixteen different toys, 7-
 31 month-olds saw the experimenter's face above a barrier made of black foam with
 32 a concealed opening in it through which she could either move her own hand or
 33 move a box towards one of a pair of toys. (Before seeing either the hand or the
 34 box action, infants were given evidence that the box was self-propelled.) When
 35 invited to choose one of the two toys, infants in the hand condition chose the
 36 target significantly more often than infants in the box condition. In order to test
 37 for the possible effect of the presence of the experimenter's head above either
 38

39 ¹⁸ Also on the face of it, this negative result seems similar to the result of a single cell recording
 40 experiment in the monkey showing that MNs in area F5 do not fire in response to a pantomime
 41 of grasping when the animal knows that there is no target (cf. Umiltà *et al.*, 2001).

42 ¹⁹ As I shall argue shortly, I don't think that what the relevant experiments test are infants'
 43 imitative capacities.

44 ²⁰ For relevant further discussion, see Gergely, 2007.

1 her hand or the box, Mahajan and Woodward (2009) designed a second study in
 2 which infants saw the same hand and box actions as before, but the experimenter's
 3 head was fully occluded. As in the previous study, infants were more likely to
 4 select the target toy of the hand action than of the box action. Again both of
 5 Mahajan and Woodward's (2009) 'imitation' studies seem to corroborate both
 6 the positive and the negative results reported by Woodward (1998, 1999) in the
 7 violation-of-expectation framework.²¹

8 Because they accept assumptions (4) and (5) of the shared-intentionality model,
 9 Hamlin *et al.* (2008) and Mahajan and Woodward (2009) are inclined to interpret
 10 their findings as evidence that infants selectively *imitate the goal* (or the goal-
 11 relevant aspects) of an agent's observed action. This interpretation presupposes that
 12 infants can determine what the agent's goal is. However, Hamlin *et al.* (2008)
 13 and Mahajan and Woodward (2009) seem to overlook what it takes both for an
 14 agent to form a goal and for an observer to determine the agent's goal. In simple
 15 cases, goal-directed actions are directed at some target. Whereas *targets* can be
 16 simple physical objects, *goals* are complex mental representations, involving three
 17 representational components. In the simplest cases, to form a goal is to mentally
 18 represent (i) an *actual* state of affairs \underline{S}_1 , e.g. a piece of food \underline{T} (for target) resting
 19 on a plate at time t , (ii) a *possible* (non-actual) state affairs \underline{S}_2 , e.g. \underline{T} 's being
 20 in one's mouth at $t+1$, and (iii) an *action* that can bridge the gap between \underline{S}_1
 21 and \underline{S}_2 . What is common to \underline{S}_1 and \underline{S}_2 is \underline{T} (the target); what distinguishes \underline{S}_1
 22 from \underline{S}_2 is one of \underline{T} 's properties, i.e. its spatial position. The represented action
 23 (e.g. the agent's reaching-and-grasping \underline{T} , followed by arm-flexion towards the
 24 agent's mouth) is a representation of the means by which the agent plans to
 25 achieve her goal by turning \underline{S}_1 into \underline{S}_2 , i.e. by causing a change in \underline{T} 's spatial
 26 position.

27 So it is one thing to argue that the agent's choice between two targets is evidence
 28 that her action is goal-directed. It is quite another to claim that this evidence
 29 is sufficient to determine the agent's goal. In fact, in all the studies conducted
 30 within the Woodward choice-based paradigm, the agent's goal is considerably
 31 underdetermined, because the agent reaches for the target in a grasping posture
 32 but does not remove the target, thus leaving the initial state of affairs unchanged
 33 (cf. Section 5 for further discussion). An alternative way of interpreting the findings
 34 of both Hamlin *et al.* (2008) and Mahajan and Woodward (2009) is that the
 35 model's *preference* for one of the two toys cues the infant's own *preference*. On this
 36 interpretation, the model's preference will only cue the infant's if the agent selects
 37 a means-action that is in accordance with the representation of her action as being
 38 goal-directed (e.g. if she reaches for the target with her hand in a grasping posture,
 39 not with the back of her hand).
 40
 41

42 ²¹ The occlusion of the experimenter's head was meant to match Luo and Baillargeon's (2005)
 43 design, to be further discussed in Section 3.

3. Choice-Based Evidence Against the Shared-Intentionality Model

On the face of it, the shared-intentionality model derives support from both Woodward's (1998, 1999) positive and negative results. In accordance with the shared-intentionality model, the positive results have been interpreted as showing that preverbal human infants have a direct and immediate understanding of an agent's goal when the agent e.g. repeatedly reaches for one of two toys with her hand in a grasping posture. The negative results also seem to corroborate the model by showing that preverbal human infants do not represent the motions of an inanimate rod or a mechanical claw as goal-directed (and thus cannot *share* their goals), because they are neither perceptually nor motorically human-like. Nor do infants seem to represent the dropping of the back of a human hand onto a toy as goal-directed, because it is not a familiar motoric means of performing a grasping action.

However, not all developmental psychologists subscribe to the shared-intentionality model of goal-ascription. An alternative is the 'teleological stance' model. Unlike advocates of the shared-intentionality model, advocates of the teleological stance model make no assumption about the primacy of infants' familiarity with actions performed by human agents in shaping their ability to ascribe goals. Instead, at the heart of Csibra and Gergely's (1998) and Gergely and Csibra's (2003) teleological stance model is the fundamental assumption that humans are endowed with a ternary computational system that parses an agent's action into three basic components: the agent's *goal*, the *means* selected by the agent for achieving her goal and the situational *constraint* (e.g. an environmental obstacle) faced by the agent. Advocates of the teleological stance model have offered evidence showing that the above ternary system enables preverbal human infants to compute any one of the three components from the other two. They can compute an agent's means-action from a prior representation of both the agent's goal and the constraints faced by the agent. They can compute an agent's goal from a prior representation of both the constraints faced by the agent and the agent's selected means-action. Finally, they can compute the constraints faced by the agent from a prior representation of both the agent's goal and the agent's means-action (cf. Gergely and Csibra, 2003).

