

Embodied Cognition and Simulative Mindreading

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Declaration:

I declare that this dissertation was written by myself, and that the work contained herein is my own, except where explicitly stated otherwise in the text.

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Abstract

Can an embodied approach to social cognition accommodate mindreading, our ability to attribute mental states to another person? Prima facie it might not. Mindreading has been conceived in terms of what Susan Hurley calls the classical sandwich picture of the mind. On this view, perception corresponds to input from world to mind, action to output from mind to world, and cognition as sandwiched in between. It separates perception and action, and takes cognition to be central and distinct from both. Embodied cognition rejects the classical sandwich. The mind evolved to guide action, to enhance an organism's coping with the world. Perception and action and action are central to cognitive activity rather than peripheral. If mindreading is a central cognitive activity, isolated from sensorimotor processing, it's hard to see how it can have a place in an embodied account of social cognition. But at the same time it seems that a complete embodied social cognition should be able to accommodate mindreading, as it is an important social cognitive skill. The present dissertation investigates how this can be done. More specifically, it investigates whether the simulation theory of mindreading can be integrated with an embodied account of social cognition. The simulation theory of mindreading holds that one understands another not by applying a theory but by using one's own mental processes to generate information about the mental processes of the other. Even though its proponents appear to have subscribed to the classical sandwich, simulative mindreading could be a central component of an embodied social cognition.

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1 Introduction

To understand another person, that is to *imitate his feelings in ourselves*, we [...] produce the feeling in ourselves after the *effects* it exerts and displays on the other person by imitating with our own body the expression of his eyes, his voice, his bearing [...] Then a similar feeling arises in us in consequence of an ancient association between movement and sensation. (1881/1988; 156-157)¹

Friedrich Nietzsche writes that understanding another person is essentially imitating the other's feelings in oneself. By copying the other's expressions and behaviour, which are the effects of certain feelings or mental states, we evoke similar feelings in ourselves. Once we feel like the other, we understand him or her, Nietzsche suggests. As Alvin Goldman (2006) observes, Nietzsche's comment anticipates the so-called simulation theory of mindreading. Mindreading is usually defined as the ability to attribute mental states to another or oneself, or to represent someone as having mental states. According to the simulation theory, we read the mind of another person by imaginatively 'putting ourselves in the other's shoes'. To predict another person's behaviour, for example, I pretend to be in the same initial states as the other and then make the decision myself, as if I was the other person. I then predict that the outcome of my simulation is the decision that the other is going to make.

Simulation theory is not the only approach to mindreading, nor the dominant one. The most popular approach to mindreading, in both philosophy and developmental psychology, holds that we understand others by means of an internal theory of mental states and behaviour. This theory, a data structure consisting of psychological laws, is supposed to mediate between our observations of behaviour in particular circumstances and our predictions and explanations, connecting for example what *x* does with what *x* believes and what *x* desires (Ravenscroft, 2004). Simulationists deny that we rely on such a theory of mind to understand others. Instead of inferring the mental states of others on the basis of psychological laws, we can simulate their minds by pretending to be them.²

Interestingly, in the above quotation Nietzsche does not only appear as a precursor of simulation theory, but also as a precursor of the so-called embodied cognition approach. Nietzsche says that we understand the other by "imitating with our body the

¹ From Goldman (2006, p. 18).

² Many accounts of ST have a hybrid nature, and involve theoretical elements. They however take simulation to be the default mechanism to understand others and the theoretical elements involved are usually different from the psychological laws of pure theory-theory accounts.

expression of his eyes, his voice, his bearing”, and that understanding arises because of “an ancient association between movement and sensation”. The idea that the body plays an important role in cognition as well as the idea that much of cognition is grounded in sensorimotor associations are central to embodied cognition. Nietzsche, one could anachronistically suggest, anticipates an embodied simulation theory of mindreading. This paper investigates the connection between simulation theory and embodied cognition; more specifically, I want to find out whether simulative mindreading can be accommodated by embodied cognition.

Traditionally, cognitive scientists have taken the mind to be an internal information processor, mainly concerned with solving abstract problems. As Andy Clark (1997) writes, “we imagined the mind as a kind of logical reasoning device coupled with a store of explicit data – a kind of combination logic machine and filing cabinet” (p. 1). Cognition is taken to be separated and distinct from perception and action, such that perceptual and motor systems might be reasonable objects of inquiry in their own right but are not considered relevant to understanding “central” cognitive processes (Hurley, 1998). Hurley (1998; 2001; 2008) has aptly characterised this model of the mind as the *classical sandwich*: it takes “perception as input from world to mind, action as output from mind to world, and cognition as sandwiched between” (2008, p. 2). Cognition is central, and interfaces between peripheral devices for perception and action. The sandwich is classical as cognition is construed as the formal manipulation of representations in an internal domain.

Embodied cognition takes a different theoretical starting point. Cognition evolved not to solve abstract problems but, paraphrasing Andy Clark (1997), ‘to make things happen’: to guide action, to enable more effective coping with the environment. The mind is first and foremost an organ for controlling the biological body, rather than a disembodied logical reasoning device (Clark, 1997). Because perceptual and motor systems are central to adaptive behaviour in the world, proponents of embodied cognition take issue with the idea that perception and action are merely peripheral. In contrast, much of our cognitive activity appears to rely on continuous perception-action coupling with the world. Think about driving a car, working with a computer, writing on a piece of paper, or running after a ball – in all cases the task at hand depends on task-relevant input from the world and task-relevant motor behaviour from the agent, in continuous and

dynamic loops. Because of continuous interactions between perception and action, through external as well as internal feedback loops, proponents of embodied cognition also reject the idea that perception and action are independent (Hurley, 1998; Clark, 1999).

Critics of embodied cognition usually respond that even if embodied cognition is right about the importance of perception and action during some cognitive activities, there is a domain of cognition that doesn't have anything to do with sensorimotor behaviour. Hallmarks of human cognition like imagination, reflection, planning, calculating in the head, and reasoning are central cognitive activities that can be operated off-line, without any relevant input or output, they'd say. Embodied cognition might be right that sensorimotor skills are very important for acting in the world, but *real* central cognition, the kind that cognitive science was about in the first place, is separated from input-output devices. The classical sandwich, the critic would conclude, is the right model for advanced cognition.

Simulation theory and theory-theory appear to take a similar position on social cognition. Their focus has mainly been on explaining and predicting behaviour in terms of mental states (Gallagher, 2001). These mental states are considered to be hidden behind the other's behaviour, to be "unobservables" that the mindreader has to discover through central cognitive activity. Perceptions of the behaviour of the other are regarded as inputs that are fed into theory of mind modules or simulation routines. Whereas theory-theory characterises the mental operations involved as a kind of rule-based symbolic inferences, simulation is usually taken to involve the creation of pretend states that should match those of the other, the inhibition of one's own mental states, an introspective act to read one's own mental state that results after a simulation, and an inference from self to other. Reading the mind of the other is thus characterised as an intellectual affair, and sensorimotor processes are usually not mentioned. All this is reminiscent of the classical sandwich.

Proponents of embodied cognition reject the classical sandwich also for advanced cognition. As Clark (1997) writes, embodied cognition holds that "intelligence and understanding are rooted not in the presence and manipulation of explicit, language-like data structures, but in something more earthy: the tuning of basic responses to a real world that enables an embodied organism to sense, act, and survive" (p. 4). More advanced cognitive abilities should be expected to have build on or to exploit previously developed

skills for adaptive sensorimotor behaviour. In Wilson's (2002) words, "even when decoupled from the environment, the activity of the mind is grounded in mechanisms that evolved for interaction with the environment – that is, mechanisms of sensory processing and motor control" (p. 626). This idea has in recent years gained much support. There is strong evidence that offline abilities like motor and visual imagery, the use of memory, and internal problem solving are enabled by the (subpersonal) re-use of sensorimotor processes (Wilson, 2002; Hesslow, 2002; Grush, 2004; Svensson & Ziemke, 2004; Svensson, Lindblom, & Ziemke, 2007; Barsalou, 2007).

An embodied approach to social cognition would also reject the classical sandwich. Embodied cognition thus clashes with traditional theories of mindreading. One way to deal with this is to conclude that mindreading cannot be accommodated by embodied cognition; for embodied accounts of social cognition, such an activity simply doesn't take place. A less controversial approach would be to find out whether mindreading can be characterised in a way that is in accordance with an embodied approach to social cognition. I will take this latter route here. Mindreading seems to me to be an important cognitive skill that we use continuously in our daily life, and if so, it is an essential component of an embodied account of social cognition.

As said above, I will investigate whether the conceptualisation of mindreading that has been offered by simulationists –simulative mindreading– can be accommodated by embodied cognition. But why draw on the work of simulationists if these have subscribed to what might be the antithesis of embodied cognition, the classical sandwich? There are several reasons to think that the simulation theory of mindreading can be re-conceived in an embodied framework. First of all, given that one of the first simulationists, Robert Gordon, does not appear to subscribe to the classical sandwich nor deny a role for sensorimotor processes, the classical sandwich might not be essential to the simulation theory. Second, the simulation theory has been described in terms that have a ring of embodied cognition. We see that in Nietzsche's statement, for example. Gordon (1995a) compares the *hot* methodology of simulation theory with theory-theory's *cold* methodology. Whereas theory-theory describes mindreading as a rather detached, intellectual affair, simulation theory holds that mindreading exploits one's own motivational and emotional resources and one's own capacity for practical reasoning. And Lindblom & Ziemke (2008) write, going beyond just a ring that "simulation theories [...] are

good examples of more radically embodied views" (p. 7). Thirdly, in Susan Hurley's Shared Circuits Model of social cognition, which is unquestionably placed in the tradition of embodied cognition, understanding others through simulation plays a key role. Together these three reasons suggest that there could be a place for simulative mindreading in an embodied social cognition.

Mindreading without the classical sandwich will however look somewhat differently. Our minds will appear to be more open to each other. Without a classical sandwich on the side of the object, behaviour is no longer simply output from the mind. Without the sandwich on the side of the subject, perception is no longer the same as input from world to mind. And mindreading is continuous with sensorimotor processes. The consequence is that mindreading can occur in perception: I can perceive the mental states of others in their behaviour. Understanding the other's actions can take us a long way towards understanding their mental states.³

The structure of this dissertation is as follows. The next two chapters are about embodied social cognition. The first discusses pre-theoretical social cognitive skills; about how these do not sit well with the classical sandwich while confirming predictions of embodied cognition. The second draws on Hurley's Shared Circuits Model, and shows that advanced cognition does not require the classical sandwich; advanced social cognitive abilities can be rooted in sensorimotor processing as well. Finally, the fourth chapter sets out to find out whether simulative mindreading can be integrated in an embodied account of social cognition – whether simulative mindreading is embodied, so to say.⁴

³ Thanks to Julian Kiverstein for stressing this point.

⁴ In the remainder of the text, I use the word 'embodied' to refer to the theoretical approach set out in this introduction. So when I ask 'Does the simulation theory present mindreading as embodied?', I mean, 'Does the simulation theory present mindreading in a way that fits the central ideas of the embodied approach to cognition?' 'Embodied' will not be used in the trivial sense of 'implemented in a body', nor will it be used in the sense of 'is constituted by the proper body', as I do not think that a proponent of embodied cognition has to hold that every cognitive mechanism or activity depends in this strong sense on the proper body.

2 Some ideas for embodied social cognition

Embodied cognition holds that the mind's function is to enable adaptive behaviour in the world. Cognition evolved and develops for controlling an acting body, for enhancing an organism's coping with the world. This doesn't mean that every cognitive mechanism is directly involved with guiding action. But in some ultimate sense every cognitive ability must be for action; it must be, so to say, grounded in sensorimotor skills. This must also be true of social cognition, proponents of embodied cognition hold.

At first view, it might seem senseless to think of social cognition as developed for action, to approach social cognitive processes as processes that enable adaptive behaviour in the world. Reasoning about others reflectively or off-line, explaining and predicting their behaviour, has nothing to do with adaptive behaviour, one might insist. As I see it, the biologically realistic starting point of embodied cognition points out that this is not the right way to approach social cognition. Embodied cognition, with its emphasis on the continuity of cognitive mechanisms, forces us to ask ourselves how, why and what social cognitive capacities evolve in a creature that is mostly concerned with surviving in a dynamic environment. It forces us to find out how advanced social cognitive abilities can emerge from skills for basic sensorimotor behaviour in the world, from resources for perception and action.

Mechanisms that evolve 'for action' need to take account of real-world and real-time pressures. They must fit the demands of life in a dynamic and often dangerous world. But the world also provides opportunities and information that cognitive mechanisms can exploit. Embodied cognition predicts the existence of domain-specific, fast and cheap mechanisms that exploit information structures in the world (Clark, 2001; Hurley, to appear). The (relatively basic) social cognitive mechanisms that are discussed in this section bear out this prediction for social cognition. At the same time it will become clearer that the classical sandwich is an inadequate model for social cognition.

2.1 Agency detection, eye-tracking and modularity

The biggest threats that animals face come from other animals. From a designer's stance, one would thus expect animals to be equipped with a rather basic devices to quickly

detect other agents. This appears indeed to be the case. Many animals, including humans, are very skilled at distinguishing agents for non-agents.

