Behaviour reading

I. Introduction

Behaviour reading is the activity of segmenting continuous bodily movements into chunks and assembling these chunks into larger units on the basis of statistical patterns and other cues in such a way that the boundaries of the chunks correspond to the boundaries of actions. To illustrate, chunks may include reaching, tearing, poking, or orienting to an object or location; and patterns may include orienting to an object's raising the probability of reaching for it.

Behaviour reading may depend on knowledge of agents' beliefs, desires, intentions and reasons. *Pure behaviour reading* is behaviour reading in which such knowledge plays no role. Following several researchers, we assume that pure behaviour reading is possible; that is, it is possible to identify units of behaviour corresponding to actions independently of knowledge of desires, intentions and the rest (*cite).

II. Applications of behaviour reading

Behaviour reading is held to be useful or even necessary for recognising intentions (Newtson, Engquist and Bois 1977: 861; Baldwin, Baird, *et al.* 2001: 708). Behaviour reading may also have functions independently of a capacity to ascribe intentions: efficiently representing events (Kurby and Zacks 2008), discerning structure in actions in such a way as to identify their effects (Byrne 1999), and predicting either what others will do (Povinelli 2001) or when an event likely to be of interest will occur (Swallow and Zacks 2008: 121).

Behaviour reading is also thought to be important for development. Much as identifying phonemes, grouping them into word-like clusters and uncovering clause-like clusters in these patterns is held to "bootstrap" the development of linguistic comprehension (Werker and Yeung 2005), so also behaviour reading is held to be a steppingstone to understanding intentional action (Saylor, Baldwin, *et al.* 2007).

III. Speech perception as a model for behaviour reading

There is a partial analogy between perceiving speech and reading behaviour. In the case of speech, acoustic and visual stimuli are segmented into phonetic primitives (chunks), and patterns among chunks are then discerned enabling individuals to identify words (Saffran, Newport and Aslin 1996) and clauses (Soderstrom, Nelson and Jusczyk 2005) independently of any semantic knowledge.

Whereas in thinking about action understanding philosophers have tended to assume that the transition from mere bodily movements to intentional action involves a single big leap, in the case of speech there are clearly multiple steps. And there are largely independent theories about how each step is taken. Identifying clauses given that one can distinguish words is made possible by hierarchical patterns plus prosodic cues (Newport and Aslin 2004; Soderstrom, Nelson and Jusczyk 2005; Seidl and Cristià 2008). Words can be detected from phonemes by tracking transitional probabilities (Saffran, Newport and Aslin 1996). It is unclear how phonemes are identified from allophones. Finally, according to the motor theory of speech perception, the step from acoustic and visual stimuli to allophones depends on mirroring the motor cognition necessary to produce the articulatory gestures (Liberman and Mattingly 1985; Galantucci, Fowler and Turvey 2006).

On this picture of speech perception, mirroring motor cognition is responsible for the fundamental step from continuous acoustic and visual stimuli to action. The representation of allophones in motor terms provides the basic units out of which everything else is built. And the things mirroring motor cognition provides, the allophones, are already actions or goals to which actions are directed (Browman and Goldstein 1992).

I want to suggest that there are parallels between speech perception and action understanding. It's not that these two are perfectly parallel, but there are surely some some similarities between speech perception and action understanding.

In understanding action we start with mere bodily movements. These are segmented into chunks of behaviour such as grasping an object or tearing a sheet. These chunks are then grouped into word-like sequences, motor actions, which correspond to simple goal-directed actions such as grasping an object in order to drink. And at some further point actions with hierarchical intentional structures, such as playing a ball game or baking a cake, can be identified from patterns in the recurrence of the word-like units of action.

Thinking of behaviour reading on the model of speech perception, while it ignores many important differences, highlights several points. First, behaviour reading involves several layers of abstraction. Second, behaviour reading depends on segmenting movements into phoneme-like chunks of behaviour. These chunks are foundational in the sense that interpretation of behaviour depends finding patterns in ways these chunks recur. Third, these chunks are not mere bodily movements but rather categories of action.