Advocates of the teleological stance model have emphasized the contribution of at least two sorts of further cues to infants' goal-ascription. While Premack (1990) argued that the agent's motion must be *self-propelled* (Premack, 1990), Csibra *et al.* (1999) and Biro *et al.* (2007) have argued that this is only a weak cue of goal-directedness. In addition, the agent's action must cause a *novel outcome* or bring about a change from one state of affairs to another (Király *et al.*, 2003; Biro and Leslie, 2007). And the agent must also give evidence that it can produce *equifinal variations* of its behavior: that is, given that the outcome (i.e. final step) of the agent's action is constant, the agent must give evidence of its ability to adapt its behavior in response to environmental changes or changes in situational constraints (Király *et al.*, 2003; Biro and Leslie, 2007). For example, given that an agent expresses a

1 behavioral preference for one of a pair of toys, the agent will accordingly vary the
2 trajectory of its motion depending on changes of the toy's spatial location.²²

3 Two of Woodward's (1998, 1999) basic negative results have been revisited
4 by advocates of the teleological stance model. In the habituation trials of Király
5 *et al.*'s (2003) choice-based experiment, 10-, 8- and 6-month-olds were presented
6 with two toys, one on the right of a stage, the other on the left. Then they saw
7 the back of a human hand repeatedly approach the toy on the left and displace
8 it from its initial position to a new position (towards the back of the stage). In
9 the test trials, the spatial positions of the toys were switched and infants saw the
10 back-of-the-hand action displace either the new toy or the old toy towards the
11 back of the stage. Király *et al.* (2003) report that 10- and 8-month-olds looked
12 reliably longer at the back-of-the-hand action upon the new toy (old side) than
13 upon the old toy (new side). Using exactly the same design, Jovanovic *et al.*
14 (2007) report that 6-month-olds also looked reliably longer at the back-of-the-hand
15 action upon the new toy (old side) than upon the old toy (new side). Woodward
16 (1999) interpreted the failure of 6- and 9-month-olds to ascribe a goal to an
17 agent performing a back-of-the-hand action onto an object in terms of the infants'
18 unfamiliarity with this type of hand-action. But as Király *et al.* (2003) point out,
19 in Woodward's (1998, 1999) seminal choice-based paradigm, one fundamental
20 outcome of a typical goal-directed grasping action is missing: namely, the target's
21 change of spatial position (or displacement). After an agent reaches for and grasps a
22 target, typically her hand does not rest on the target: rather the target is moved to
23 a novel position. In effect, what Király *et al.* (2003) and Jovanovic *et al.* (2007) did
24 was to provide infants in both habituation and test trials with the missing ingredient
25 of a normal grasping action from Woodward's (1998, 1999) experimental paradigm:
26 the back-of-the-hand action *displaced* its target. When the missing ingredient was
27 restored, 9- and 6-month-olds gave evidence of representing the back-of-the-hand
28 action as goal-directed.

29 Biro and Leslie (2007) report the results of a set of four experiments that cast new
30 light on Woodward's (1998, 1999) negative result with the inanimate rod: these
31 experiments explore the putative impact of adding two cues of goal-directedness to
32 the action of an inanimate rod on a designated target: a salient outcome or change of
33 the target's spatial position, and the rod's displaying equifinal variations of behavior.
34 The familiarization conditions in all four experiments included a presentation of
35 two toys: a ball on the left and a teddy bear on the right. In the familiarization trials
36 of the first experiment, 12-, 9- and 6-month-olds were divided into two groups:
37 half the infants of each age were assigned to the 'poking hand' condition and half
38 to the 'poking tube' condition. In the former, infants saw the experimenter's hand
39

40 ²² Because Csibra and Gergely (1998), Gergely (2007) and Gergely and Csibra (2003) stress the
41 fact that the teleological representation of an agent's action is reality-based (i.e. non-mentalistic),
42 they emphasize the role of an agent's goal-state, i.e. the physical outcome of the agent's action,
43 in the content of the teleological representation.

1 (with her index finger extended) poke one and the same toy (i.e. the ball) ten
2 times. In the latter condition, they saw an inanimate wooden tube (or rod) poke
3 one and the same toy (i.e. the ball) ten times. After four familiarization trials, the
4 toys' positions were switched, and in the test trials, half the infants in the poking
5 hand condition saw the hand poke the same toy again at a different location and
6 half saw the hand poke the new toy at the old location. Half the infants in the
7 poking tube condition saw the tube poke the old toy at a new location and half
8 saw the tube poke the new toy at the old location. Infants in all three age groups
9 in the poking hand condition looked reliably longer at the new toy event than at
10 the old toy event. The results were less clear-cut for infants in the poking tube
11 condition (especially for the 9-month-olds). Perhaps the poking tube action was
12 less interesting than the poking hand action. Perhaps the equifinal variations of
13 behavior were less effectively displayed by the poking tube than by the poking
14 hand.