Heider and Simmel (1944) were the first to study agency detection experimentally. They created a short movie containing interacting simple geometrical objects to investigate the perception of “apparent behavior”. To get an idea of what happens in the movie, see the following description of the first three scenes:

1. T moves toward the house [a rectangle of which part of one side could open in a door-like way], opens door, moves into the house and closes door.
2. t and c appear and move around near the door.
3. T moves out of the house toward t.
4. T and t fight, T wins: during the fight, c moves into the house.

Independent of what instructions participants received before watching the movie, they used intentional terms to describe the ‘behaviour’ of the simple geometrical objects, creating stories about love, jealousy and infidelity. The participants interpreted the objects as agents with intentions. Since this seminal study many studies have replicated these results. The fact that the geometrical objects used in the 2D animations employed in most experiments on agency detection are very simple suggests it isn’t features of the objects but of their movements that make us perceive agency.

Although the mechanism underpinning agent detection yields impressions of agency that are usually considered characteristic of higher-level cognitive processing, theorists have concluded that it has, as Scholl & Tremoulet (2000) write, the marks of a *perceptual* mechanism – it is “fairly fast, automatic, irresistible and highly stimulus-driven” (p. 299). When an object that we observe moves in a specific way – it changes its speed, or it changes its direction, for example – it is *given* to us as an agent, rather than that we have to *infer from what we perceive* that we are dealing with an agent.⁵ Stated differently, the attribution of agency to a given object does (usually) not occur by a theoretical or inferential step on behalf of the observer on the basis of what he perceives; instead, the observer directly perceives the object as an agent.

One can object that the participant reports from the simple-object-studies do not support such a conclusion, as, in the words of Mar & Macrea (2007), “individuals may not be *perceiving* intentionality, but merely reporting the observation of intentional behaviour as a result of other factors such as demand characteristics and calculated inference” (p. 112).

⁵ I use the word ‘inference’ here and in the remainder of this text as a personal-level term.

This problem has been largely circumvented by means of infant studies, which do not make use of introspective reports but of the attention time that the infant pays to cues (Mar & Macrea, 2007). Infants are able to distinguish between inanimate objects and agents on the basis of their movements (Johnson, 2003; Gallagher, 2001). Indeed, infants, as well as other animals, are skilled agent detectors even though they are presumably bad at inferences. Brain imaging studies provide some additional support for the perceptual character of agent detection: Blakemore and colleagues (2003) have shown that the detection of intentionality in studies that follow the Heider & Simmel paradigm is neurally underpinned mainly by parietal networks dedicated to complex visuo-spatial detection. Furthermore, I think we should take the phenomenology seriously here: we experience intentionality, not inferring intentionality.

The claim that agency detection is perceptual rather than inferential should not be taken to mean that there aren't underlying subpersonal functional and neuronal processes that enable agency detection. It is not my aim to re-invoke the myth of the given, that is, the idea that input from the environment is passively received from the mind. Rather, it means that (social) perception is richer than the classical sandwich predicts. The classical sandwich depicts perception as a passive process in which the world is translated into percepts that are subsequently transduced to cognitive mechanisms, where understanding obtains. As Scholl & Tremoulet (2000) point out, on such a model one would expect that the attribution of agency occurs by an inferential process *after* perception has provided the necessary data to central cognitive mechanisms. The findings on agency detection do not support this view, as they suggest that the attribution of agency seems to occur already in perception; others are *presented to us* as agents, in a personal-level sense, rather than that we have to infer from what we perceive that they are agents. Scholl & Tremoulet (2002) suggest that this shows that the visual processing that takes place in perceptual modules is more elaborate than was previously supposed. Such a response allows them to uphold a firm distinction between perception, cognition and action; processing that was thought to occur in cognitive modules turns out to take place in perceptual modules.

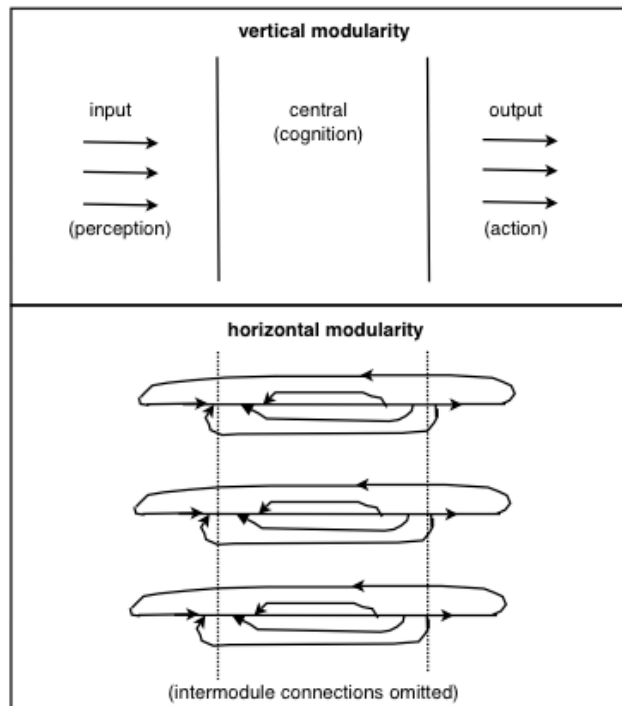


Figure 1: vertical versus horizontal modularity.
Adapted from Hurley (1998, p. 407).

The findings can however also be interpreted as suggesting that the strict separation of perception, cognition and action needs to be relaxed. Proponents of embodied cognition tend to adhere to a horizontally modular model of the mind, rather than a vertically modular view like the classical sandwich (see figure 1) (Hurley, 1998; 2001). On such a view, the mind's architecture consists of content-specific subpersonal modules or layers that loop through sensory and motor processes (as well as through the environment). Horizontal modules are dedicated to tasks, rather than to broad functions, in contrast to the vertical modules in the classical sandwich model. Each subpersonal layer is a complete input-output loop that is essentially continuous and dynamic, in the sense that it involves external as well as internal feedback.

As Susan Hurley has stressed in many of her writings, a horizontally modular picture does not, in contrast to the classical sandwich, presuppose isomorphism between subpersonal and personal levels (Hurley, 1998; 2001). The distinction between the personal level and the subpersonal level is a distinction between descriptions of contentful actions and mental states of *persons* and informational or neural descriptions. The subpersonal level of description is the level of information-processing and of dynamic causal interactions within the organism and between organism and environment (Hurley, 2008).

But, as many philosophers have stressed, such processes are not correctly attributed to persons. Persons see, want, think and act; they do not integrate visual information into objects, extract semantic information from signs, or execute motor signals. Although subpersonal descriptions explain how personal-level phenomena become possible or, to use Hurley's term for this, how they are *enabled*, they by no means need to share structure with personal-level descriptions. Perception and action do not map respectively on input and output, but can depend on complex relations between input and output. This means, among other things, that, with the right feedback relations in place, motor and extra-sensory processes can play a role in perception.

What does this mean for the detection of agency? On a horizontally modular model of the mind, agency might be perceived directly by the organism, even though subpersonal cognitive processing outside of visual areas is involved; the enabling subpersonal dynamics does not need to respect traditional boundaries between sensory, cognitive and motor processes. Admittedly, for agency detection the choice between 'smart' perceptual modules and horizontal modules isn't straightforward, but other social cognitive mechanisms, we'll see below, are better accommodated by a horizontally modular view than by the classical sandwich. What is important for now is that the findings on agency detection show that perception is richer than the classical sandwich predicts – complex social phenomena like agency are perceived rather than that they have to be inferred in a later processing stage through central cognitive processes.

In the introduction we saw that embodied cognition holds that evolution and development tend to select cognitive mechanisms that are domain-specific, highly reactive and environmentally driven. Special purpose routines and heuristics will enhance an organism's coping with a real-time environment for cheap as they enable the mind to make maximal use of the structure of information in the environment (Clark, 2001). The discussed mechanism of agent detection clearly fits the bill. It responds to specific movements that are characteristic of those of biological agents, but not to those characteristic of non-animate objects. It does so automatically and irresistibly, without requiring effort on the side of the observing agent.

Once something has been detected as an agent, it would –for many animals, in many circumstances– be helpful to learn more about the detected agent. A basic mechanism that appears to play an important role in gathering information about the

other is eye-tracking. Humans, as well as many other animals, have a strong disposition to focus on the eyes when observing another. Infants show a preference for faces and respond in a distinctive way to human faces, different from how they respond to other objects (Tomasello et al., 2005). Infants as young as 2 months look almost as long at the other's eyes as they look at the other's whole face, but spend significantly less time at other parts of the face (Maurer, 1985). Such a face-and-eye focus makes perfect sense from the current perspective on cognition, as these areas tend to provide information that one wants to gather as quickly as possible, like information about the other's intentions and emotions. Furthermore, following the gaze of another allows the child to see (1) that the other person is looking in a certain direction and (2) that the other person sees what she is looking at (Baron-Cohen, 1995; Gallagher, 2001).

Some researchers (e.g. Baron-Cohen (1995)) suggest that an inference is required to understand that an observed person actually *sees* what she is looking at. The infant needs to develop a theoretical understanding of the difference between seeing and not-seeing, on the basis of its own experience, and to generalise this understanding to other agents by means of analogy. Gallagher (2001) convincingly argues that such an inference is unnecessary: "on the face of it, that is, at a primary (default) level of experience, there does not seem to be an extra step between looking at something and seeing it" (p. 89). Before learning that someone can be looking in a certain direction and not seeing something that is located in that direction, the child does not differentiate between looking at and seeing. Just as an infant can distinguish agents from non-agents without any inferential capacities, it pre-inferentially knows that the other can see what she is looking at.

Eye-tracking is a domain-specific mechanism that works fast, automatically, and effortlessly, and is thus the kind of special-purpose mechanism that embodied cognition predicts. Because of this character, Baron-Cohen (1995) has argued that it must be enabled by a perceptual module, a specialised part of the human visual system, just as Scholl & Tremoulet (2000) suggested that intentionality detection is enabled by a perceptual module. However, eye-tracking seems not only to involve activity of the visual system, but also activity of the motor system: the observer detects the eyes of the other, and follows the other's gaze, by means of eye movements, to find out what they are directed at. The subpersonal processes that enable eye-tracking seem thus to include a complete input-output loop, wherein eye movements are effects of sensory input from the environment

(i.e. the eyes of the other) as well as causes for new sensory input (i.e. what the other is looking at). As we saw, such distributed mechanisms are predicted by a horizontally modular model of the mind. In contrast, as a vertically modular model separates perception from action, and posits that they need to be mediated by distinct cognitive processes, it is unclear how the classical sandwich accounts for eye-tracking.

2.2 Perceiving intentions and emotions

The next step in the development of useful social cognitive mechanisms, after being able to detect other agents and being able to see what they're seeing, would be the capacity to discern what drives their behaviour – to learn about their mental states. An approaching animal that intends to eat with you should be responded to differently than an animal that intends to eat you. Reading the emotions of another can help you to appraise events (I might not have seen the tiger that you did see), and enables us to respond better to the other's needs (if someone you try to approach looks scared you know that some initial comforting is required). Clearly, it would for many animals be adaptive to be able to understand another's intentions and emotions quickly and effortlessly. As information about the emotions and intentions of others is required as fast as possible in a dynamic and potentially hostile environment, embodied cognition predicts domain-specific, automatic, irresistible and environment-driven processing.⁶

There is converging and convincing evidence for the existence of such mechanisms. Humans are, from a very early age onwards, skilled at understanding the actions and intentions of others. Infant-studies show that by 10 months of age, infants (or rather, their brains) divide streams of continuous behaviour into units that correspond to what we would recognise as separate goal-directed acts (Baldwin & Baird, 2001). 9 to 18 months old infants show more impatience when an adult keeps a toy for himself than when he was making a good effort to give it over, even though failing to do so (Tomasello, Carpenter, Call, Behne, & Moll, 2005). Infants of 9 months are able to distinguish purposeful from accidental actions, and by 14-15 months they tend to imitate the former but not the latter (Carpenter, Akhtar & Tomasello, 1998). Infants of that age can also, at least sometimes, discern the intention of another's failed action as testified by them going on to

⁶ Although analytically intentions appear to be closely related to beliefs and desires, it seem to be possible to represent someone's intention without representing his beliefs and desires (Jacob & Jeannerod, 2005).

re-enact a successful version of that action (Meltzoff, 2005). Given that 9 to 12 months infants already understand the basics of goal-directed action, it seems implausible that theory of mind or an explicit use of inferences play a role here, as these abilities are supposed to develop years later.⁷

The posture, movements, (facial) expressions and gestures of others provides besides information about intentions also information about their emotions. As with intentions, we can discern these from an early age. Gopnik and Meltzoff (1997) found, for example, that infants by their second or third month already “vocalize and gesture in a way that seems ‘tuned’ [affectively and temporally] to the vocalizations and gestures of the other person” (p. 131).⁸ Moore, Hobson and Lee (1997), using actors with point-lights attached to various body joints, report that subjects are able to identify emotions in a darkened room, apparently only on the basis of their movements.

In recent years, much research has been done to understand the mechanisms that enable the understanding of actions and emotions. As the choice to discuss them in one section suggests, there is an interesting similarity between the two. Both our understanding of the emotions of others and our understanding of their actions appears to depend a functional process that is usually called *mirroring*.

