Lecture 02 : A Puzzle about Understanding Action : Origins of Mind

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Monday, 18th January 2021

Contents

1. When Do Humans First Track Goals?

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When do human infants first track goal-directed actions and not just movements? A variety of evidence suggests that the answer is, from around three months and certainly by 9 months of age.

In this lecture, my overall aim is to convince you that there is a puzzle about the ontogenetic development of goal tracking in humans. But I'm starting with (what appears to be) a very simple question …

When do human infants first track goal-directed actions rather than mere movements only?

I take for granted that goals are not intentions. The former are outcomes to which an action could be directed, whereas the latter are mental states. Since I focus on pure goal-tracking, I also assume that:

> 'intention attribution and action understanding are two separable processes' (Uithol & Paulus 2014, p. 617).

On the basis of a habituation experiemnt, Woodward et al. (2001, p. 153) claim that

> 'Six-month-olds and 9-month-olds showed a stronger novelty response (i.e., looked longer) on new-goal trials than on new-path trials (Woodward 1998). That is, like toddlers, young infants selectively attended to and remembered the features of the event that were relevant to the actor's goal.'

But is this justified? Suppose we distinguish targets from goals. Then we can ask whether infants are merely tracking targets (and not otherwise tracking goals). And since Woodward (1998) does not vary the goal other than by varying the target, findings from that experiment cannot answer this question.

Other experiments do involve manipulating not just the targets of actions but (also) the types of action (Behne et al. 2005; Ambrosini et al. 2013). I therefore tenatively conculde that infants can track goals from nine months of age (or earlier).

The next question is, How do they do this?

2. The Teleological Stance

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How do infants (and perhaps adults) identify the goals of observed actions? The leading, best developed proposal is Gergely and Csibra's Teleological Stance (Gergely et al. 1995; Csibra & Gergely 2007; Gergely & Csibra 2003).

Csibra & Gergely (1998, p. 255) characterise the 'Teleological Stance' as exploiting this principle to track goals:

> 'an action can be explained by a goal state if, and only if, it is seen as the most justifiable action towards that goal state that is available within the constraints of reality'

This implies that tracking goals is the reverse of planning an action.

Planning is the process of moving from goals to means, whereas tracking goes in the reverse direction, from means to goals. But what is common to the two is the relation between means and goals. In both cases, planning and goal-tracking, the means that are adopted should be a best available way of bringing the goal about.

Note that this is not exactly an answer to our question, How can infants track goals from nine months of age (or earlier)? It provides what Marr would call a computational description.

2.1. The Simple View

To answer that question, we need to combine the Teleological Stance with a hypothesis about the representations and algorithms which are involved in pure goal-tracking.

One hypothesis is the Simple View of goal tracking:

> Infants' (and adults') goal tracking depends on beliefs concerning relations which hold quite generally between means and goals; and they identify particular goals by making inferences from these beliefs plus their observations.

I'm uncertain whether Csibra et al would endorse the Simple View. But there are some places where they appear to come close:

> 'when taking the teleological stance one-year-olds apply the same inferential principle of rational action that drives everyday mentalistic reasoning about intentional actions in adults' (Gergely & Csibra 2003; compare Csibra et al. 2003, Csibra & Gergely 1998, p. 259)

> 'Such calculations require detailed knowledge of biomechanical factors that determine the motion capabilities and energy expenditure of agents. However, in the absence of such knowledge,

> one can appeal to heuristics that approximate the results of these calculations on the basis of knowledge in other domains that is certainly available to young infants' (Csibra & Gergely 2013).

However, at another point they could be interpreted as stepping back from the Simple View (Csibra & Gergely 2007, pp. 72–4). There is also no clear reason for them to accept the Simple View: their overall theoretical position is consistent with it, but does not appear to require its truth.

Irrespective of who (if anyone) endorses it, the Simple View is a good starting point for at least three reasons. First, it involves postulating no novel psychological states, processes or systems. (It does not entail the existence of a goal-tracking module, for example.) Second, there are cases in which it is known to apply (you and I can work through an application of the Teleological Stance explicitly, writing down each step). Third, there are no published, suitably detailed accounts of any alternative.

3. Limits on Infant Goal Tracking

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Infants' pure goal-tracking appears to be subject to a striking limit: in their first nine months of life, they can only track the goals of an action if they can perform a similar enough action around the time the action occurs. The existence of this limit is a fact that stands in need of explanation.

Infants' pure goal-tracking appears to be subject to a striking limit:

> Infants in their first nine months of life can only track the goals of an action if they can perform a *similar enough*[1] action around the time the action occurs.

What evidence supports the claim that this limit exists?