15 In the second experiment, the tube could lift the toys by means of pieces of
16 Velcro attached to them. In the familiarization condition of the second experiment,
17 infants in the same three age groups as in the first experiment were first presented
18 with an inanimate rod that demonstrated self-propelledness by freely moving
19 around and changing its path in a random fashion. Then the infants saw the tube
20 lift up and then replace one of the toys. In the test trials, the toys' positions
21 were switched and infants saw the tube touch (without lifting) either the same
22 toy or a new toy. Only the 12-month-olds looked reliably longer at the new
23 toy (old location) event. The 9-month-olds also looked longer at this event, but
24 the difference was not significant. The 6-month-olds looked equally at the two
25 events.

26 The stimuli in the third experiment were the same as those in the second
27 experiment, with one important exception: in the test trials, the tube not only
28 touched but also lifted up either the same toy as in the familiarization trials or the
29 new toy. In the third experiment, Biro and Leslie (2007) only tested 9- and 6-month
30 olds: 9-month-olds looked reliably longer at new toy events, but 6-month-olds
31 looked equally at both the new and the old toy events.

32 The familiarization trials in the fourth experiment were like those in the third
33 experiment with one important exception: now Velcro pieces were attached to the
34 top, front and back of both toys. As a result, the tube was able to display new cues
35 of equifinal behavior by approaching the target toy from three different angles and
36 picking it up by sticking to three different parts of the designated toy. The test
37 trials were similar to those in the third experiment: this time, 6-month-olds looked
38 reliably longer at new toy events. Thus, 6-month-olds seem to represent the action
39 of an inanimate rod as goal-directed if provided with information about the novelty
40 of the outcome of the rod's action on the object in both the familiarization and the
41 test trials and also with strong cues of equifinal variations of the rod's behavior in
42 the familiarization condition. Importantly, both the target's change of position and
43 the cues of the rod's equifinal variations of behavior were missing in Woodward's
(1998) experimental design.

1 Luo and Baillargeon (2005) also re-examined Woodward's (1998, 1999) negative
2 results. In their first experiment, which involved a box covered with green paper,
3 they compared two conditions: the experimental and the control conditions. The
4 familiarization trials in both conditions were preceded by an 'orientation event'
5 during which 5-month-olds saw the box give evidence of being self-propelled by
6 moving back and forth at the center of the apparatus floor. In both conditions,
7 infants received four familiarization trials. During the familiarization trials in the
8 experimental condition, the infants were presented with a cylinder on the left and
9 a cone on the right and then they saw the box repeatedly move to the right and
10 contact the cone. During the two test trials in the experimental condition, the cone
11 and the cylinder switched positions and the infants saw the box move towards and
12 contact either the cylinder (new target and old side event) or the cone (old target
13 and new side event). During the familiarization trials in the control condition, the
14 infants were presented with only a single object, i.e. the cone on the right, and
15 they saw the box move towards and contact the cone. During the two test trials in
16 the control condition, the cone and the cylinder were (as in the test trials of the
17 experimental condition) respectively on the left and the right and (just as in the
18 experimental condition) the infants saw the box move towards and contact either
19 the cylinder (new target and old side event) or the cone (old target and new side
20 event). In the experimental condition, 5-month-olds looked reliably longer at the
21 new target event than at the old target event, but in the control condition, they
22 looked equally at both events.

23 The result of Luo and Baillargeon's (2005) first experiment are difficult to
24 reconcile with the basic assumptions of the shared-intentionality model, which
25 predicts that 5-month-olds should not represent the behavior of a box as goal-
26 directed on the grounds that a box is perceptually and motorically very unlike
27 a human agent. Arguably, the orientation event played an important role in
28 providing infants with cues that the box was a self-propelled agent—cues that
29 were absent from Woodward's (1998) experiment with either the inanimate rod
30 or the mechanical claw. If so, then the question still arises: why did Mahajan and
31 Woodward (2009) find that 7-month-olds' choice of a toy was cued by the choice
32 of a human hand, but not of a box? Arguably, two distinguishing features may
33 account for the different experimental results. First, Mahajan and Woodward (2009)
34 familiarized the infants with the targets, but not with seeing repeated actions of the
35 box directed towards one of a single pair of targets, as did Luo and Baillargeon
36 (2005). Secondly, the cues of the box's self-propelledness contained in a separate
37 orientation event might have been richer in Luo and Baillargeon's (2005) than in
38 Mahajan and Woodward's (2009) experiment.

39 Importantly, the contrast between the experimental and the control conditions
40 in Luo and Baillargeon's (2005) first experiment corroborates the role of choice
41 information in the infants' representation of the displacements of the self-propelled
42 box as goal-directed: the fact that, in the control condition, 5-month-olds were
43 familiarized with a self-propelled box that repeatedly contacted the same object
(i.e. the cone) when there was no competing target was not sufficient to cause

1 them to expect the box to continue to contact the same object in the presence
 2 of a competing target. In the control condition, where no choice information was
 3 presented in the familiarization trials, the question arises whether infants represent
 4 the action of the box as directed towards the goal of contacting the cone and
 5 whether, lacking choice information, they did not rule out the possibility that the
 6 box could change its goal in the presence of a new target. I shall return to this
 7 issue at the end of the next section, in which I review some further developmental
 8 evidence against the model, based on experiments focusing on efficiency rather
 9 than choice.

12 4. Single-Target-Efficiency-Based Evidence Against 13 the Shared-Intentionality Model

14 Advocates of the teleological stance model have designed another experimental
 15 paradigm for exploring the conditions in which preverbal human infants represent
 16 an agent's action as goal-directed. I call this paradigm the single-target-efficiency
 17 paradigm. In this paradigm, exemplified by Gergely *et al.*'s (1995) and Csibra *et al.*'s
 18 (1999) experiments, preverbal human infants are provided with cues of efficiency
 19 about the means selected by an agent for performing a goal-directed action on a
 20 single target.