Keysers & Craighero (2006) observe that often when we see someone else undergoing an emotion it feels like we share this state with the other. For example, we often experiences sadness ourselves when we see another person cry. This feeling, Keysers & Craighero (2006) argue, is more or less correct: when observing an emotion occurring to another, it is re-activated or mirrored in ourselves. At least to some extent the behavioural and physiological responses that are peculiar to particular emotions or sensations occur also when merely observing them in others (Preston & De Waal, 2002, p.14). Moreover, brain areas involved with the experience of particular emotions become active when we observe others undergoing emotions of that type. Concerning disgust, it has been found that the insula is involved both with feeling disgusted by something and perceiving disgust in someone else. Not only does the insula light up in fMRI studies both when experiencing disgust and observing someone else being disgusted (Wicker et al., 2003);

⁷ Let me note that it is plausible that the ability to perceive intentions builds on the earlier developed skills for agent detection and eye-tracking. Understanding an agent’s intentions presupposes the observer’s understanding of her as an agent as well as the observer’s understanding of her as seeing things, like objects to which she has goals, obstacles to potential goals, and results of actions (Tomasello et al., 2005)

⁸ Cited from Gallagher (2001, p. 90).

people with a damaged insula lose both their ability to experience disgust as well as to recognise it in others (Calder et al., 2000; Adolphs et al., 2003). The intensity of the activation of the insular cortex is proportional to the degree of disgust observed (Rizzolatti & Sinigaglia, 2008). Similarly findings have been reported concerning fear and the amygdala: it is active both when participants are experiencing fear and when recognising fear in others, and both capacities are impaired when the amygdala is damaged.⁹ A paired deficit in emotion production and (face-based) recognition has also been found for anger (Goldman, 2006).

The evidence on shared circuits for emotions suggests that we understand the emotions of others through a functional process that is usually called *mirroring* (Keysers & Craighero, 2006; Goldman, 2006; Rizzolatti & Sinigaglia, 2008). When we observe someone exhibiting the signs related to a particular emotion, emotional circuits that are active when we have that type of emotion ourselves are *re-used*. Through such re-activation of our own relevant emotional circuits, visual stimuli appear to be coded in a more meaningful way (Rizzolatti & Sinigaglia, 2008). This doesn't mean that we couldn't learn how to identify emotions in others without the insula, or without shared circuits, Rizzolatti & Sinigaglia (2008) stress. But, quoting William James, they argue that our perception of emotions would be reduced to a perception "purely cognitive in form, pale, colourless, destitute of emotional warmth" (p. 189).¹⁰ Mirroring of emotional processes enriches our perception such that we can directly perceive the emotions of others.

Before mirroring processes were related to emotional perception, there was strong evidence for a role for mirroring in action and intention understanding. In the early nineties, the Parma team discovered so-called 'mirror neurons' (MNs) in the brains of macaque monkeys. MNs are located in what is usually classified as a motor area of the brain, but have besides motor properties visual properties. They discharge when an agent is performing a specific motor action, but respond just as well in the sight of object-related actions performed by others. Importantly, MNs exhibit congruency in how they respond to actions of self and other: for example, neurons that fire when I grasp an object will fire as well when I see someone else grasping an object, but not when –or to a lesser extent–

⁹ Although I should note there is currently some controversy about the exact role of the amygdala in the experience and observation of pain. See for discussion Keysers & Craighero (2006) and Goldman (2006; section 6.2).

¹⁰ From James (1890, p. 450).

when I throw an object. Interestingly, as Fadiga et al. (1995) report, this activation coincides with facilitation of the same muscle groups in the observer as in the acting agent. In normal agents this muscle activation is covert, and does not result in actual (replicated) movements. But in patients who show 'imitation behaviour' this is different. Without good reason, they copy the actions of people who they observe. This appears to be the result of damage to the prefrontal areas, which govern inhibitory control of, among other things, motor schema's. Taken together, this evidence suggests that MNs are involved with the copying of motor plans of others, but that these motor plans are inhibited so to not result in overt action. They appear to mirror the actions of others, representing these as-if they were performed by the observer herself. Although mirror neurons were discovered through single-cell recording studies on monkey brains, there currently is rich evidence that a system consisting of mirror neurons exists in the human brain (according to the 'Parma team', it is widespread and centered on the inferior parietal lobule and the premotor cortex, which includes Broca's area (Gallese, 2005; Iacoboni, 2005; Rizzolatti, 2005; Rizzolatti & Sinigaglia, 2008).

MNs show different degrees of selectivity and congruence. If we focus on their visual properties, MNs can be subdivided in 'grasping-mirror-neurons', 'holding-mirror-neurons', etcetera; that is, MNs respond to the sight of a specific type of action. However, some MNs respond less selectively, and discharge during the observation of two, or even three different types of motor actions. If we now introduce motor properties, we see different degrees of congruence. For strictly congruent MNs the correspondence between the activity elicited by observed and that elicited by executed actions is nearly identical. However, about 70% of the MNs are merely broadly congruent: acts coded by the neuron in visual and motor terms are clearly connected, though not identical. The link can present different levels of generality: there are MNs that respond to two or three observed acts, but just to one performed act; MNs that respond both when monkey observes grasping with precision and with whole grip, but only to precision when it concerns execution; and even MNs that respond to one kind of action visually, but a different (but correlated) action when performed (Rizzolatti & Sinigaglia, 2008, pp. 83-84). The observation that most of the MNs are broadly instead of strictly congruent have lead some researchers (e.g. Csibra, 2004) to object that mirror neurons do not really seem to 'mirror' actions of others. This criticism seems to be based on a misunderstanding of what the Parma-team claims about

the representation of actions. As Susan Hurley writes in response to Csibra,¹¹ it is important to see that “for mirror neurons to play an important role in implementing subpersonal simulation functions or the capacity to understand observed actions, they don’t need to do so individually – don’t need to be ‘grandmother cells’ of action understanding”. It is more plausible that MNs “participate in distributed mirror systems that enable aspects of social cognition”, like action understanding. If an action is represented by a network of MNs, the findings on congruency do not pose a problem but a rather expected.

Researchers of the Parma Team, who discovered MNs, have suggested that MNs are fundamental to action understanding. As said, when I observe an action, my MNs get activated in a way that is similar to when I would perform that action myself. That is, a visual event is coded in terms of the corresponding motor event, thereby instantly related to my own motor repertoire. Through this link with my own motor system, I have information about the causes of the other’s action. According to Rizzolatti & Sinigaglia, one thereby “immediately perceives the meaning of these ‘motor events’ and interprets them in terms of an intentional act” (p. 98).

One could object, with Csibra (2004), that such a motor understanding seems to be superfluous because we have visual mechanisms to recognise and understand the actions of others. Rizzolatti & Sinigaglia (2008) respond that such a visual system would in all likelihood not be sufficient for real understanding because it is highly selective to specific visual elements of observed acts, and would therefore not bring any unitary meaning. MN activation adds an element to our perception of action that could hardly be derived from purely visual properties (Rizzolatti & Sinigaglia, 2008, p. 99). Interestingly, recent studies show that mirror neurons can enable action understanding even when visual data of the action is lacking. When monkeys were unable to see the final stage of an action, their MNs responded irrespectively, suggesting that the earlier visual data had already triggered the monkey’s motor repertoire such that it was able to integrate “the missing part of the observed action, recognizing its overall meaning in the partial sequence seen” (Rizzolatti & Sinigaglia, 2008, p. 101; Umiltà et al., 2001). A motor representation of an action performed by others is generated even when a full visual description of the action is lacking. It has also been found that a particular type of MN has audio-visual properties besides motor properties, becoming active both when the monkey observes a sound-producing action

¹¹ On the interdisciplines forum, http://www.interdisciplines.org/mirror/papers/4/8#_8.

and when it merely hears the sound but doesn't see the action (Kohler et al., 2002). It thus seems that MNs can form action representations on the basis of sound alone. Vittorio Gallese (2007) provides another reason why MNs are essential for a full understanding of another's actions. He writes that "only the embodied simulation mediated by the activation of the mirror neuron system enables the capacity of knowing 'how it feels' to perform a given action. Only this mechanism enables intentional attunement with the observed agent" (p. 661). It is because our own motor system becomes activated when we observe an action that we directly perceive them as actions, that we have a direct action understanding. Notice that this argument is similar to the one for emotion understanding. It seems that mirroring mechanisms, which are domain-specific and operate automatically and fast, provide organisms to quickly grasp (some) of the mental states of others.

More so than the findings on agency detection and eye-tracking, the findings on mirror neurons presents a problem for the classical sandwich. Mirror neuron activity supports the idea that that perception and action share a common code of representation in the brain (Hurley & Chater, 2005; Preston & De Waal, 2002). Observation of the behaviour of another appears to automatically activates one's own representations for that behaviour. Wolfgang Prinz has supported this idea in many studies (e.g. Prinz, 1997; 2005), showing that perceiving someone performing a certain action facilitates one's own performance of this action. The common-coding hypothesis explains why newborns are able to imitate the facial expressions of other people without being able to use visual feedback of their facial movements (Hurley & Chater, 2005; Hurley, 2008). It can also explain the automatic, unconscious chameleon effects and related robust priming effects that have been extensively reported by John Bargh and colleagues (Hurley, 2008). But the idea that actions of self and other are represented in the same way conflicts with the classical sandwich's assumption that perception and action are independent. If perceiving actions and executing actions share subpersonal processes, the classical sandwich cannot accommodate action perception.¹²

¹² Note that the classical sandwich can already not accommodate the idea that motor processes affect perceptual content.

2.3 Some objections for theories of mindreading

This chapter has two central and related claims, which both provide objections to traditional approaches to social cognition. The findings in this chapter suggest that we are in the possession of a set of pre-theoretical social cognitive abilities that emerge rather early in development, several years before the onset of more advanced capacities. Before children can reason about others, and understand that they can have beliefs different from their own, they already have an understanding of others. According to Shaun Gallagher (2001; 2005), skills of agency detection, eye-tracking, and the ability to perceive the intentions and emotions of others in their behaviour enable the child to develop (a) an understanding of what it means to be an experiencing subject, (b) an understanding of what it means that certain things are such subjects whereas others aren't, and (c) an understanding that these other subjects are in some respects similar and in some respects different from oneself. These basic social cognitive skills, he suggests, when used in interactions with others, provide children with the hermeneutic background that is required for the development of more advanced social cognitive abilities.

This positive claim comes with an objection to traditional approaches to social cognition. Both TT and ST have focused their study of social cognition on our capacity to explain and predict each other's behaviour (Gallagher, 2001). They have ignored the existence of more fundamental abilities to understand others, and framed social cognition too intellectually. They have also not realised that these pre-theoretical abilities play a primary role in all face-to-face interactions with others, and aren't merely precursors to mindreading (Gallagher, 2001; 2005; with Hutto, 2008). Gallagher & Hutto (2008) have recently suggested that for many of our interactions with others, the abilities presented in this chapter, combined with verbal understanding and a grasp of contextual norms, are all we need. If that is right, theorists of mindreading have mischaracterised social cognition.

The second claim is that agency detection, eye-tracking and the perception of emotions and intentions are not readily accommodated by the classical sandwich. Agency detection and eye-tracking are skills with cognitive import, even though they do not involve any theoretical inferences or central cognition. Eye-tracking appears to depend on subpersonal coupling between sensory and motor processing, rather than only on processes internal to vertical modules. Perception of emotions and actions are processed in the same circuits that process their execution, which conflicts strongly with the classical

sandwich's strict separation of perception and action. From the perspective of embodied cognition, I argued above, the findings do however make perfect sense.

Most proponents of TT and ST appear to have subscribed to the classical sandwich for social cognition. The findings presented here suggest that the classical sandwich must be rejected as a model to accommodate social cognition, which could have consequences for their views. However, the theorist of mindreading can now voice the same response as embodied cognition's critic did in the introduction: it has only been shown that the classical sandwich is inadequate for some basic social cognitive mechanisms, which hadn't caught his interest in the first place. He can readily accept that the classical sandwich is not suited for agency detection, eye-tracking, and the perception of actions and emotions, and even that basic social cognitive capacities are continuous with sensorimotor processes, while holding that advanced social cognition like mindreading must be accommodated by the classical sandwich. The next chapter, which is centred on Susan Hurley's Shared Circuits Model, sets out to show that this isn't right.

3 Social cognition without the classical sandwich

In the previous chapter it was suggested that mirror neurons (MNs) might play an essential role in our understanding of the actions of others. MNs appear to represent the goal-related actions of self as well as those of others. But how much information can motor activation on the basis of observation of another's behaviour provide about the intentions of another? According to Jacob & Jeannerod (2005), mirror neurons might enable one to perceive the intentions involved in basic actions, but not the more far-reaching intentions that the agent tries to fulfil by making these movements. Grasping a cup and pressing a switch are examples of basic actions, which are under control of what they call a motor intention. A basic action is usually performed as a means to a further end, like for example quenching one's thirst or taking the cup to clean it, or putting the light on or putting it off. Non-basic actions are under control of prior intentions, in Jacob & Jeannerod's terms. The observed movements of another, Jacob & Jeannerod point out, do not determine which non-basic action is being performed. Grasping a cup can be done both to drink or to clean; pressing a switch to turn the light on as well as turning it off. Jacob & Jeannerod submit that mirroring can give an observer information about the other's motor intentions, by re-activating the motor causes behind the agent's movements in the observer, but doesn't have the resources needed to discern the other's prior intention.

If Jacob & Jeannerod's objection is correct, the mirror neuron system appears to enable only a meagre form of action understanding. Additional inferences or theory could be needed to go beyond directly perceived motor intentions. This could be taken to mean that our resistance to the classical sandwich has to be dropped for advanced social cognition. Although some aspects of others can be directly perceived without a role for central cognitive processes, a comprehensive understanding of the other depends on central processes that work on information that has been provided by perception.