3.1. Evidence from Observations of Proactive Gaze: Background

To understand the evidence, it is helpful helpful to step back and first consider something interesting about adults when they perform, and when they observe, actions. In performing actions—stacking blocks, say—you do not look at your hand but at the block it will pick up, or, when holding a block,

[1] I stipulate that two actions are *similar enough in a context* if they are either both of the same kind (for example, both reaching actions) or else similar enough that the differences make no difference for the purposes of goal tracking in that context. For example, reaching and pre-reaching are similar enough in many contexts.

at the location where it will place a block. In acting, our eyes move just ahead of the action. Flanagan & Johansson (2003) showed that the same pattern occurs when adults observe another agent acting. In observing an action, the eyes move just ahead of the action. Such proactive eye movements have been used to measure goal tracking in adults (e.g. Ambrosini et al. 2011).

3.2. Evidence from Observations of Proactive Gaze

3.2.1. Background

When observing a hand that is approaching some objects and about to grasp one of them, infants will, like adults, often look to the target of the action in advance on the hand arriving there (Falck-Ytter et al. 2006). As in the case of adults, we may take this proactive gaze to be evidence of goal tracking. But the occurrence of this proactive gaze in infants is related to their own abilities to represent the observed actions motorically. To a first approximation, we might say that for those infants who are not yet able to reach, their eyes do not arrive on an object to be grasped in advance of the hand grasping it (Kanakogi & Itakura 2011).

3.2.2. Evidence of Limits

If we consider proactive gaze for different kinds of observed actions (such as various kinds of grasping actions or putting objects into containers), we find that infants' gaze to the target of an action becomes more proactive as they become able perform the particular kind of action observed (Ambrosini et al. 2013; Cannon et al. 2012 (who studied 12-month-olds)).

In adults, tying the hands impairs proactive gaze (Ambrosini et al. 2012); in infants, boosting grasping with 'sticky mittens' facilitates proactive gaze (Woodward 2009; see also Sommerville et al. 2005; Sommerville et al. 2008; Ambrosini et al. 2013; Skerry et al. 2013).

Further evidence comes from studies which compare reaching bodies with nonbodily events (Kanakogi & Itakura 2011; Cannon & Woodward 2012 Adam et al. 2016).

3.2.3. Other sources

It is also possible to find links between action ability and goal tracking using habituation rather than anticipatory looking (Sommerville & Woodward 2005).

3.2.4. At the time the action occurs

None of the evidence considered so far bears on *when* infants must represent actions motorically. To establish the above limit, we need studies in which infants' abilities to act are temporarily impaired or enhanced.

Bruderer et al. (2015) temporarily impaired six-month-olds' abilities to act in one of two ways by getting them to suck either a tongue-constraining dummy or a lip-constraining dummy. They found a corresponding effect on infants' abilities to track actions.

4. Mirror Neurons

Lecturer: Richard Moore

5. The Motor Theory of Goal Tracking

Lecturer: Stephen A. Butterfill

According to the Motor Theory of Goal Tracking, in humans, some pure goal-tracking processes involve only motor processes and representations. This Theory supports a conjecture about development: In the first nine months of life, all pure goal-tracking is explained by the Motor Theory. Other goal-tracking processes emerge later in development.

According to the Motor Theory, infants' (and adults') pure goal-tracking sometimes depends on the double life of motor processes (see Sinigaglia & Butterfill 2015 for details).

More carefully the Motor Theory of Goal Tracking} depends on four claims:

1. in action observation, possible outcomes of observed actions are represented motorically;
2. these representations trigger motor processes much as if the observer were performing actions directed to the outcomes;
3. such processes generates predictions;
4. a triggering representation is weakened if the predictions it generates fail.

The result is that, often enough, the only only outcomes to which the observed action is a means are represented strongly. motor processes occur in action observation partly because the means-ends computations they enable are the core part of a goal-tracking process.

5.1. The Developmental Motor Conjecture

This conjecture states that:

> in the first nine months of life, all pure goal tracking is explained by the Motor Theory. Other goal-tracking processes emerge later in development.

This conjecture is inspired by Gredebäck & Falck-Ytter (2015), Hunnius & Bekkering (2014) and Woodward & Gerson (2014) among others. (These authors have interestingly different theoretical positions and would be unlikely to endorse the conjecture, for good reasons (see below). However, they all provide considerations which motivate considering this conjecture.)

This Conjecture, if true, would neatly explain why goal tracking in the first months of life is limited. But there's a problem. It is not quite true to say that infants' goal tracking is limited by their abilities to represent actions motorically.