21 12- and 9-month-olds were divided into two groups: the 'rational action'
 22 (or experimental) group and the 'non-rational action' (or control) group. In the
 23 habituation trials for both groups, infants first saw a large circle on the left and a small
 24 circle on the right: first, they saw the large circle expand, contract and regain its
 25 original size. Then they saw the small circle perform a similar expansion-contraction
 26 sequence. The difference between the habituation trials for each group was that,
 27 in the rational action group, infants saw a rectangle located midway between the
 28 two circles, whereas in the non-rational action group, infants saw the rectangle on
 29 the right of the small circle. Finally, they saw the smaller circle move in a parabolic
 30 trajectory from right to left and land next to the larger circle. In the rational action
 31 condition, the presence of the rectangle midway between the two circles could
 32 be perceived as constraining the leftwards motion of the small circle; but in the
 33 non-rational action condition, the rectangle was located to the right, not the left,
 34 of the small circle. In the test trials, the rectangle was removed and infants in both
 35 conditions saw the small circle either travel through the same parabolic trajectory as
 36 before (old action) or move in a straight line (new action), until it reached the large
 37 circle. Infants of both ages in the rational action group looked reliably longer at the
 38 old action than at the new action. Infants in the non-rational action group did not.

39 On the one hand, it seems as if the removal of the situational constraint (i.e.
 40 the rectangle) was sufficient to trigger the infants' expectation that the agent (i.e.
 41 the small circle) would select the shortest (most efficient) path to achieve its goal
 42 (i.e. reach the large circle). Even though infants in the experimental condition had
 43 already seen the small circle move in a parabolic trajectory when a rectangle was

1 located on its left, they showed more surprise when, in the absence of the rectangle,
 2 it re-enacted the same trajectory than when it moved in a straight line. On the other
 3 hand, only if they had been habituated to seeing the agent's parabolic trajectory in
 4 the constraining presence of the rectangle did infants expect the agent to select the
 5 shortest (most efficient) path.²³

6 Kamewari *et al.* (2005) have further explored the relative contributions of
 7 efficiency cues and the agent's human-like perceptual appearance to infants' capacity
 8 to reason about goals. They performed three experiments with videos displaying
 9 the actions of a human agent, a humanoid robotic agent and a box, in each of
 10 which 6.5-month-olds were divided into an experimental and a control group. In
 11 the habituation trials for each experiment, infants in the experimental group saw an
 12 agent take a detour around an obstacle (a box) before reaching his target (another
 13 box); but in the control group, infants saw the same agent take a detour without a
 14 constraining obstacle. In test trials, infants in both groups saw the agent either take a
 15 detour or move in a straight line, in the absence of any obstacle. When the agent was
 16 either a human or a humanoid robot, infants in the experimental condition looked
 17 reliably longer at the detour path event than at the straight path event, but infants
 18 in the control condition did not. When the agent was the box, infants of neither
 19 condition did. Kamewari *et al.* (2005, p. 319) conclude that 'around 6 months old,
 20 initial understanding of goal-directed action is teleological, being simultaneously
 21 influenced by certain perceptual features of actions or knowledge about the agents'.

22 Interestingly, as Csibra (2008) has noticed, when the agent was the box, but not
 23 when the agent was either a human or a humanoid robot, infants in the control
 24 group looked significantly longer at the straight path event than at the detour path
 25 event. Arguably, as Csibra (2008) further emphasizes, in the habituation trials in
 26 Kamewari *et al.*'s (2005) experiment, the box reproduced exactly the same motions
 27 on each trial, displaying no equifinal variation in its behavior—as in Gergely *et al.*
 28 (1995) and Csibra *et al.* (1999)—and fewer cues of self-propelledness than in Luo
 29 and Baillargeon's (2005) orientation events. This lack of equifinal variation and poor
 30 cues of self-propelledness may have caused the surprise of 6.5-month-olds when they
 31 saw the box change path and move in a rectilinear efficient path in the test condition.

32 To test the potential role of cues of equifinal behavioral variations in goal-
 33 ascription within the single-target-efficiency paradigm, Csibra (2008) compared
 34 6.5-month-olds' responses to two conditions: the single route and the variable
 35 route conditions. In both conditions, he divided the infants into an experimental
 36 and a control group. In the single route condition, infants from the experimental
 37 group were habituated (as in Kamewari *et al.*, 2005) to seeing a moving box make
 38 a detour around an obstacle and move towards a target (another box). Infants
 39 from the control group were habituated to seeing an agent box make a detour

41 ²³ Interestingly, Rochat *et al.* (2008) report that macaque monkeys also look reliably longer at
 42 the less efficient of a pair of familiar grasping actions (experiment 1), but not if the displayed
 43 action is unfamiliar (experiment 3).

1 without any obstacle and move towards another non-moving box. In the variable
2 route condition, infants from the experimental group were habituated (unlike in
3 Kamewari *et al.*, 2005) to seeing a moving box make a variable detour, i.e. by
4 turning sometimes left, sometimes right, around an obstacle, and move towards a
5 target (i.e. another non-moving box). In the test trials of both conditions, infants
6 saw the moving box either make a detour or go straight towards the target box
7 without any obstacle. In the single route condition, 6.5-month-olds from either
8 the experimental or the control group did not look reliably longer at the detour
9 path event than the single path straight path event. In the variable route condition,
10 infants from the experimental group did, but infants from the control group did not.