In this section I want to argue that this fallback to the classical sandwich isn't necessary. Susan Hurley's Shared Circuits Model shows, we will see, that the sensorimotor processes involved with mirroring can also enable comprehensive action understanding, as well as more complex social cognitive abilities. As Hurley's theory places great importance on the role of simulation in social cognition, it may provide a bridge between embodied social cognition and the simulation theory of mindreading.

3.1 From instrumental control to simulative mirroring

Hurley's Shared Circuits Model (SCM), of which the latest version is extensively discussed in Hurley (2008), is intended to show how "subpersonal informational resources for situated social cognition" can be built on those for "active perception", while at the same time uniting a large body of evidence and theory in a common framework (Hurley, 2008, p. 2). As it avoids the classical sandwich and holds that higher cognitive processing is continuous with sensorimotor processes, it is firmly placed in the tradition of embodied cognition. Hurley's model is an example of a horizontally modular structure, and draws on resources from control theory. To see clearly how action understanding, as well as more advanced social cognitive abilities, emerge out of structures for active perception, it is instructive to start with a simple control system. This section discusses the basics of Hurley's model; the next section shows how from the control system presented in this section social-cognitive abilities can emerge.

A simple control system contains 6 essential elements: (1) a target or reference signal, (2) an input signal, (3) exogenous events in the environment, (4) a comparator, which determines whether target and input signals match and the direction and degree of any mismatch or error, (5) the output of the control system, regulated by comparison between target and input signals, and finally, (6) a feedback loop by which output has effects on subsequent input signals. Control theory is used in engineering to model artificial systems –the thermostat is the best known example– but can also be used to model organisms. For our interests, output consists of motor signals, where input is a combination of exafferent input (input resulting from exogenous events) and reafferent feedback (input resulting from the organism's own activity). Visual input resulting from movements of others forms an example of exafference, while reafference includes visual and proprioceptive input resulting from one's own movements.

The previous comparator system can be enhanced by an internal feedback loop. In the system pictured in Figure 2, copies of motor signals (efference copy) are fed back into the system through what is usually called a 'forward model' or 'emulator'. The emergence of this feedback loop is explained by the Hebbian adagio that cells that 'fire together wire together': over time, associations are established between motor signals and the input that results after these have been executed. For example, when I move a leg I often see my leg move, and over time associations are formed between neural processes that tend to cause

movement and neural processes that enable perception of such movement (Hurley, unpublished). Consequently, when a motor signal to move my leg is executed, neural processes concerned with perceiving my leg move can become active before actual feedback from my leg is received. These internal associations between efference and reafference constitute the forward model. With a forward model, copies of motor signals can evoke associated input signals. The forward model maps efference copies directly onto 'expected' results, simulating the sensory consequences of motor signals.

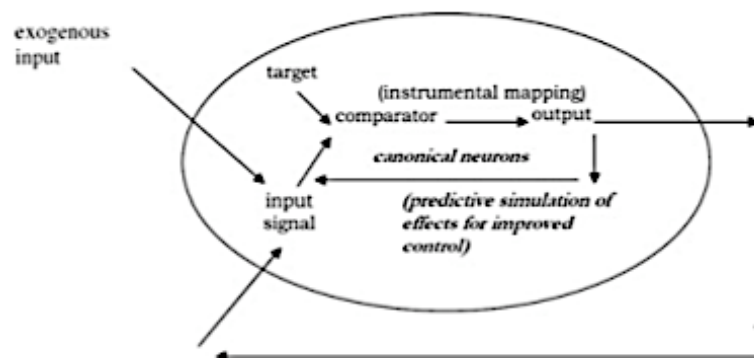


Figure 2: Simulative prediction of effects for improved control. From Hurley (2008, p. 13).

Simulation is used here and in the remainder of the text in the sense of 're-use'. In simulation, a process is re-used to generate information about such a process. In the present case, the re-used processes are motor processes: they are used not to cause movements but re-used to anticipate associated sensory feedback (Hurley, unpublished). Predicted feedback can be used to adjust motor output in order to match the target, which can speed and smooth control functions that would otherwise have to wait for actual sensory feedback (Grush, 2004; Hurley, 2008). There is strong evidence that at least some aspects of motor control are subserved by some sort of forward model (Blakemore, Wolpert, & Frith, 2002; Grush, 2004).

In the previous chapter it was suggested that motor processes can affect perceptual content, in contrast to what the classical sandwich supposes. The forward model shows how this can work: given a motor signal, sensory consequences or feedback can be simulated. The internal feedback loops simulates the external feedback loop. As Hurley (2008) suggests, canonical neurons appear to be involved in an internal feedback loop, as these neurons respond both when one is performing an object-related action of a certain type and when one is merely observing an object with which that particular kind of

action can be performed. Canonical neurons appear to have 'learned' to respond to the kind of sensory input that in the past was associated with actions in which they were involved, such that when an object is observed information becomes available about which actions that object *affords*. If the system has, in contrast to the present one, a mechanism for output inhibition, sensory input generated by an observed object can activate information about the *possible actions* that can be performed without the system actually executing any of them.¹³

Hurley (2008) argues that the instrumental associations that enable simulative prediction can also be used for (simulative) mirroring. The central idea is that the bidirectional associations between motor signals that caused certain movements and the sensory consequences of these movements on which feedback anticipation relies can also be used in *reverse*. Inputs can

now evoke related motor outputs; perceived effects are directly mapped onto the motor causes they are associated with. Observed actions will be *mirrored* or replicated in the observer; if mirroring is sufficiently strong and not inhibited, overt copying of the observed

behaviour results (Hurley, 2008, p. 13). This is again a form of simulation: as Hurley (2008) writes, "mirroring simulates motor activation that would produce results similar to those observed" (p. 17). Whereas motor processes were previously re-used so to anticipate sensory feedback, they are now re-used to perceive another's behaviour as action (Hurley, unpublished).

Let me note shortly that emotion understanding also depends on simulation (Keysers & Craighero, 2006; Goldman, 2006; Hurley, unpublished). As we saw in the previous chapter, when we observe the emotions of others our own emotional systems become active as if these states are occurring to ourselves. This is a form of simulation – the observer's emotional processes are re-used to enable emotional understanding.

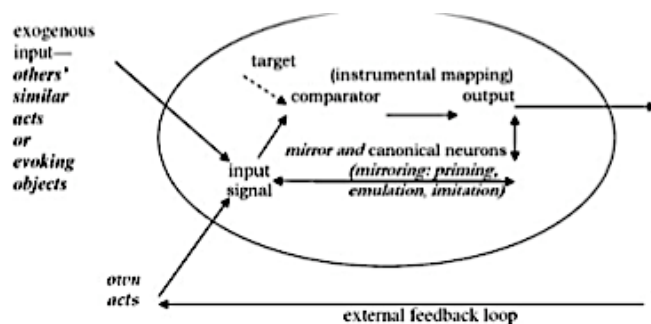


Figure 3: Mirroring. From Hurley (2008, p. 14).

¹³ There also seems a link to the sensorimotor contingency theory of perception here. At any given moment, input can generate efference copies, which could in turn invoke anticipated sensory feedback. Even when standing still, the organism will 'know' on the basis of its current input how its (potential) movements can affect subsequent sensory input. Such an organism would have knowledge of sensorimotor contingencies.

3.2 From simulative mirroring to strategic deliberation

We are now apparently at the same point as where Jacob & Jeannerod's (2005) objection came in. Mirroring activates in an observer the motor causes behind the other's behaviour, but, the objection goes, it does not provide any information about the more far-reaching intentions of the others, which would explain why the basic action is performed. Hurley's SCM provides us with the resources to resist this objection. Surely Jacob & Jeannerod are right that mirroring another's motor intention by itself usually does not constitute action understanding.¹⁴ But when such a motor intention enters a well-trained mirror neuron *system*, Hurley (2008) argues, information about more than just the other's the motor intention can become available.

To see how this works, the previous control system must be somewhat extended so to include output inhibition (see Figure 4). Monitored output inhibition allows the system to use its processes for instrumental action 'off-line'.¹⁵ Efference copy can be generated without actually executing the motor signal. Simulative prediction can now, drawing on instrumental associations in the normal direction, generate information about *possible* actions. Mirroring can, drawing on them in reverse, generate information about another's action without copying it. The latter enables an observer to perceive the motor cause behind the other's behaviour. But it's the combination of simulative prediction and mirroring that enables an observer to go beyond the other's motor cause. As Hurley (2008) writes: "by bringing together information about motor causes of one's own and others' similar observed actions, mirroring enables simulation of means/ends associations from either direction: Observed action retrodicts motor activation in the observer via mirroring of causes, which are associated with further results via simulative prediction of effects" (p. 14). After the motor cause of another's action has been mirrored in the observer, forward models can be run in the usual direction so to predict the future effects of mirrored motor activity, providing information about the ends of the observed action.

¹⁴ If someone's goal would only to press a switch, or only to grasp a cup, mirroring a motor intention would suffice, it seems.

¹⁵ A system without monitored input inhibition would copy the actions of others and execute them as it's own, and thus not be able to distinguish endogenously caused actions from actions that are caused exogenously. With monitored output inhibition it can. By inhibiting actions copied from others *and* monitoring this inhibition, information about others' actions is separated from information about one's own (Hurley, 2008, p. 17).

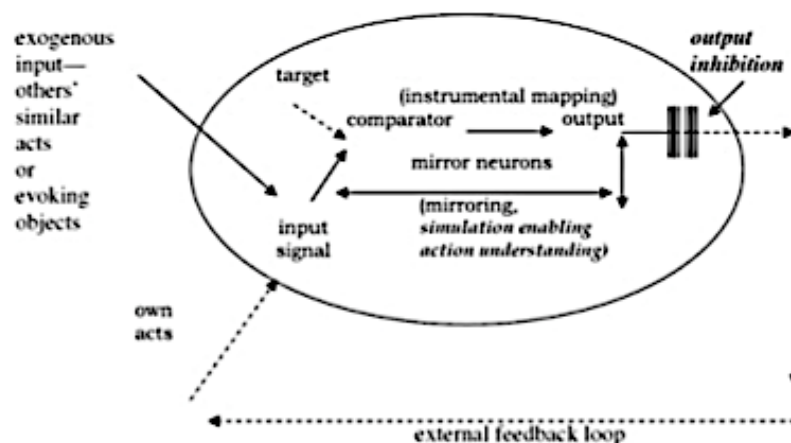


Figure 4: Simulative mirroring (or prediction) combined with monitored output inhibition, enabling action understanding (or instrumental deliberation).. From Hurley (2008, p. 17).

On Hurley's view, then, mirroring can, because of its relations with simulative prediction, provide information about the goals of the other's movements, enabling an observer to understand others as acting on intentions. How sophisticated this action understanding is –i.e., whether the observer can understand non-basic rather than basic actions, prior intentions rather than motor intentions– depends on the grain and complexity of the observer's instrumental control capacities, Hurley argues.¹⁶ A system with a wide range of potential means/ends chains at its disposal can form more elaborate predictions on the basis of a mirrored motor activity than a system with less advanced capacities for instrumental control. Whereas the combination of mirroring and and simulative prediction can provide an animal with fine-grained, complex means/ends associations with information about the goals of certain observed movements, an animal with coarser control capacities will not be able to perceive that much in the other's movement. As Hurley (2008) writes,

No doubt a monkey can move her hand to grasp a piece of sushi and move it to her mouth to eat it. But I can move my hand to operate chopstick to pick up sushi to dip it in soy sauce and then move it in my mouth to eat it, in order to impress my boss; given associate simulative mirroring functions, i may start to resent you for eating the last piece of sushi as soon as you reach for your chopsticks. (p. 15)

¹⁶ I take intentions, goals and ends to be roughly the same here. An agent performs an action to satisfy an intention/goal/end, and it is this state that an observer grasps when he understands another's behaviour as an action.

Someone who knows how to eat sushi with chopsticks will identify reaching for chopsticks instantly as a means to eat a piece of sushi; someone who doesn't (say, the typical monkey) won't recognise this end in the perceived movement. Action understanding depends thus in a very direct way on one's capacities for instrumental, worldly behaviour. In short, Hurley's model shows how a mirror neuron system with the right grain and complexity could enable an action understanding that goes far beyond grasping just the other's motor intentions. As such a system would be able to read the intentions of others, simulative prediction and mirroring would enable (an early stage of) mindreading.

A recent study of Iacoboni and colleagues (2005) suggests that the human mirror neuron system is *actually* able to generate information about the non-basic actions or prior intentions of others. In the study, participants were shown three different movie-clips: (1) grasping an object without any nearby objects; (2) context only, that is, scenes containing still objects like teacups and saucers; (3) grasping an object performed in two different contexts, a during-tea scene and an after-tea scene. In the third condition, the context was made such that a further intention than just the motor intention associated with grasping was suggested, either 'grasping a cup to drink' or 'grasping it to clean up'. Interestingly, the third condition, compared with the other two conditions, yielded a significant increase in brain activity in premotor areas known to contain mirror neurons. As the relevant difference between (1) and (3) is the suggestive context, it seems that contextual information can modulate mirror neuron activity so to allow more comprehensive action processing. The findings indicate that the mirror neuron system not only codes for observed basic actions but also for the ends to which such actions can be means (Rizzolatti & Sinigaglia, 2008, p. 128; Goldman, 2006, p. 139). In line with Hurley's (2008) proposal, Rizzolatti & Sinigaglia (2008) suggest that this is because the observer's mirror neuron system, after having mirrored another agent's motor activity, automatically anticipates possible successive acts that could continue the chain. In the first condition there is no contextual information that suggests the existence of a further intention, but in the third condition there is. The findings suggest that, in contrast to what Jacob & Jeannerod (2005) claim, an observer's mirror neuron system *does* have the resources to disambiguate putting the light on from putting the light off when she observes an agent pressing a switch; contextual information about the current state of the room can be used by the mirror

neuron system, such that besides perceiving that the light is being turned off it might even enable an observer to instantly realise that observed other is going to bed.