IV. What is behaviour?

In research on speech perception there has been a debate about what it is the proper function of speech perception to track. Some researchers proposed that

the function of speech perception is to track instances of acoustic categories (*ref); others proposed that speech perception tracks articulatory gestures (Liberman and Mattingly 1985). (More exactly, the proposal is that we perceive "the intended phonic gestures of the speaker" (Liberman and Mattingly 1985: 23))

The same question arises for behaviour reading. 'Behaviour' is used as a term for intentional action, as a term for bodily movement, and in other ways besides. Which notion of behaviour is it the proper function of behaviour reading to track?

Given that behaviour reading is possible independently of ascribing intentions, the action tracked in behaviour reading should not all be characterised as intentional actions. A natural alternative is to suppose that the relevant notion of behaviour must be movements by bodies or body parts. This alternative is unacceptable, however. The power of behaviour reading depends on extracting patterns, which requires chunks that recur; and bodily movements rarely or never recur. Further, extracting patterns that are sometimes relevant to intentions requires some degree of invariance with respect to anatomical and postural differences between individual agents and environmental obstacles to action. The movements involved in achieving even the simplest goal, such as picking an apple, lack any such invariance. [*Corrado offered much more powerful considerations here in Milan.]

Comparison with speech is useful here. Phonemes are realised by different allophones on different occasions (Davenport and Hannahs 1998: 96ff.), and allophones in turn are realised by various acoustic signals (Repp and Liberman 1987; Nygaard and Pisoni 1995: 72–5). That is, phonemes are separated from acoustic and visual signals by at least two layers of abstraction. Given the requirements of recurrence and intention-relevance on behavioural chunks, they must be similarly distant from movements. Indeed, variation in many of the same factors affect both speech and action—anatomy, posture, manner of execution (e.g. fast vs. slow, loud vs. soft), and environmental impediments. Context is a further factor: the way a phonetic gesture or behavioural chunk is realised depends on neighbouring chunks (Davenport and Hannahs 1998: 130ff.; Johnson-Frey, McCarty and Keen 2004). Invariance with respect to context and the other factors requires layers of abstraction between movement and behavioural chunks. This is why the basic chunks used in behaviour reading cannot be movements.

If it is neither goal-directed action not movement, which kind of behaviour is it the function of behaviour reading to track?

A conjecture is already implicit in some work on behaviour reading: behavioural chunks are motor actions. Just as articulatory gestures are the basic units of speech perception, so it seems plausible that the basic units of behaviour reading will be motor actions of some kind.

In favour of the conjecture. Several considerations favour the conjecture that behavioural chunks are motor actions, including object- and location-directed motor actions. First, motor actions are components of intentional action, so the conjecture makes it clear how identifying patterns of them in behaviour reading could feed into understanding intentional aspects of action. Second, motor actions follow rules that are not reducible to biomechanical constraints in any straightforward way (Jeannerod 1994). For example, in grasping there are rules governing when grip size expands and contracts (Jeannerod, Arbib, *et al.* 1995). The rule-bound nature of motor actions helps to explain how they could be recognised in moving bodies. Third, the object-directed nature of some motor actions plays a key role in behaviour reading. This is partly because it allows for the identification of patterns involving objects (for example, orienting to *an object* is often followed by grasping *that object*), which is valuable because behaviours directed to the same object are likely to have interesting relations. Object-directedness is also valuable as a clue to intention, for the objects to which behaviours are directed often feature in the contents of the intentions agents are acting on. For these reasons, motor actions, particularly object-directed motor actions, are ideal as the phoneme-like chunks for behaviour reading.

Two problems for the conjecture. To explicate and defend the conjecture we need to say what a motor action is. And once we have clarified the concept of motor action we will be in a position to ask *which* motor actions are involved in behaviour reading, given that for any action the motor system contains multiple representations of it.