11 Further experiments in the single-target-efficiency paradigm by Southgate *et al.*
12 (2008) corroborate the crucial role of efficiency cues in infants' goal-ascriptions.
13 Southgate *et al.* (2008) divided 6- to 8-month-olds into an experimental and a
14 control group. Infants in the experimental group were familiarized with seeing
15 a video showing a human hand perform a two-step goal-directed action during
16 which the hand removed a box lying in its path before it retrieved a target. In the
17 control group, infants were familiarized with seeing a video showing a human hand
18 inefficiently remove a box that did not lie in its path before retrieving a target. In the
19 test trials, infants in both groups saw a human hand perform either the same hand
20 action as infants in the experimental group had seen during the familiarization trials,
21 or a biologically impossible but more efficient action whereby it retrieved the target
22 by snaking around the obstacles. Infants in the experimental group, but not infants in
23 the control group, looked reliably longer at the biologically possible but less efficient
24 hand-action than at the more efficient but biologically impossible hand-action. This
25 last result suggests that cues of efficiency act as a potent guide to goal-ascription
26 by preverbal human infants. Moreover it is also difficult to accommodate within
27 the shared-intentionality model because it further suggests that infants' ability to
28 make use of efficiency cues for goal-ascription may precede, and even override,
29 their expectations about the contrast between biologically possible and impossible
30 human actions, based on perceptual and motor familiarity with human agents (in
31 accordance with the first three assumptions of the model).

32 That the use of efficiency cues may precede and override choice information
33 is also strongly suggested by results reported by Biro and Verschoor (2008), who
34 compared the responses of 9- and 7-month-olds in three conditions. In the
35 familiarization events of the 'efficient goal condition', infants saw a human hand
36 reach through the side of the stage, remove the lid of one of a pair of boxes
37 (each of which contained a toy) and grasp the toy inside. In the familiarization
38 events of the 'non-efficient goal condition 1', infants saw the hand remove the lid
39 of one of the boxes before grasping one of the toys, but this time the toys were
40 in front of, not inside, the box. In the familiarization events of the 'non-efficient
41 goal condition 2', no box was present and the hand performed a mime of lifting
42 the lid of an absent box before grasping one of the two toys. In the test trials of
43 all conditions, the positions of the toys were switched and infants saw the human
hand grasp either the old toy (at a new location) or a new toy (at an old location).

1 Biro and Verschoor (2008) report that in the efficient goal condition, both 9- and
2 7-month-olds looked reliably longer at the new toy (old location) event than at
3 the old toy (new location) event; but they did not in either of the non-efficient
4 conditions. If so, then efficiency cues override preference information.

5 Further evidence against the shared-intentionality model has recently been
6 adduced by Luo (2011), who has adapted the control condition of Luo and Bail-
7 largeon's (2005) first experiment. In her first experiment, Luo (2011) replicated
8 the contrasting results obtained by Luo and Baillargeon in their experimental and
9 control conditions, but with 3-month-olds: in the experimental, but not the control
10 condition, infants had choice information about a box repeatedly contacting one of
11 two targets. Like 5-month-olds, 3-month-olds looked reliably longer at the box's
12 new target action than the old target action in the experimental condition, but not
13 in the control condition.

14 During the familiarization trials of her novel second experiment, Luo (2011)
15 offered 3-month-olds cues of both self-propelledness and equifinal variations of
16 the agent's behavior in the single-target-efficiency paradigm: after an orientation
17 event in which a box gave evidence of being self-propelled, infants saw the box
18 repeatedly contact a single target (without any competing target) by adapting the
19 direction of its motion (from right to left and vice-versa) to the target's changing
20 spatial position. In the test trials, infants saw the box contact either the same target
21 (old target action) or a new target (new target action). 3-month-olds looked reliably
22 longer at new rather than old target actions.

23 To sum up, by adding cues of equifinal variations of a box's behavior (which were
24 missing from the experiment by Kamewari *et al.* 2005), Csibra (2008) showed that
25 6.5-month-olds ascribe a goal to a moving box that makes a variable detour around
26 an obstacle lying on its path towards its target. Southgate *et al.* (2008) strongly
27 suggest that the ability of 6- to 8-month-olds to make use of efficiency cues for
28 goal-ascription precedes and even overrides their expectations about biologically
29 possible human hand actions. Taken all together, the experimental results of Luo
30 and Baillargeon (2005) and Luo (2011) show that 3-month-olds are disposed to
31 ascribe a goal to a self-propelled box if either of two requirements is met: if the
32 box displays either choice information (about one of two competing targets) or
33 equifinal variations of behavior (by adapting the direction of its displacements to the
34 target's changing positions). Clearly, given the absence of perceptual and motoric
35 likeness between a moving box and either a human agent or her bodily parts, none
36 of these goal-ascriptions to a self-propelled box could have been predicted by the
37 shared-intentionality model.

38 As Luo and Baillargeon (2005) and Luo (2011) show, 5- and 3-month-olds do
39 not look longer at a new target action performed by a self-propelled box if they are
40 not provided with either choice information or cues of equifinal variations of the
41 box's behavior. So the question arises: would the perceptual and motoric familiarity
42 of preverbal human infants with human hand actions dispose them to represent a
43 human hand action as goal-directed in the absence of both choice information and
44 cues of equifinal variations of the hand's action? In fact, the preliminary question

1 arises of how (in the control condition) infants represent the action of the self-
2 propelled box towards a single target when they lack both choice information and
3 cues of equifinal variations of behavior.