6. A Puzzle about Goal Tracking

Lecturer: Stephen A. Butterfill

Why is some, but not all, of nine-month-olds' goal tracking limited by their abilities to represent actions motorically at the time of observing an action?

An early breakthrough by Gergely et al. (1995) demonstrates that older infants can track the goals of actions performed by geometric shapes. These include expanding, contracting and bouncing over a high wall—all things few infants can do.

These findings have been extensively replicated and extended (see Csibra 2003; Gergely & Csibra 2003 for reviews). Importantly for our purposes, much the same findings can be observed with younger, 9-month-old infants (Hernik & Southgate 2012) and even 6.5-month-old infants (Csibra 2008). Related observations indicate that even 3-month-olds may be capable of extracting goal-related information from displays involving simple geometric shapes (Luo 2011).

If we take both this evidence and also the evidence about limits mentioned in *Limits on Infant Goal Tracking* (section §3) at face value, we arrive at a puzzling conclusion:

> For infants in the first nine months of life, some, but not all, of their goal tracking is limited by their abilities to represent actions motorically in this way: they can only track the goals of

an action if they can represent a similar enough action motorically at the time the action occurs.

Why is this puzzling? We need to understand why this pattern of limits exists. But we cannot explain it by appeal to the Simple View (from *The Teleological Stance* (section §2)): that View predicts no such limits. And we cannot explain it by appeal to the Developmental Motor Conjecture (from *The Motor Theory of Goal Tracking* (section §5)), which predicts inescapable limits. So no theory of pure goal-tracking can explain earliest infants' abilities.

6.1. Appendix: Another Puzzle

Daum et al. (2012) created a modified version of Woodward's paradigm which allowed them to measure two different responses to a single scenario, anticipatory looking and dishabituation. Their modified paradigm involved cartoon fish moving in ways which infants (and probably adults too) are unlikely to represent motorically. They found evidence for goal tracking by nine-month-olds in their dishabituation responses but not in their anticipatory looking. In fact, the nine-month-olds' anticipatory looking indicated that they expected the fish to move along the same path irrespective of any more distal goal it might have; and it was only the three-year-olds (not the one- or two-year-olds) whose anticipatory looking indicated goal tracking.%

? also found evidence of goal tracking in six-month-olds' pupil dilation but not their anticipatory looking.

Why does nine-month-olds' goal tracking sometimes manifest itself in dishabituation (or pupil dilation) but not anticipatory looking?

Glossary

computational description A computational description of a system or ability specifies what the thing is for and how it achieves this. Marr (1982) distinguishes the computational description of a system from representations and algorithms and its hardware implementation. 3, 9

goal A *goal* of an action is an outcome to which it is directed. 2

habituation Habituation is used to test hypotheses about which events are interestingly different to an infant. In a habituation experiment, infants are shown an event repeatedly until it no longer holds their interest, as measured by how long they look at it. The infants are then divided into two (or more) groups and each group is shown a new event.

How much longer do they look at the new event than at the most recent presentation of the old event? This difference in looking times indicates *dishabituation*, or the reawakening of interest. Given the assumption that greater dishabituation indicates that the old and new events are more interestingly different to the infant, evidence from patterns of dishabituation can sometimes support conclusions about patterns in how similar and different events are to infants. 5

motor representation The kind of representation characteristically involved in preparing, performing and monitoring sequences of small-scale actions such as grasping, transporting and placing an object. They represent actual, possible, imagined or observed actions and their effects. 6

Principles of Object Perception These are thought to include no action at a distance, rigidity, boundedness and cohesion. 9

pure goal-tracking Tracking goals is *pure* when does not involve ascribing intentions or any other mental states. 2–4, 6, 8

representations and algorithms To specify the representations and algorithms involved in a system is to specify how the inputs and outputs are represented and how the transformation from input to output is accomplished. Marr (1982) distinguishes the representations and algorithms from the computational description of a system and its hardware implementation. 3, 8

Simple View This term is used for two thematically related claims. Concerning physical objects, the Simple View is the claim that the Principles of Object Perception are things we know or believe, and we generate expectations from these principles by a process of inference. Concerning the goals of actions, the Simple View is the claim that the principles comprising the Teleological Stance are things we know or believe, and we are able to track a goals by making inferences from these principles. 3

target The *target* or *targets* of an action (if any) are the things the towards which it is directed. 2

Teleological Stance To adopt the Teleological Stance is to exploit certain principles concerning the optimality of goal-directed actions in tracking goals (Csibra & Gergely 1998). 3

track a goal For a process to track a goal of an action is for how that process unfolds to nonaccidentally depend in some way on whether that outcome is indeed a goal of the action. For someone to track the goals of an action is for there to be processes in her which track one or more goals of that action. 2, 9

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