Hurley (2008, p. 17) is right to note that it is an additional question as to whether information about the intentions of others that the mirror neuron system generates enables a personal-level understanding of the other actions and intentions. But given that we do usually understand the actions and intentions of others, and given that the mirror neuron system appears to generate exactly the required information, it is likely that the mirror neuron system enables personal-level action understanding. Such action understanding does not seem to involve any inferences or theory.¹⁷ Mirror neuron systems respond automatically and fast to the actions of others, and the processes involved – processes that are re-used – are sensorimotor. This seems to enable a direct action and intention understanding. When I see you walking towards the lamp I don't have to infer that you're going to put it on; I directly see that that's what you're doing.

Even though emotion and intention reading are key social cognitive abilities, one might object that the social-cognitive abilities of the system in Figure 4 aren't *really* advanced. Mirroring is environment driven, depends on there being an other that is actually having an emotion or acting. We might have shown how basic forms of mindreading can emerge from sensorimotor processes, but it doesn't follow that advanced thinking about others – which we can do without being in contact with the relevant others – can also be build on the same structures.

Hurley's SCM does however also show how simulative prediction and mirroring can enable offline social cognition. The key to this is monitored simulation of input. Offline abilities, in contrast to online abilities, do not depend on interactions with the environment. Offline abilities like motor imagery, visual imagery, or thinking about something or someone can be triggered *endogenously*, without the object of process being in the vicinity. I can now from behind my desk imagine walking on the moon, decide to find out what the outcome is of 76 x 89 or think about how my mother will react when I tell her that I'm not coming home until after September. Rather than depending on input from the world, these activities can be triggered by input that is generated endogenously.

¹⁷ This is not to claim that theory and inferences never play a role in action understanding. It seems obvious that they can. But they do not play a role in the action understanding enabled by simulative prediction and mirroring.

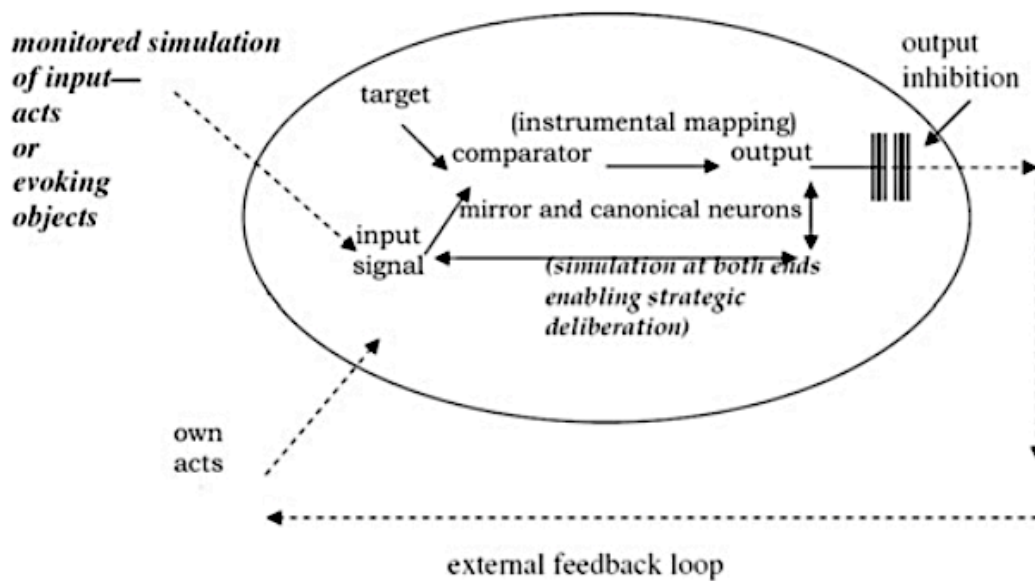


Figure 5: Counterfactual input simulation enabling strategic deliberation. From Hurley (2008, p. 18).

Figure 5 shows how monitored simulation of input occurs. The idea is quite straightforward: besides responding to actual input, the system can now also generate counterfactual input that can be run through simulations. The system can now simulate *possible* acts of others.¹⁸ Combined with simulation of different possible acts by self and their results, a skill that was enabled with the implementation of output inhibition, the system is able to ‘speculate’ on how possible acts of self could result in possible acts by others, and vice versa. When interacting with others, this skill can be used for coordination and cooperation, as it allows one to anticipate on how others will respond to your future actions (Hurley, 2008). But with monitored simulation of input thinking about others is no longer dependent on input provided by the actions of another. One can endogenously generate potential actions of others, and run whole scenario’s of interaction ‘in the head’. Monitored simulation of input thus enables what Hurley (2008) calls ‘strategic game-theoretic deliberation’.

3.3 Advanced social cognition can be embodied too

Hurley’s Shared Circuits Model starts with a system that can only perform instrumental action. But with seemingly simple functional adaptations to its sensorimotor structure, a

¹⁸ Hurley (2008) shows how monitoring of this input is necessary to differentiate possible acts from acts that were actually performed by others.

system has been modelled that can do offline strategic game-theoretic deliberation. In line with the evidence on shared circuits for action, sensorimotor associations that serve simulation first in control are exploited for mirroring. In control, sensory effects are simulated given motor processes; in mirroring, motor processes are simulated given sensory effects. With the introduction of possibilities of inhibition, a structure emerges that enables action understanding, mindreading and strategic deliberation. Hurley's model does not presuppose the classical sandwich, but has instead a horizontally layered structure that include a complete input-output loop. It is firmly placed in the tradition of embodied cognition, as it shows how abilities for social cognition are continuous –or better put, how they can emerge– from structures for adaptive sensorimotor behaviour.

Hurley's model does not include an ability for perceiving emotions in the facial expressions of others. The reason is that facial expressions, in contrast to movements, are less clearly related to instrumental action. As Hurley (unpublished) writes: "since facial expressions are primarily expressive rather than goal-directed or instrumental, the idea of monitoring sensory feedback in order to obtain a match to a goal seems out of place here (actors aside)" (p. 11). It is thus far not clear how emotion understanding should be modelled by control-theory.¹⁹ But note that the findings on emotional understanding fit the general idea of embodied cognition. As Rizzolatti & Sinigaglia (2008) write, "our emotions supply our brain with an important instrument for navigating the sea of sensory information and automatically triggering the most appropriate responses to ensure our survival and wellbeing" (p. 174). Emotions guide actions, and evolved for adaptive behaviour in the world. That emotional understanding would depend on a re-use of such structures is in accordance with embodied cognition.

Hurley's model brings us impressively far into the domain of social cognition. There is even a place for mindreading, even though it is relatively simple. As there is a central role for simulations in her model, there is reason to think that embodied social cognition might be able to draw on resources from the simulation theory of mindreading for a more complete account of mindreading. However, there are also some reasons to think this might not work. The previous chapter provided some reasons to think that ST and an embodied approach to social cognition conflict, for example concerning the classical sandwich and the basic character of some of our social cognitive abilities. Furthermore,

¹⁹ But see Kiverstein & Clark (2008, p. 47) on an interesting proposal for how to integrate emotion understanding in the Shared Circuits Model.

Goldman has explicitly argued that control-theoretic models like Hurley's draw on a different sense of 'simulation' than the one that's relevant for the simulation theory of mindreading. The next question intends to sort this problem out, and find out whether the simulation theory of mindreading can be integrated into an embodied approach to social cognition.

4 Is simulative mindreading embodied?

Robert Gordon (1986) challenged received wisdom when he suggested that we have no need for a special *theory* of mind to understand others as we can *use our own mind to model* the mind of the other. Gordon's proposal led to an ongoing debate between simulationists and theory theorists, in which Alvin Goldman proved himself to be one of simulation theory's (ST) staunchest defenders. Below I first introduce ST, after which a second section introduces a first way of why to think of ST as embodied. The third section discusses some apparent conflicts between embodied cognition and the simulation theory of mindreading, but in the fourth it will be argued that, at least on a specific reading, simulative mindreading fits an embodied approach to social cognition well.

4.1 Introducing the simulation theory of mindreading

According to what is often called 'theory theory' (TT) our understanding of others is enabled by a theory of mind, which is either innate or developed during childhood on the basis of experience. Just as scientists posit theoretical constructs to explain phenomena of their interest, we posit mental states to explain and predict the behaviour of others (and that of ourselves, for that matter) (Gopnik & Wellman, 1992). Adherents of TT hold that mindreading is enabled by a data structure consisting of laws which mediates between our observations of behavior-in-circumstances and our predictions and explanations of that behaviour (Ravenscroft, 2004).

Simulationists deny that we need a theory to understand others. Instead of predicting what the other is going to do on the basis of behavioural data and a set of psychological laws, I can simply imagine what I would do if I was in the other person's situation. Gordon calls this *practical simulation* in his seminal paper, "a simulated deciding what to do" (p. 161). I can read the other's mind by *using* my own mental processes of the same type as the other's, rather than theorising *about* mental processes.

Merely deciding what I would have done in the other's situation is however in many cases not sufficient, as it would tell me what I would do if I would be in the other's situation, whereas I'm interested in what the *other* will do. To simulate the other successfully, I must make adjustments for relevant differences between me and the other, as well as inhibit (or quarantine, as Goldman calls it) my own intentions or other mental

states. We run simulations of the minds of others on our own mind by choosing the right input states and by making some relevant modifications to account for idiosyncrasies of the other. Sometimes, it is sufficient to shift spatiotemporal perspective, but in other cases one might have to switch “institutional” or other social roles, or make adjustments to upbringing, education, values, temperament or epistemic situation (Gordon, 1986; 1992). But, Gordon (1986) writes, “within a close-knit community, where people have a vast common fund of ‘facts’ as well as shared norms and values, only a minimum of pretending would be called for” (p. 164). That is why in most cases we get by with projecting our own mental states onto others without making any adjustments. According to Gordon (1992), such total projection is the default mode of simulation: “when we are aware of others –that is, aware of them as others– we are constantly, automatically projecting onto them our own beliefs about the environment” (p. 16).

According to simulationists, simulation allows us also to explain another’s behaviour: I place myself in the other’s shoes, make relevant modifications to my model of the other, form hypotheses of potential reasons that one might have to act in the observed way, and test whether such reasons would indeed under the current model lead to the observed behaviour. If I cannot decide between several hypotheses, I can try to get more information that would yield support to a specific hypotheses or try to falsify others. According to Gordon (1986), I will through such testing usually find myself, after a number of errors, “‘tracking’ the other person fairly well, forming a fairly stable pretend-world for that person” (p. 164).

4.2 Embodied simulations

Simulationists hold that to read the mind of another, a person uses processes of the same kind as the other. On first view, it might look that this starting point alone is sufficient to make ST embodied. The reasoning would be that, as ST holds that we use our own mechanisms to understand the other, it holds that we use our own body to understand the other. It thus construes mindreading as an embodied ability.

But that won’t work. The argument draws on a trivial sense of embodiment. No TT-theorist, nor any die-hard cognitivist for that matter, would deny that the mechanisms that we use to understand others and to make sense of the world are physically implemented in our bodies. No one would deny that we use our bodies to understand others and the

world. So proponents of embodied cognition, who stand united in their rejection of cognitivism, mean more with ‘embodied’ than just ‘physically implemented in a body’. Rather, it is *because* cognition is embodied that proponents of embodied cognition reject how it was traditionally approached, and replace it with a view that is evolutionary and biologically more plausible. The fact that cognition is essentially for adaptive behaviour in the world has *shaped* the cognitive architecture. The fact that cognitive mechanisms have evolved and still develop in specific types of physical bodies, in environments with particular aspects, has serious consequences for how cognitive mechanism function and how they should be studied.

To find out whether simulative mindreading can be integrated with embodied social cognition, we need to find out whether it fits or conflict with specific ideas of embodied cognition. What I take to be one of the central ideas in embodied cognition is that higher-cognition is not separate from perception and action, but instead rooted in processes for adaptive behaviour in the world. In the previous chapter it was argued that such grounding could take form in terms of simulation: advanced social cognitive abilities like action understanding, mindreading and strategic deliberation could be enabled by a subpersonal re-use of sensorimotor processes, by simulations of processes that originally evolved for instrumental action in the world. It seems that if we can interpret ST as holding that we *re-use* our processes to read the mind of the other, and these processes themselves can be grounded in adaptive behaviour, we have a way to interpret simulative mindreading as embodied. However, there are also some aspects of ST that count against this possibility.

4.3 Challenging the simulation theory of mindreading

Embodied cognition poses three problems for the simulation theory of mindreading, one phenomenological, one practical, and one logical. The three problems are related, and there is, or so I will argue, one response that solves them all.

Let’s start with the phenomenological objection, which has been posed by Gallagher at multiple places (Gallagher, 2001; 2005; 2007a; 2007b; with Hutto, 2008). Simulationists of mindreading like Goldman and Gordon hold that our default way of understanding each other is through simulative mindreading. Gallagher & Hutto (2008) have recently criticised this idea. They write: “if in fact such processes are primary,

pervasive, and explicit, they should show up in our experience –in the way that we experience others– and they rarely do” (p. 2).