4 According to Luo and Baillargeon's (2005, pp. 604-5) own interpretation, 'they
5 (a) categorized the box as an agent, (b) interpreted the box's actions during famil-
6 iarization as directed toward the goal of contacting the cone, and (c) recognized
7 that the box might change its goal and hence its actions after the cylinder was
8 introduced'. On this interpretation, infants do represent the box's action towards a
9 target as goal-directed, but lacking choice information in the familiarization trials,
10 they simply suspend their judgment on the box's goal when a second target is intro-
11 duced in the test trials. In other words, preference information (provided to infants
12 in the experimental group, but not in the control group) could be said to modulate
13 goal-ascription. However, the results of Luo's (2011) second experiment somewhat
14 weaken Luo and Baillargeon's (2005) interpretation, since by introducing cues of
15 equifinal variations of the box's behavior without introducing any choice informa-
16 tion, Luo (2011) caused 3-month-olds to look longer at a new target action than at an
17 old target action performed by the box. According to an alternative interpretation,
18 the very fact that infants do not look longer at a new target action performed by a
19 self-propelled box if they are not provided with either choice information or cues of
20 equifinal variations shows that they fail to represent the box's action as goal-directed.

21 Further evidence reported by Hernik and Southgate (submitted) is relevant to
22 the question of how infants represent the action of a self-propelled box directed
23 towards a single target, and to assessing Luo and Baillargeon's (2005) claim that in
24 the absence of a competing target, infants do represent the action of a box towards
25 a single target as goal-directed, but simply suspend judgment on the box's goal
26 when a second target is introduced in the test trials. Hernik and Southgate divided
27 9-month-olds into an experimental and a control group. In the familiarization trials,
28 infants in the experimental group saw a box take a detour around a wall in order to
29 contact a target located behind the wall on its left side. Infants in the control group
30 saw a box contact a target by making the same detour without any obstacle. Then
31 during the 'orientation trials', infants from the experimental group saw two targets
32 behind a wall, one of which was the same as in the familiarization trial, but now on
33 the right side of the wall. Infants from the control group saw two targets (without
34 any wall), one of which was the same, but not in the same spatial position, as in
35 the familiarization trials. Finally, infants from the experimental group saw the box
36 perform either a new target (old path) action or a new path (old target) action in
37 the presence of the wall. Infants from the control group saw the box perform either
38 a new target (old path) action or a new path (old target) action in the absence of
39 the wall. Hernik and Southgate (submitted) report that infants in the experimental
40 group, but not in the control group, looked reliably longer at new target (old path)
41 than new path (old target) actions of the box.

42 These results suggest that cues of efficiency in the absence of choice information
43 were sufficient to allow goal-attribution to the box by infants in the experimental
44 group. But they also suggest that lacking both preference information and efficiency

1 cues, infants in the control group might simply have failed to represent the action
 2 of the box as goal-directed. If so, then contrary to Luo and Baillargeon's (2005)
 3 interpretation of their own first experiment, the fact that infants from the control
 4 group saw the box perform a simple action of contacting a target during the
 5 familiarization trials did not cause them to ascribe a goal to the box. It would
 6 follow that preference information (made available during the familiarization trials
 7 to infants in the experimental group, but not in the control group) cannot modulate
 8 goal-ascription for the simple reason that, lacking both efficiency cues and choice
 9 information, infants in the control group did not attribute a goal to the box.

10 On the face of it, a simple hand action directed towards a target should be
 11 perceptually and motorically far more familiar to human infants than the action
 12 of a box. The question arises whether human infants are disposed to represent a
 13 human hand action as goal-directed in the absence of both choice information and
 14 cues of equifinal variations of the hand's action. Clearly, the shared-intentionality
 15 model should lead us to expect a positive answer to the question. However, this
 16 expectation is not supported by results of experiments performed by Biro *et al.*
 17 (submitted) on 12-month-old human infants, whose responses Biro *et al.* compared
 18 in three conditions. In the familiarization trials of the 'efficient action' condition,
 19 infants saw a human hand first open a transparent box and grasp a teddy bear
 20 located inside the box. In the familiarization trials of the 'non-efficient action'
 21 condition, infants saw the human hand perform the same action as in the efficient
 22 action condition, but the teddy bear was in front of (not inside) the box. In the
 23 familiarization trials of the 'simple action' condition, there was no box and infants
 24 saw the hand simply grasp the teddy bear. In all three conditions, the grasping hand
 25 came out of an opening in a wall to the right of the scene and the teddy bear
 26 was located near the wall. Then in the pre-test condition, all infants saw the teddy
 27 bear now on the left and another toy on the right. Finally, in the test trials, all
 28 infants saw the human hand either move along the same path and grasp a new toy
 29 or move along a new path and grasp the same teddy bear. Biro *et al.* (submitted)
 30 report that in the efficient action condition, infants looked reliably longer at the
 31 new toy (old path) action than at the old toy (new path) event, whereas in the
 32 non-efficient condition or the simple action condition, they did not. In accordance
 33 with assumptions (1)–(3) of the shared-intentionality model, it might have been
 34 expected that, in the absence of choice information and cues of efficiency, preverbal
 35 human infants would still represent a simple hand action, unlike the action of a box,
 36 as goal-directed. But the results of Biro *et al.*'s (submitted) experiment contradict
 37 this expectation.

39 5. Why Should Performing Goal-Directed Actions Help Infants 40 to Ascribe Goals To Others?