Having explained what motor actions are, we will then face a second problem. How are motor actions represented? To represent intentional actions as such you have to understand what an intention is, because intentional actions are actions caused by intentions (e.g. Davidson 1978 [1980]). Similarly, to represent motor actions as such you have to understand motor cognition, because motor actions just are actions produced by motor commands. This is apparently problematic for the conjecture that behavioural chunks are motor actions. For there is no independent evidence that humans or other species capable of behaviour reading understand what motor actions are. Given that behaviour readers do not represent motor actions as such, how could it be that

the proper function of behaviour reading it to track motor actions?

(It is easy to miss the force of this second problem given findings that individual neurons fire in response to motor actions. Doesn't this demonstrate that motor actions are represented? No, it shows that cells carry information about motor actions, which is defeasible evidence that some cognitive processes track motor actions. This does not entail that the individual represents those actions (Pacherie and Dokic 2006: §3).)

Solutions to both problems hinge on the existence of mirroring motor cognition.

Mirroring motor cognition solves the two problems

Mirroring motor cognition is the activation of those motor commands in the observer of an action which would be enable the observer herself to execute an action of that type. A primary function of mirroring motor cognition of action is to segment motion into behavioural chunks:

> "the behaviour observed in another individual could be seen as a sequence of simple elements or, using our terminology, of motor acts. The system of mirror neurons would provide the neural basis for recognizing and segmenting 'motor actions' into strings of discrete elements, each of which is a motor act in the observer's repertoire." (Rizzolatti, Fogassi and Gallese 2001; compare Byrne 2003).

When seeing or hearing an action motor commands are activated in the observer corresponding to those activated in the agent. This pattern of activation in the observer enables her to segment the behaviour into chunks that are motor actions. Research on which motor commands are mirrored specifies which motor actions constitute the behaviours which it is the proper function of behaviour reading to track.

The second problem was how motor actions could be tracked in behaviour reading if (as we argued) they are not represented as such. Mirroring motor cognition answers this question, and it does so without requiring representational resources. By activating her own motor system, an individual can categorise observed motor actions without reliance on representational resources over and above those involved in acting. She is thus able to track motor commands not by representing them but by activating them (Jeannerod 2001: S104). It follows that the motor actions which constitute behavioural chunks are the motor actions which are mirrored.

To illustrate this idea with an analogy, suppose you want to talk about an action you have observed. One way to do this is with a representation: if you recognise the action, you could name or describe it. Another way to introduce the action into our conversation, which does not depend on knowing what the action is, is to reproduce it. Reproduction is not representation but it can sometimes serves similar purposes. Our proposal, then, is that behaviour readers segment movements into motor actions not by representing but by reproducing (that is, mirroring) the motor commands in terms of which they are individuated (cf. Jeannerod 2001: S104).

Solving the 'which motor action' problem. The first problem in characterising behaviour reading is how to discover which motor actions constitute the primitive chunks. If the chunks are segmented by means of mirrored motor activations, one way to address this question is by asking which units are mirrored.

Massimo Gangitano and colleagues investigated this question by studying what happens when a grasping action takes an unexpected and unnatural course (2004). Their subjects observed videos in which a hand grasped a ball, except that in some conditions the hand closed half-way to the ball before re-opening. When the motor action was interrupted mid-way, motor cognition in the observer was significantly reduced or ceased. (As in (Gangitano, Mottaghy and Pascual-Leone 2001), this finding was obtained by measuring artificially stimulated motor-evoked potentials in observers.) The authors conclude that the plan for a whole motor action is mirrored and that this plan is not updated during an ongoing motor action. Accordingly we can conclude that the unit mirrored is at least as large as the plan for a motor action such as grasping.

V. Conclusion

If the motor theory of speech perception is correct, speech perception is behaviour reading in the special case where the behaviours read are phonetic gestures. The present hypothesis is a generalisation of the motor theory of speech perception, according to which phonetic gestures are identified by the simulation of motor commands for their production (Liberman and Mattingly 1985; Galantucci, Fowler and Turvey 2006).

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