As Gallagher & Hutto realise, proponents of the simulation theory of mindreading will respond that simulative mindreading can occur largely non-consciously. To assess this response, it is instructive to see how simulationists in general depict simulative mindreading. Goldman (2006) writes:

Predicting another’s decision is a stock example that ST aims to explain. It says that an attributor goes about this task by imaginatively putting herself into the target’s shoes. She pretends to have the same initial states –for example, the same desires and beliefs– and then makes a decision given those initial pretend states. Having made a decision in the pretend mode, the attributor predicts that this is the decision the target will make. (p. 19).

[...] it is important for the success of a simulation for the attributor to *quarantine* his own idiosyncratic desires and beliefs (etc.) from the simulation routine. (p. 29)

Gordon & Cruz (2003) add:

simulation would typically require indexical adjustments, such as shifts in spatial, temporal, and personal points of view, to place oneself in the other's physical and epistemic situation in so far as it differs from one's own. One may also compensate for the other's reasoning capacity and level of expertise, if possible, or modify one's character and outlook as an actor might, to fit the other's background and behavioral history.

Traditional simulationists describe simulative mindreading as a personal-level process that involves several stages and several advanced operations from the side of the simulator.

Does it make sense to say that a simulator can do all that without being conscious of it?

Can one put oneself in the shoes of another without noticing it? I tend to answer both questions negatively. Gallagher & Hutto (2008) seem to be right to conclude that the fact that we don’t have awareness of employing simulative mindreading in this way very regularly suggests that we don’t do it that regularly.

Besides this phenomenological argument, an embodied approach to social cognition provides also a practical objection against the idea that simulative mindreading is our default way of understanding each other. Social cognition is usually situated. It takes place during interaction with others, in which the behaviour of the other continuously influences you and you continuously influence the behaviour of the other. It is doubtful whether one has, during intensive second-person interaction, the time and the resources to create a model of the mind of the other. This problem only increases when an interaction situation involves multiple others, or when during interaction we are involved

in other cognitive activities; it seems very hard to simultaneously simulate the minds of multiple others in the ways just described, and the demands of other cognitive activities appear to conflict with those for elaborate simulative mindreading. It is thus doubtful whether we are able to model the mind of others in our many of our interactions with them. It is also doubtful whether we *need* to. Basic social cognitive abilities for the perception of intentions and emotions, social heuristics, verbal understanding and implicit knowledge of contextual norms might for many interactions be sufficient (Gallagher & Hutto, 2008).

The logical objection concerns simulationists' apparent subscription to the classical sandwich.²⁰ Let's take another look at Goldman's description of simulation.²¹ Goldman writes that an observer first creates pretend states through a process that Goldman dubs enactment imagination. These endogenously created pretend states are then fed into her own cognitive mechanisms, ending up in an output state that can be attributed to the other. Note that these first two steps can also be found, although subpersonally described, in Hurley's model: strategic deliberation depends on the simulation of input, which are subsequently fed through the system's own processes and which culminate in an output state that is attributed to the other. But problems seem to appear when we get to Goldman's description of how this output is attributed to the other. After the mindreader has imagined himself in the other's situation, he first needs to "make an introspective identification" of the resulting mental state on the basis of concepts of mental states, after which the identified state is attributed to the simulated other by means of an inferential step. The mindreader reads his own mind, and then infers, on the basis of an assumed similarity or analogy, that the simulated other is in similar states. Mindreading is thus depicted as an essentially central cognitive affair. Furthermore, Goldman appears to consider the role of perception and action to be merely peripheral. He writes for example that mirroring depends on the existence of a specific causal pathway, with two components:

²⁰ I call this objection 'logical' because the classical sandwich unjustifiably presupposes isomorphism between input/output and perception/action, conflating subpersonal and personal levels (Hurley, 1998).

²¹ Because Goldman presents a mainstream version of ST, is its most vocal supporter, and has recently published a book that discusses his brand of SM extensively, I focus my discussion here on him. Robert Gordon's simulation theory might avoid this objection.

(a) a subpath within the sender from his own mental state to a behavioral expression of that state and (b) a subpath within the receiver from an observation of the sender's behavior to a mental state that matches the sender's. (2006, p. 133).

As Goldman talks about "mental states", which are states of persons rather than of subpersonal mechanisms, I take his description to be on the personal level. The other's mental states reside in an internal domain, but can cause certain behaviours. The observer perceives this behaviour, and this perception causes a similar mental state in the observer. Perception and action appear thus to play respectively the roles of input from mind to world and output from world to mind. Let me note that Goldman (2006) insists that such mirroring of mental states is not yet mindreading, as "mental attribution [...] requires two mental acts by the attributor: selecting a mental-state category, or classification, and imputing an instance of that classification to the pertinent target" (p. 133). On Goldman's view, mindreading is essentially an intellectual endeavour.²²

The previous chapter suggests that simulative mindreading can be characterised less demandingly, and without a commitment to the classical sandwich. Hurley's Shared Circuits Model shows that mirroring, combined with monitored output inhibition, can enable the perception or *reading* of the other's intention. In the act of perceiving a goal-directed action, a mental state is attributed to the other. Similarly, it seems that we attribute emotions to others when we perceive their emotions in their posture and facial expressions. Whereas Goldman appears to hold that a mindreader first perceives the other's behaviour and after that has to perform additional mental acts to attribute mental states to the other, it seems that we usually read the other's mind in her behaviour. The other's mental life is no longer hidden behind behaviour. Such perceptual mindreading is of course, as explained in the previous chapters, enabled by subpersonal causal processes, which in this case are sensorimotor and emotional processes that are automatically activated by input generated by the other's behaviour. Perception of action and emotion does not map on input, but is instead enabled by a complex subpersonal dynamics.

Although perceptual mindreading, as I will call it, depends on input from others that activates one's own sensorimotor or emotional processes, there does not seem to be a role for introspection and attribution from the first person to the third. In the Shared

²² Let me note that Goldman (2006) does take the findings on mirroring to be important for mindreading, just like Gordon (2005). Goldman (2006) goes to great lengths arguing that the evidence on mirroring of emotions and mirroring of actions and intentions is better explained by ST than by TT. But he also holds that mental acts are required for mirroring to become what he calls *mirroring for mindreading*. See also Gallese & Goldman (1998).

Circuits Model, self and other are distinguished due to monitored output inhibition; when mirrored motor activity isn't executed as an action, the system has information that the information being processed relates to another person. An inference from self to other isn't necessary, as the processed action wasn't attributed to the self before it was attributed to the other, in contrast to what Goldman (2006) assumes. Because of this, the mindreader does not read his own states, and project these on the basis of inference to the other, but directly reads those of the other. What about concepts of mental states? This is a large topic, about which I only want to say two things that point in the direction that concepts aren't necessary for mindreading. First, it seems to me that the information about the other's emotions and actions that can be generated through re-use of our own circuits does not need to be conceptual to be informative about the states of others. Second, young children and other animals appear to be able to perceive the emotions and intentions, and it is generally assumed that they do not have a conceptual repertoire. I thus follow Gallagher (2001) and Gordon (1995a; 1995b) and hold that concepts are not required for mindreading. Importantly, my claim is not that mental concepts, inference or introspection never play a role in mindreading; it is only that they are not essential to mindreading.

I do not wish to argue that all mindreading is of this perceptual kind; rather, I would like to propose that simulative mindreading is a graded phenomenon, and that we can use it in different degrees for understanding of others.²³ We might describe it in terms of a dimension, from simple to elaborate. On one side of the dimension perceptual mindreading, which occurs fast and automatically and allows us to directly grasp (simple) intentions and emotions of others. In the dimension's centre we find simulative mindreading that helps us explain and predict the behaviour of others, but does not involve adjustments for the fact that the other is a different person – we simply project most of ourselves on the other. In contrast with perceptual mindreading, such 'lazy' mindreading, as I will call it for its lack of pretence, does not depend on others being in the perceptual field of the mindreader; it can be operated offline as well as online. Another difference with perceptual mindreading is that its outcomes go beyond what is directly perceived. Its outcomes could involve unscrutinised impressions of the motivation behind the other's behaviour, and lie at the basis of the expectations that we automatically form of

²³ This idea isn't new. Hurley (2008) stresses that mindreading is a graded phenomenon, citing Tomasello. The claim that I'm making is however not developmental; I'm arguing that we can have different grades of simulative mindreading to understand another.

others. Also, this grade of simulation might allow for a more complex understanding of the emotions and intentions of others, and of the other's beliefs, desires and other attitudes. Gordon (1986) seems to argue for the existence of such an intermediate form of simulative mindreading, as he writes:

I suspect that, once acquired, the capacity for practical simulation operates primarily at a sub-verbal level, enabling us to anticipate in our own actions the behavior of others, though we are unable to say what it is that we anticipate or why" (p. 170).

He goes on to speculate that our decision-making or practical reasoning system regularly gets automatically disengaged from its 'natural inputs', to be fed with "suppositions and images (or their 'subpersonal' or 'subdoxastic' counterparts)" (p. 170).

On the 'complex' side of the dimension, simulative mindreading involves active modelling the other's mind, including making relevant adjustments for idiosyncrasies and selecting pretend states. In contrast to the previous two grades, such simulative mindreading takes considerable effort, time and resources, and, so it seems, conscious control of the agent. It is through 'elaborate mindreading' that a mindreader can place herself in the shoes of the other and take (to some extent) a point of view different from her own.

Admittedly, this proposal is quite speculative. But it can be defended. I think the previous chapters have provided considerable evidence for the existence of perceptual simulative mindreading. One's personal experience suggests that we can also do elaborate mindreading. This grade is also closely related to the descriptions of simulation given by traditional simulationists. The idea that there are in-between forms like lazy simulative mindreading is motivated by Hurley's model, which shows that simulation circuits that enable perceptual mindreading can also enable comprehensive action understanding and strategic deliberation, and the finding that our expectations and explanations of other's are strongly biased by our own perspective on the world (cf. Goldman, 2006).

We can now return to the practical and phenomenological objection. Before I suggested that simulative mindreading, as characterised traditionally, is not suited for situated second-person interactions. That also seems to be true of elaborate simulative mindreading. But what about perceptual and lazy simulative mindreading? Let's focus on an interaction that includes several people. Gallagher & Hutto (2008) ask "is it possible to simulate the neural/mental/emotional states of two other people at the same time if in fact our simulations must be such that we instantiate, undergo, or experience, those two

(possibly very different) states?" (p. 3) No, that doesn't seem to be possible to do that at exactly the same time, but it also doesn't seem to be true that we can perceive two different states of two different people at exactly the same time. We need to focus our attention on someone to perceive what's going on with him or her. Perceptual simulative mindreading can automatically and quickly, in the perceptual act, generate information about the others' intentions and emotions. If lazy simulative mindreading works fast and effortlessly as well, it can also do social cognitive work during interactions with multiple others, it seems to me. It could provide us with impressions of the motivations behind what people say and do, and with expectations of what is going to happen next. At least according to my own phenomenology, it seems to be correct that our brain generates this sort of information even during intensive interactions with several others.

It thus seems that less elaborate forms of mindreading are suited for our second-person interactions with others, and that the practical objection has been answered. What about the phenomenological objection? Gallagher & Hutto (2008) are right, I wrote above, that elaborate simulative mindreading should involve some consciousness of elements of the simulation process, which a simulationist doesn't have to deny. But when used lazily, simulative mindreading could only involve consciousness of the result. And in its perceptual form, only the emotions and intentions of the other reach awareness. On this view, it appears that the fact that we do not regularly experience ourselves as simulating the other does not count against an important role for simulative mindreading in social cognition. In fact, if the perception of intentions and emotions is as central to our social cognitive life as Gallagher & Hutto (2008) write, it seems that simulative mindreading is one of our primary abilities to understand others.

4.4 Is simulative mindreading embodied?

In this last chapter I want to discuss two questions. First, is the account of simulative mindreading proposed in line with embodied cognition? Second, is it in accordance with ST? I argue that the answer to both questions is 'yes'.

I start with the second question. A first reason to think that simulative mindreading as described in the previous section might not be in accordance with ST is provided by Goldman's claim that simulation essentially involves (1) an analogical inference from oneself to others and (2) introspective reading of one's own mental states, and requires (3)

prior possession of the concepts of mental states that are ascribed to others. These elements appear not to be found in perceptual mindreading as described above, and some of them possibly neither when used in a more elaborate degree. However, despite Goldman's claim that these three are necessary elements in simulative mindreading, one can certainly have a simulation theory of mindreading that doesn't involve them – the clearest example of this is Robert Gordon's simulation theory, who in several papers (1995a; 1995b) has distanced himself from these three requirements.

A second reason to doubt that the proposal of the previous section is in accordance with ST is the former's relation with Hurley's control-theoretic Shared Circuits Model. Goldman (2006) argues that the notion of simulation used in control-theoretic contexts has a different sense than the one that's relevant for simulative mindreading, and questions Hurley's efforts on relating the two on that grounds. He suggests that when a control-theoretic model simulates a phenomenon, it does this much in the way that a weather-computer simulates the weather; control-theoretic simulations are theory-based, and do not generate intersystem resemblance between simulator and simulated.