41
 42 Arguably, the shared-intentionality model derives support from further experiments
 43 also within the choice-based paradigm, reported by Sommerville and Woodward

1 (2005). In the habituation condition of the first study, 12-month-olds were
2 presented with a pair of toys sitting on different-colored cloths: e.g. a duck on a
3 yellow cloth and a tortoise on a blue cloth. The infants were habituated to seeing
4 a human agent repeatedly pull the yellow cloth and retrieve the duck. In the test
5 trials, the toys' positions were switched so that the duck now sat on the blue cloth
6 and the tortoise on the yellow cloth. Infants saw the human agent either retrieve
7 the same toy (i.e. the duck) by pulling the new (blue) cloth or the new toy (i.e. the
8 tortoise) by pulling the old (yellow) cloth. 12-month-olds looked reliably longer
9 at new toy (old cloth) trials than at new cloth (old toy) trials, indicating that they
10 interpreted the cloth pulling as a means selected by the agent to achieve her goal of
11 retrieving one of the two toys. In the same conditions, however, 10-month-olds
12 as a group did not look longer at the new toy (old cloth) trials than the new cloth
13 (old toy) trials.

14 Sommerville and Woodward (2005) also report the results of a second study
15 designed to investigate the impact of infants' first-person motor experience upon
16 their ability to understand means-end goal-directed actions performed by others.
17 Sommerville and Woodward (2005) found that ten-month-olds who were able to
18 *produce* more well-organized means-end actions looked reliably longer at new toy
19 (old cloth) trials than at new cloth (old toy) trials. Similarly, Sommerville *et al.*
20 (2005) report that as a group, 10-month-olds, who had been habituated to seeing
21 a human agent repeatedly retrieve one of two toys by pulling a cane with her
22 right hand, did not look longer in the test trials when the human agent pulled
23 the same cane with her right hand to retrieve a new toy than when she pulled
24 a novel cane with her left hand to retrieve the old toy. However, they report
25 that 10-month-olds who had been *actively trained* to use a cane to retrieve an
26 out-of-reach toy did look reliably longer at new toy (old cane) trials than at new
27 cane (old toy) trials.

28 Sommerville *et al.* (2005) report that, after being habituated to seeing a human
29 hand in a grasping position repeatedly reach for, and rest on, one of two toys,
30 3-month-olds, unlike 5-month-olds, did not look longer at new toy (same side)
31 trials than at old toy (new side) trials. 3-month-olds also happen to be unable to
32 accurately reach and grasp objects. Sommerville *et al.* (2005) supplied 3-month-olds
33 with Velcro mittens that enabled them to accurately grasp objects. They divided
34 3-month-olds into two groups: the reach-first group and the watch-first group.
35 While infants in the reach-first group were allowed to reach for objects (with
36 Velcro mittens) before being habituated to seeing a human hand in a grasping
37 posture repeatedly reach for and rest on one of two toys, infants in the watch-first
38 group were presented with habituation trials before being allowed to reach for
39 and grasp objects. Sommerville *et al.* (2005) found that whereas infants in the
40 watch-first group did not look longer at new toy (old side) events than at old
41 toy (new side) events, infants in the reach-first group did so reliably. Sommerville
42 *et al.* (2005) also report that infants in the reach-first condition looked significantly
43 longer on the first habituation trial than infants in the watch-first condition,
suggesting that their own preceding motor experience enhanced their attention to

1 another's goal-directed action. Furthermore, Gerson and Woodward (submitted)
 2 report that unlike 3-month-olds who were given the opportunity to execute (with
 3 Velcro mittens) grasping actions (active training), 3-month-olds who were given
 4 the opportunity to observe others grasp toys (observational training) did not look
 5 longer at new toy than old toy events (cf. Woodward *et al.*, 2009). As Rochat
 6 *et al.* (2008, p. 231) describe these findings, 'motor familiarity, but not perceptual
 7 familiarity, influences the capacity of 3-month-old infants to extract goals from
 8 observed action'.

9 Thus, the insistence of the shared-intentionality model on the role of infants'
 10 motor experience in goal-ascription seems vindicated. Moreover, as mentioned
 11 above, some of Woodward's (1998, 1999) negative behavioral results in human
 12 infants seem to mirror some of the negative results of single-cell recording in area
 13 F5 of the monkey. It is therefore not surprising that advocates of the shared-
 14 intentionality model have turned to mirroring (or MN activity) as a likely neural
 15 mechanism linking the execution and perception of action. As Hamlin *et al.* (2008)
 16 write, 'it has been proposed that [these] mirror representations exist early in life and
 17 play a role in development [...] Consistent with this proposal, recent experiments
 18 have documented relations between infants' ability to produce well-organized goal-
 19 directed actions and their comprehension of others' actions as goal-directed [...] These two abilities are correlated [...] and interventions that alter infants' action
 20 production affect their subsequent perception of others' actions'.²⁴

21 Sommerville *et al.* (2005) provide convincing evidence that, unlike 3-month-olds
 22 who cannot accurately grasp objects, 3-month-olds who were enabled to accurately
 23 grasp a toy using Velcro mittens looked longer at new target (old side) than at
 24 old target (new side) actions. Thus, first-personal motor experience of reaching
 25 and grasping helps human infants to represent others' actions as goal-directed. This
 26 result seems to call for a mechanism able to couple the execution of grasping actions
 27 and the perception of grasping actions performed by others. However, as I will now
 28 argue, for two converging reasons MN activity is not likely to be the mechanism
 29 that accounts for why motor experience promotes infants' understanding of others'
 30 goal-directed actions, as exemplified in Sommerville *et al.* (2005).