Recently, use of the notion of 'simulation' has become popular in cognitive science. Evidence from a range of disciplines suggest that many, if not all, of human higher-level cognitive processes make use of (partial) simulations of sensorimotor processes through the re-activation of neural circuitry involved with perception and action (Wilson, 2002; Hesslow, 2002; Svensson & Ziemke, 2004; Grush, 2004; Svensson, Lindblom & Ziemke, 2007; Garbarini & Adenzato, 2004; Decety & Grezes, 2006; Barsalou, 2007).²⁴ Different descriptions are in use. Lawrence Barsalou (2007) writes that "simulation is the reenactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind" (p. 619). According to Svensson, Lindblom & Ziemke (2007), the basic idea of simulation "is that neural structures that are responsible for perception and/or action are also used in the performance of several cognitive tasks" (p. 243). The relevant sense of simulation in these contexts seems to be that of an *intrapersonal re-use* of a process to generate information related to such a process. There is nothing interpersonal about the simulation involved in visual imagery or motor imagery, cases of which Goldman (2006) explicitly argues that they involve the relevant sense of

²⁴ Simulation is here thus used in a subpersonal sense. I get to the distinction between subpersonal and personal simulations in the next chapter.

simulation; it are cases of simulation because visual processes are re-used in visual imagery and motor processes re-used in motor imagery (Hurley, unpublished).

Hurley (unpublished) argues that the primary sense of 'simulation' when used in contexts of mindreading is also that of intrapersonal re-use: what is essential about mindreading by simulation is that one's own mental processes are used to generate information about such processes, rather than a theory about mental processes. Used in this sense, interpersonal resemblance is not necessary for an act to count as simulative mindreading: a mindreader can fail to resemble a process or state of another, for example because the other is an actor, and still be engaged in simulative mindreading because her own processes are re-used. This seems to be right. It also means that the attainment of an interpersonal (as well as intrapersonal) resemblance of mental states is not sufficient for simulation. As Hurley (unpublished) writes: "in general, a given process can be reused without producing similar states, and similar states can be produced by different processes" (p. 4). Hurley's definition of simulation as re-use thus correctly avoids that using a theory to replicate mental states of another can be called simulative mindreading.

This short conceptual analysis allows us to respond to Goldman's objection to control-theoretic simulation, Hurley (unpublished) shows. The simulations in the Shared Circuits model are clear cases of intrapersonal re-use. In simulative prediction, "motor processes that tend to cause behaviour are intrapersonally re-used to anticipate the sensory effects or feedback from such processes", Hurley writes (p. 11). In mirroring, "motor processes that tend to cause behavior are reused intrapersonally to perceive another's behavior as action" (p. 11). Moreover, in contrast to what Goldman suggests, interpersonal resemblance of states is sufficient nor necessary to simulation or mirroring.²⁵ If an agent that I observe moves sufficiently similar to a human being, even though it is in fact a Terminator with very different internal processes, I might well be able to perceive it's behaviour as actions due to mirroring without there being any interpersonal resemblance. In fact, Gazzola and colleagues (2007) have shown that the human mirror neuron system can be activated just as strongly by robotic actions as by human actions. Interpersonal resemblance, it seems, is merely *an artefact of intrapersonal simulation*: it are processes of myself that are re-used to understand the other, but because my system is similar to that of

²⁵ Goldman (2006) says mirroring is a form of mental simulation because "cognitive states of one organism are matched or mirrored by similar cognitive states in an observing organism" (p. 132).

the other, as long as the other is human and not a robot, interpersonal resemblance results. 'Mirroring' turns out to be a somewhat misleading name.

These first two responses suggest that what I've called perceptual simulative mindreading is in accordance with ST. Lazy mindreading and elaborate mindreading have been only loosely described, so it is harder to analyse whether they fit ST or not. I suppose that this shouldn't cause problems, however, because lazy and especially elaborate simulative mindreading appear to fit existing descriptions of simulation by traditional simulationist like Gordon (1986; 1992; 1995a) and Goldman (2006). The idea that simulative mindreading is graded –that simulations can vary on factors like extent of pretence, extent of inhibition or quarantine of one's own states, how conceptually complex they are, how conscious they are, and whether they are offline or online– appears to be argued for by both of them. Furthermore, the aspects of lazy simulative mindreading that do not fit ST *prima facie* should be those aspects that it shares with perceptual simulative mindreading, as lazy simulative mindreading is a mix of elaborate and perceptual simulative mindreading, and perceptual simulative mindreading has already been defended above.

But before I get to the other question, some clarification is needed about the level of description on which the several grades of simulative mindreading take place. Perceptual simulative mindreading involves subpersonal simulations, but the most elaborate form appears to be personal. Gallagher & Hutto (2008) suggest that this asymmetry is problematic. They argue that there is no justification to use the term simulation in a subpersonal sense because "simulation, as defined by ST, is a personal-level concept that cannot be legitimately applied to subpersonal processes" (p. 2). I don't think this is right. Rather, I wish to suggest that personal level simulation depends on subpersonal simulation. I will explain what I mean.

Above it was argued that 'simulation' as a concept in cognitive science and neuroscience refers to a re-use of processes so to generate information about these processes, and that intrapersonal re-use is also the primary sense of simulation for mindreading. Re-use is subpersonal rather than personal. When an organism perceives the action of another it does not itself re-use its own processes; the organism just perceives, and this perception is enabled by a re-use of processes. Similarly, when I perform an act of elaborate simulative mindreading and place myself in your shoes in an effort to adopt your perspective, it is not *me who re-uses* my own processes; rather, this personal level act of

simulation is enabled through subpersonal re-use of mental processes. Drawing on Hurley's (unpublished) argument, it appears to me that (interpersonal) simulation in the personal-level sense is enabled by simulation in the subpersonal sense of intrapersonal re-use. Turning Gallagher & Hutto's (2008) claim around, I'd say that 'simulation' can only be legitimately applied to personal-level processes if these are enabled by subpersonal simulations.

That re-use isn't something personal, but subpersonal, doesn't mean that it is done a brain or by a process. Re-use or simulation describes an intrapersonal *relation* that obtains between abilities or processes, not something that is *performed* by processes or abilities. 'Visual imagery re-uses visual processes' means that the subpersonal basis of visual imagery includes visual processes. This is not without a reason: visual imagery requires certain information, and this can be provided by visual processes. Similarly, 'action perception re-uses motor processes' means that our perception of actions is enabled by processes involved with our own motor behaviour. Again there is a good reason for this, as motor processes can generate information that is required for perceiving action. Re-use is thus a product of evolution and development. Not that evolution planned to create visual imagery or action perception; something happened, and it happened to work.²⁶

This brings me to the second question, concerning the fit between simulative mindreading and embodied social cognition. Drawing on the description given of embodied cognition in the introduction, I think three questions are of main importance here: (1) Does simulative mindreading fit the requirements of active interaction in the world?; Is simulative mindreading grounded in processes for adaptive behaviour? (3) Does simulative mindreading avoid the classical sandwich?.

The first question was already addressed in the previous section. Traditional accounts of simulative mindreading appear to be open to the objection that simulation cannot be used to understand others in intensive interactions, especially if multiple others are involved. Such interactions instead seem to require basic social cognitive skills like agency detection, eye-tracking and the perception of intentions and emotions. However, once we see that the perception of intentions and emotions depends on simulative

²⁶ Hurley (2008) suggests that mirroring is exaptive, a fortunate consequence of the use of instrumental associations for anticipation of sensory effects when executing motor signals. In a recent text she writes: "the interpersonal aspect of mirroring arises as an artefact of neural failure to distinguish between the sensory effects of one's own motor processes (seeing your own hand movement) and sensory inputs from similar observed behavior (seeing another's similar hand movement)" (unpublished, p. 11).

mindreading, this problem fades away. Simulative mindreading is more basic than some proponents of ST suggested, and can be applied in intensive interaction.²⁷

The answer on the second question draws on the central role of re-use in simulative mindreading. One reason why re-use or simulation is such a popular phenomenon in our cognitive structure is that it's so easy to 'create': just a few little changes, and whole new functionality emerges. With re-use, cognitive abilities emerge for cheap, exactly in line with embodied cognition's spirit. More specifically, I think that embodied cognition's central idea that advanced cognition is grounded in processes for adaptive behaviour can be cashed out in terms of re-use, where higher cognitive abilities re-use processes for adaptive behaviour, like emotional or sensorimotor processes.

Hurley's SCM shows how this can be the case for simulative mindreading. Perceptual simulative mindreading is enabled by simulative mirroring and simulative prediction; in both cases motor processes are re-used. We saw in the previous chapter after the introduction of monitored output inhibition the system can generate information about the other's future actions. The kind of predictions that the system can create go now beyond the perceptual, in the direction of what I called 'lazy' simulative mindreading. Hurley's most complex SCM-organism can even do strategic deliberation, which given its offline and non-perceptual character I take to be a more elaborate (though still 'lazy') form of simulative mindreading. Such a system can in principle, it seems, generate explanations of perceived actions: it can test what kind of possible actions would bring about certain observed consequences. As all these skills are enabled by sensorimotor processes for instrumental action, Hurley's model shows that simulative mindreading, at least in its perceptual and lazy forms, is grounded in processes for adaptive behaviour.

But what about elaborate simulative mindreading, the kind that ST was about in the first place? Say you're sitting in your chair, trying to find out which present your partner would really like to get for his or her birthday. This can be done through elaborate simulation, it seems. Presumably, this involve extensive pretence, concepts of mental states, active use of memory, and other high-level cognitive processes. It seems probable that the sensorimotor and emotional simulation routines that are essential to perceptual perceptual-to-lazy mindreading play a role as well, given that cognition exploits what's

²⁷ This seems as good a place as any to note that I do not want to claim here that all mindreading is simulative; it seems highly plausible that theory (or narrative, cf. Hutto (2007)) plays an important role in our understanding of other as well.

already there. But the processes involved in elaborate simulative mindreading, including those that are re-used, seem to be hardly only sensorimotor processes. That should however not be a problem. Embodied cognition would be absurd if it holds that all of the mind's subpersonal processes are sensorimotor. What it does claim is that the higher-cognitive processes involved in elaborate simulative mindreading must be somehow grounded in more basic processes for adaptive behaviour. There is no reason to think that such accounts cannot be given, so as long as we do not presuppose theories on higher cognitive mechanisms that contradict this central idea of embodied cognition, I think elaborate simulative mindreading is in accordance with embodied social cognition.

About the third question we can be short. Simulative mindreading does not presuppose the classical sandwich, as we've just claimed that it is grounded in sensorimotor processes for adaptive behaviour in the world. Hurley's Shared Circuits Model has shown explicitly how perceptual and lazy forms of simulative mindreading can be accommodated by an alternative horizontally layered structure. For elaborate simulative mindreading we will have to avoid, in contrast to what Goldman seems to do, letting central cognitive processes do all the magic. But again, there's no reason to think this can't be done.

5 Conclusions

Simulative mindreading can be accommodated by embodied cognition. The odds might not have looked good at first, as simulationists appeared to have subscribed to the classical sandwich, approached social cognition as a highly intellectual affair, and did not seem to take account of the plurality of social cognitive mechanisms. But even though these elements do not fit an embodied approach to social cognition, as I argued in chapter two, the mechanism that simulationists take to be central for our understanding of others, namely simulation, can be part, –maybe even *needs* to be part– of embodied social cognition.

The apparent problems between the simulation theory of mindreading and embodied social cognition fade away once we get clear on what ‘simulation’ is. Traditional simulationists have usually described simulation as a process of explicitly modelling the other, taking it to essentially involve central cognitive operations like introspection and an inference by analogy from self to other.²⁸ But all this is not essential to simulation, we saw in the previous chapter. Drawing on recent work by Susan Hurley, I argued that what is essential about simulative mindreading is that it involves intrapersonal re-use of subpersonal processes. Although embodied social cognition might still not want to take over the claim that simulative mindreading is our default way of understanding others, simulative mindreading conceived like this turns out to be rather basic itself - it’s the mechanism involved with perceiving intentions and emotions of others. Moreover, Hurley’s Shared Circuits Model illustrates that simulative mindreading doesn’t presuppose the classical sandwich and is enabled by sensorimotor processes rather than central cognitive operations.

In fact, a further integration of embodied social cognition and the simulation theory of mindreading might be fruitful. Embodied cognition is critical of cognitivist approaches to cognition, of which TT is a good example. By conceiving simulative mindreading in an embodied framework, stressing its grounding in adaptive processes, the contrast with TT appears to become much clearer. Embodied social cognition on the other hand needs a way to get to advanced offline social cognition like elaborate simulative mindreading that doesn’t conflict with its central assumption that cognitive

²⁸ Robert Gordon is an important exception here; he himself has argued against some of these elements in Gordon (1995a; 1995b).

processes are geared to adaptive behaviour in the world. Re-use of already existent subpersonal processes to enable more advanced abilities seems to be an excellent mechanism to achieve this. The simulation theory of mindreading and embodied social cognition might thus turn out to be ideal bed partners.

Literature

- Anderson, M.L. (2007). How to study the mind: An introduction to embodied cognition. In: F. Santoianni and C. Sabatano, eds., *Brain Development in Learning Environments: Embodied and Perceptual Advancements*. Cambridge: Cambridge Scholars Press.
- Adolphs, R., Tranel, D., & Damasio, A.R. (2003). Dissociable neural systems for recognizing emotions. *Brain and Cognition*, 52, 61-69.
- Baldwin, D.A., & Baird, J.A. (2001). Discerning intentions in dynamic human action. *Trends in Cognitive Sciences*, 5 (4), 171-778.
- Baron-Cohen, S. (1995). *Mindblindness: An Essay on Autism and Theory of Mind*. Cambridge (Mass.): MIT Press.
- Barsalou, L.W., Niedenthal, P.M., Barbey, A.K., & Ruppert, J.A. (2003). Social Embodiment. *The Psychology of Learning and Motivation*, 43, 43-92.
- Barrett, J.L., & Johnson, A.H. (2003). The role of control in attributing intentional agency to inanimate objects. *Journal of Cognition and Culture*, 3 (3), 208-217.
- Blakemore, S.-J., Boyer, P., Pachot-Clouard, M., Meltzoff, A., Segebarth, C. & Decety, J. (2003). The detection of contingency and animacy from simple animations in the human brain. *Cerebral Cortex*, 13, 837-844.
- Calder, A.J., Keane, J., Manes, F., Antoun, N., & Young, A.W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience*, 3, 1077-1078.
- Carpenter, M., Akhtar, N. & Tomasello, M. (1998). 14- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behaviour Development*, 21, 315-330.
- Chiel, H.J., & Beer, R.D. (1997). The brain has a body: adaptive behaviour emerges from interactions of nervous system, body and environment. *Trends in Neuroscience*, 20, 553-557.
- Clark, A. (1997). *Being there: Putting brain, body, and world together again*. Cambridge, MA: MIT Press.
- Clark, A. (1998). Magic Words: How Language Augments Human Computation. In P. Carruthers and J. Boucher, eds., *Language and Thought: Interdisciplinary Themes* (162-183). Cambridge: Cambridge University Press.
- Clark, A. (1999). Visual Awareness and Visuomotor Action. *Journal of Consciousness Studies*, 6, 1-18.
- Clark, A. (2001). Reason, Robots, and the Extended Mind. *Mind and Language*, 16 (2), 121-145.
- Clark, A. (2008). Pressing the flesh: A tension in the study of the embodied, embedded mind?. *Philosophy and Phenomenological Research*, 76 (1), 37-59.
- Clark, A. & Chalmers, D. (1998). The extended mind. *Analysis*, 58, pp. 7-19.
- Csibra, G. (2004). [Mirror neurons and action observation. Is simulation involved?](http://www.interdisciplines.org/mirror/papers/4). *Interdisciplines.org*, <http://www.interdisciplines.org/mirror/papers/4>.
- Damasio, A. (1999). *The Feeling of What Happens*. London: Vintage.
- Decety, J., & Chaminade, T. (2005). The Neurophysiology of Imitation and Intersubjectivity. In: S. Hurley and N. Chater, eds., *Perspectives on Imitation: from Neuroscience to Social Science: Volume I* (119-140). Cambridge (Mass.): MIT Press.
- Dennett, D.C. (2000). Making Tools for Thinking. In: D. Sperber, ed., *Metarepresentations: A Multidisciplinary Perspective* (17-29). New York: Oxford University Press.
- Gallagher, S. (2001). The Practice of Mind: Theory, Simulation or Primary Interaction?. *Journal of Consciousness Studies*, 8, 83-108.
- Gallagher, S. (2005). *How the body shapes the mind*. Oxford: Oxford University Press.
- Gallagher, S. (2007a). Simulation trouble. *Social Neuroscience*, 2 (3-4), 353-365.

- Gallagher, S. (2007b). Logical and phenomenological arguments against simulation theory. In: D. Hutto and M. Ratcliffe, eds., *Folk Psychology Re-assessed* (63-78). Dordrecht: Springer Publishers.
- Gallagher, V. (2008). Direct perception in the intersubjective context. *Consciousness and Cognition*, 17, 535–543.
- Gallagher, S. & Hutto, D. (In press). Understanding others through primary interaction and narrative practice. In: Zlatev, Racine, Sinha and Itkonen, eds., *The Shared Mind: Perspectives on Intersubjectivity*. Amsterdam: John Benjamins.
- Gallese, V., & Goldman, A.I. (1998). Mirror neurons and the simulation theory of mindreading. *Trends in Cognitive Science*, 2, 493–501.
- Gallese, V. (2004) [Intentional Attunement. The Mirror Neuron system and its role in interpersonal relations. Interdisciplines.org](http://www.interdisciplines.org/mirror/papers/1), <http://www.interdisciplines.org/mirror/papers/1>.
- Gallese, V. (2005a). “Being Like Me”: Self-Other Identity, Mirror Neurons, and Empathy. In: S. Hurley and N. Chater, eds., *Perspectives on Imitation: from Neuroscience to Social Science: Volume I* (101-118). Cambridge (Mass.): MIT Press.
- Gallese, V. (2005b). From neurons to phenomenal experience. *Phenomenology and the Cognitive Sciences*, 4, 23–48.
- Gallese, V. (2007). Before and below ‘theory of mind’: embodied simulation and the neural correlates of social cognition. *Philosophical Transactions Royal Society B*, 362, 659–669.
- Garbarini, F., & Adenzato, M. (2004). At the root of embodied cognition: Cognitive science meets neurophysiology. *Brain and Cognition*, 56, 100–106.
- Gazzola, V., Rizzolatti, G., Wicker, B., & Keysers, C. (2007). The anthropomorphic brain: The mirror neuron system responds to human and robotic actions. *Neuro Image*, 35 (4), 1674-1684.
- Goldman, A.I., & Gallese, V. (2000). Reply to Schulkin. *Trends in Cognitive Science*, 4 (7), 255-256.
- Goldman, A.I. (2004). [Mirror Systems, Social Understanding and Social Cognition, Interdisciplines.org](http://www.interdisciplines.org/mirror/papers/3), <http://www.interdisciplines.org/mirror/papers/3>.
- Goldman, A.I. (2005). Imitation, mind reading, and simulation. In: S. Hurley and N. Chater, Eds., (2005), *Perspectives on Imitation: from Neuroscience to Social Science: Volume II* (80-81). Cambridge (Mass.): MIT Press.
- Goldman, A.I. (2006). *Simulating Minds*. Oxford: Oxford University Press.
- Gopnik, A., & Meltzoff, A. (1997). *Words, Thoughts, and Theories*. Cambridge (Mass.): MIT Press.
- Gopnik, A., & Wellman, H. (1992). Why the child’s theory of mind really is a theory. *Mind and Language*, 7, 145-171.
- Gordon, R.M. (1986). Folk Psychology as Simulation. *Mind and Language*, 1 (2), 158-171.
- Gordon, R.M. (1992). The Simulation Theory: Objections and Misconceptions. *Mind and Language*, 7 (1-2), 11-34.
- Gordon, R.M. (1995a). ‘Radical’ simulationism. In: P. Carruthers and P.K. Smith, eds., *Theories of theories of mind*. Cambridge: Cambridge University Press.
- Gordon, R.M. (1995b). Simulation Without Introspection or Inference from Me to You. In M. Davies and T. Stone, eds., *Mental Simulation: Evaluations and Applications*. Oxford: Blackwell Publisher.
- Gordon, R. M., & Cruz, J. (2003). Simulation theory. In *Encyclopedia of cognitive science*. Vol. 4 (9–14). London: The Nature Publishing Group/Macmillan Reference Ltd.
- Gordon, R.M. (2005). The shared self/other space (and other matters) redux. *Interdisciplines*, http://www.interdisciplines.org/mirror/papers/5/6#_6.

- Grush, R. (2003). In Defense of Some Cartesian Assumptions Concerning the Brain and its Operations. *Biology and Philosophy*, 18, 53-93.
- Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology*, 57(2), 243-259.
- Hurley, S.L. (1998). *Consciousness in Action*. Cambridge (Mass.): Harvard University Press.
- Hurley, S. (2001). Perception and Action: Alternative Views. *Synthese*, 129, 3-40.
- Hurley, S. (2005). Social heuristics that make us smarter: Instrumental rationality, collective rationality, and mind reading. *Philosophical Psychology*, 18 (5), 585-612.
- Hurley, S. (2008). The Shared Circuits Model: How Control, Mirroring and Simulation Can Enable Imitation, Deliberation, and Mindreading. *Behavioral and Brain Sciences*, 31 (1), 1-22.
- Hurley, S. (to appear). "Public Ecology of Responsibility". In: Z. Stemplowska and Carl Knight, *Responsibility and Justice*. (publication negotiations in progress).
- Hurley, S. (unpublished). Commentary on Goldman's *Simulating Minds*. Author Meets Critics, Pacific APA 2007.
- Hurley, S., & Chater, N. (2005). Introduction. In: S. Hurley and N. Chater, eds., *Perspectives on Imitation: from Neuroscience to Social Science: Volume I* (1-52). Cambridge (Mass.): MIT Press.
- Hutto, D. (2007). The Narrative Practice Hypothesis: Origins and Applications of Folk Psychology. In: D. Hutto, (ed.) *Narrative and Understanding Persons*. Cambridge: Cambridge University Press.
- Iacoboni, M. (2005). Understanding Others: Imitation, Language and Empathy. In: S. Hurley & N. Chater (2005a), 77-100.
- Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, G., Mazziotta, J.C., & Rizzolatti, G. (2005). Grasping the intentions of others with one's own mirror neuron system. *PLoS Biology*, 3, 529-535.
- James, W. (1890). *Principles of Psychology*. New York: Holt, Rinehart & Winston.
- Jacob, P., & Jeannerod, M. (2005). The motor theory of social cognition: a critique. *Trends in Cognitive Sciences*, 9 (1), 21-25.
- Johnson, S.J. (2003). Detecting agents. *Philosophical Transactions of the Royal Society London B*, 358, 549-559.
- Keysers, C., & Gazzola, V. (2006). Towards a unifying neural theory of social cognition. In: *Progress in Brain Research*, 156, 379-401.
- Kiverstein, J., & Clark, A. (2008). Bootstrapping the mind. *Behavioral and Brain Sciences*, 31 (1), 41-52.
- Lindblom, J., & Ziemke, T. (2008). Interacting Socially through Embodied Action In: F. Morganti, A. Carassa, and G. Riva, eds., *Enacting Intersubjectivity: A Cognitive and Social Perspective on the Study of Interactions* (49-63). Amsterdam: IOS Press.
- Maurer, D. (1985). Infants' perception of facedness. In: T. Field and N. Fox, *Social Perception in Infants*. Norwood, NJ: Ablex.
- Meltzoff, A. (2005). Imitation and other minds: The "like me" hypothesis. In: S. Hurley and N. Chater, eds., *Perspectives on Imitation: from Neuroscience to Social Science: Volume II* (55-77). Cambridge (Mass.): MIT Press.
- Moore, D.G., Hobson, R.P., & Lee, A. (1997). Components of person perception: an investigation with autistic, non-autistic retarded and typically developing children and adolescents. *British Journal of Developmental Psychology*, 15, 401-23.
- Preston, S.D., & De Waal, F.B.M. (2002). Empathy: Its ultimate and proximate bases. *Behavioral and Brain Sciences*, 25, 1-72.
- Prinz, J.J. (2004). *Gut Reactions: A Perceptual Theory of Emotion*. New York: Oxford University Press.

- Prinz, W. (1997). Perception and Action Planning. *European Journal of Cognitive Psychology*, 9 (2), 129-154.
- Prinz, W. (2005). An Ideomotor Approach to Imitation. In: S. Hurley and N. Chater, eds., *Perspectives on Imitation: from Neuroscience to Social Science: Volume I* (141-156). Cambridge (Mass.): MIT Press.
- Ravenscroft, I. (2004). Folk Psychology as a Theory. *Stanford Encyclopaedia of Philosophy*, <http://plato.stanford.edu/entries/folkpsych-theory/>.
- Svensson, H., & T. Ziemke (2004). Making sense of embodiment: Simulation theories and the sharing of neural circuitry between sensorimotor and cognitive processes. <http://www.cogsci.northwestern.edu/cogsci2004/papers/paper364.pdf>.
- Svensson, H., Lindblom, J. & Ziemke, T. (2007). Making sense of embodied cognition: simulation theories of shared neural mechanisms for sensorimotor and cognitive processes. In: T. Ziemke, J. Zlatev, and R. Frank, eds., *Body, language, and mind: Embodiment* (241-270). Berlin: Mouton de Gruyter.
- Rizzolatti, G. (2005). The Mirror Neuron System and Imitation. In: S. Hurley and N. Chater, eds., *Perspectives on Imitation: from Neuroscience to Social Science: Volume I* (55-76). Cambridge (Mass.): MIT Press.
- Rizzolatti, G., & Sinigaglia, C. (2008). *Mirrors in the Brain. How Our Minds Share Actions and Emotions*. New York: Oxford University Press.
- Scholl, B.J., & Tremoulet, P.D. (2000). Perceptual causality and animacy. *Trends in Cognitive Sciences*, 4 (8), 299-309.
- Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, 28, 675-735.
- Tremoulet, P.D. & Feldman, J. (2000). Perception of animacy from the motion of a single object. *Perception*, 29, 943-951.
- Umiltà, M., Kohler, E., Gallese, V., Fogassi, L., Fadiga, L., Keysers, C., & Rizzolatti, G. (2001). I know what you are doing: A neurophysiological study. *Neuron*, 31, 155-165.
- Wicker, B., Keysers, C., Plailly, J., Rovet, J.P., Gallese, V., Rizzolatti, G. (2003). Both of us disgusted in my insula: the common neural basis of seeing and feeling disgust. *Neuron*, 40, 655-664.