31 Consider first the surprising result reported by Biro *et al.* (submitted) in their
 32 simple action condition (discussed at the end of Section 4). MN activity is elicited
 33 in non-human primates by the perception of simple hand actions directed towards
 34 a target. So MN activity should be elicited in human infants by the perception of
 35 a simple hand action directed towards a single target. If so, then it would seem to
 36 be predicted by the shared-intentionality model that when infants are familiarized
 37 with seeing simple hand actions repeatedly directed towards a single target (e.g. a
 38 teddy bear), they should represent the hand action as being goal-directed. In other
 39 words, infants in the simple action condition of Biro *et al.* (submitted) should look
 40 longer at new target than at old target hand actions. But Biro *et al.* (submitted)

41

42

43 ²⁴ Cf. Del Giudice *et al.*, 2009.

1 report that they do not. So on the assumption that MN activity is being elicited
2 in 12-month-olds in the simple action condition of Biro *et al.* (submitted), their
3 negative result suggests that MN activity does not underlie infants' goal-ascription
4 as tested in the violation-of-expectation paradigm by comparing new target and
5 new path events.

6 I now turn to Sommerville *et al.*'s (2005) finding about the role of infants'
7 motor experience in facilitating their representation of others' actions as goal-
8 directed. Arguably, MN activity could be involved in the intervention stage
9 of Sommerville *et al.*'s (2005) experiments when they enable infants to execute
10 grasping by providing them with Velcro mittens. Indeed, MN activity has been
11 shown to be elicited in monkeys by both the execution and the perception of
12 hand actions directed towards a target. However, it is highly unlikely that MN
13 activity is also at work in either the habituation/familiarization trials or the test
14 trials of Sommerville *et al.*'s (2005) experiment. In accordance with Woodward's
15 (1998) choice-based paradigm, what Sommerville *et al.* (2005) take as evidence
16 for the representation of an agent's action as goal-directed is the fact that after
17 being habituated to (or familiarized with) seeing an agent repeatedly choose
18 one of two targets, infants are more surprised by a new target event than by
19 a new path event. MN activity could be the common neural mechanism that
20 accounts for why motor experience enhances infants' representation of others'
21 actions as goal-directed only if it were at work during both the execution of
22 grasping actions by infants and their perception of a human hand that repeatedly
23 chooses one of two targets in the habituation/familiarization trials. But there is
24 no evidence for the assumption that the perception of an agent's choice between
25 two competing targets should elicit MN activity in either the agent's or the
26 observer's brain.

27 If MN activity is not the mechanism coupling infants' execution of grasping
28 actions and their perception of another's hand repeatedly choosing one of two
29 targets, then what explains the role of infants' motor experience in goal attribution?
30 Arguably, what the execution of acts of grasping (made possible by the use of
31 Velcro mittens) may provide 3-month-olds with is *outcome* information, missing
32 from their perception of the actions performed by others in Woodward's choice-
33 based paradigm, in which the hand reaches its target in a grasping posture without
34 lifting it. Moreover, as reported by Gerson and Woodward (submitted), only infants
35 involved in active training, not in observational training, looked longer at new toy
36 events than old toy events. So the question is: what relevant information is being
37 carried by the execution of an act of grasping a toy that is not carried by observing
38 the same act executed by another? Arguably, whereas observing an act of grasping
39 provides the observer with purely visual information about the target's displacement,
40 executing an act of grasping a toy also provides an infant with proprioceptive, haptic
41 and perhaps even efference copy information about the outcome of the action. If
42 so, then the evidence for the role of motor experience in infants' capacity to reason
43 about goals is also evidence for asymmetry, rather than symmetry, between being
an agent and being the observer of an action performed by another.

1 Concluding Remarks

2
3 In Sections 3–4 of this paper, I have reviewed developmental evidence that is
4 hard to square with assumptions (1)–(3) of the shared-intentionality model, which
5 claims that the early capacity of human infants to reason about an agent's goals
6 is shaped by the human-like perceptual appearance of the agent and the fact that
7 the agent's motor act falls within the infant's motor repertoire. In Sections 1 and
8 2, I have argued on conceptual and empirical grounds that assumptions (4) and
9 (5) of the shared-intentionality model overlook both the complexity intrinsic to the
10 mental representation of a goal and the gap between having and ascribing a goal.
11 In Section 5, I have further argued that the developmental evidence showing that
12 infants' motor experience enhances their ability to reason about goals should not
13 be interpreted as evidence for the role of MN activity in goal-ascription by human
14 infants.

15 As I argued in Sections 3–4, the evidence does not seem to vindicate the
16 crucial role assigned to the perceptual and motoric interpersonal likeness between
17 infants and the observed agents of goal-directed actions by advocates of the
18 shared-intentionality model. However, there is another dimension of interpersonal
19 similarity between an infant and an agent of a goal-directed action that seems to
20 be overlooked by advocates of the shared-intentionality model of goal-attribution.
21 Suppose that, as predicted by the shared-intentionality model, when preverbal
22 human infants see an agent efficiently perform a goal directed-action, they come to
23 share the agent's goal. If so, then, like an efficient agent, they must have the ability
24 to form goals, even if they still lack the capacity to perform the action efficiently. (It
25 is one thing to lack the executive capacity for efficient action. It is another to lack
26 the capacity to represent and process information about the efficiency of an action
27 performed by another.) In that case, they must be able to conceptually represent
28 an action as an efficient means towards bridging the gap between two states of
29 affairs (cf. Section 2). This conceptual ability would still fall short of possession of
30 the concept GOAL (cf. Section 1). However, by giving evidence that they can not
31 only form goals but also reason about goals and ascribe a goal to an agent (i.e. form
32 beliefs or judgments about the goals of others), it follows from my arguments in
33 Section 1 that infants also give evidence that they possess a (rudimentary) concept
34 GOAL.

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