

In the mid 90's there was a major neuroscientific discovery which might drastically alter sport science in general and philosophy of sport in particular. The discovery of *mirror neurons* by Giacomo Rizzolatti and colleagues in Parma, Italy, is a substantial contribution to understanding brains, movements and humans. Famous neuroscientist V. S. Ramachandran believes the discovery of mirror neurons “will do for psychology what DNA did for biology”.<sup>1</sup> Somehow mirror neurons have not received the deserved attention in the philosophy of sport, but perhaps now is the time to reflect on some implications and consequences. The discovery of mirror neurons may increase our insights about our ability to learn, understand, intend and produce skillful motor actions.

In this article I will first examine what mirror neurons are and how they function in monkeys and humans. Second, I will review some objections to the so-called mirror neuron theory of action understanding, and respond to some of these objections. Third, I will inquire into some implications for philosophy, which I believe are also fundamental to several topics in the philosophy of sport. I will then try to relate some of the most interesting aspects of mirror neurons to recent debates by Birch (2009; 2011; 2016), Breivik (2007; 2014), Hopsicker (2009), and Moe (2005; 2007) on knowledge, skill, consciousness and intentionality. Finally, I will speculate on what further neuroscientific research might teach us about the nature of being a moving subject.

## **Finding mirror neurons, finding out how they work**

The discovery of mirror neurons happened almost accidentally. While Rizzolatti and colleagues were doing single-cell recordings on macaque monkeys grasping objects, something extraordinary happened:<sup>2</sup> when an experimenter grasped a cup of coffee, the same neurons fired when the monkey *observed* the experimenter grasping as had fired when the monkey itself had *executed* the act of grasping. Neurons were found in the brain's motor area F5 that responded both when a monkey performed a motor act, and when the monkey observed another monkey or human performing the same act. That was an astonishing incident. It meant action *observation* causes in the observant the automatic activation of the same neural mechanism triggered by action *execution*: the same neurons that are involved in the footballer's execution of the penalty kick, might also fire in the brain of the observer (e.g. the goalie) of that kick. Rizzolatti and colleagues established the hypothesis that contrary to

the belief that the motor system was a purely executive system in a serially organized brain, there were actually neurons that had both visual *and* motor properties, working in parallel. The now famous mirror neurons allow a direct matching between the visual description of an action and its execution. Mirror neurons match movements we observe to movements we can do, and help us understand the actions of others. This is to say that mirror neurons are active to help us understand what is going to happen next when a teammate or opponent is about to make a pass. Let's make a further inquiry into the properties and function(s) of mirror neurons.

It was long believed that neurons and different brain regions had distinct functional properties. Not so. The posterior motor areas (F1-F5) are heavily connected to the parietal lobe and the cingulate cortex, suggesting that sensory information from the parietal lobe is used to organize and control movement by coding the space around us. The motor system works in parallel with the sensory system so that we are able to differentiate objects and implement movements. When long term planning and intentions associated with the cingulate cortex kick in, we may begin to talk about *actions*, not mere mechanical movements. Neuroscientific theories claiming that processes in the brain are widely distributed and work in parallel is not new (see e.g. Baars 1997; Changeux 2004; Edelman 1992), so what is? It is the scientific understanding that perceiving and planning could not be done without a moving body in a world. Without referencing the body, it is impossible to apprehend the distance, orientation and possibilities of objects. What philosopher Evan Thompson (2007, 13-15) calls the enactive approach (see also Ilundáin-Agurruza (2014a) for a nice overview of positions in the so-called program of embodied cognition) is a project trying to “naturalize” phenomenology by integrating neuroscience, psychology and philosophy. Such an approach, could lead to a Khunian paradigm-shift, away from a deconstructive understanding of the body and human behaviour. The parallel workings of the brain are crucial to acting appropriately in the world, and how mirror neurons function implies that the motor system is both part of and a cognitive system in itself.

The best way for evolution to make things happen fast and fluid is to give neurons *more* than one property. Rizzolatti and Sinigaglia (2008, 21) provide an example: picking up an object, say a ball, is a combination of two processes, reaching and grasping. It may seem that reaching precedes grasping, but neuronal recordings show that grasping starts simultaneously as the arm moves to reach. The hand assumes the shape needed to grasp instantly! To grasp something, activation of the primary motor cortex (F1) is required.<sup>3</sup> F1

does not respond to visual stimuli and cannot transform the geometrical properties of an object to make an appropriate grasp. This is done in the F5 (Rizzolatti & Sinigaglia 2008, 22). F5 does not code individual movements but motor *actions*, which are goal directed and hence intentional. Single-cell recordings show that bending a finger when scratching does not activate the same neurons as bending a finger to grasp (Rizzolatti & Sinigaglia 2008, 23). The same mechanical movement has a different *meaning* (they have different (motor) *goals*), and hence different neurons are activated.<sup>4</sup> The mechanical movements in a coin toss and a tennis serve toss might be identical, but since the goals, and hence meaning, are different they have different neural activation. A portion of these neurons in F5 are called *canonical* neurons and respond selectively also to visual objects: an individual neuron fires both when a ring is grasped for (motor property), and when only seen (visual property). The same neuron does not fire when a square is seen, or grasped for (Rizzolatti & Sinigaglia 2008, 26-29). Through what Edelman (1992) calls “neural Darwinism”, or pruning of synaptic connectivity, we learn how different motor responses lead to efficient prehensions (see also Birch 2010). Rizzolatti and Sinigaglia’s (2008, 35, 46-47) interpretation is that F5 contains a vocabulary of motor acts so that we have a repertoire which is at the basis of cognitive functions usually associated with the visual system. Some of the neurons in F5 then, discharge both when we observe, and when we do: the visual and motor responses have the same functional meaning, because the (motor) goal is identical.

Unlike canonical neurons, the mirror neurons in F5 are not activated when observing objects, but when motor actions involve object interaction (Rizzolatti & Sinigaglia 2008, 79-80). Mirror neurons come in classes of specific acts, like grasping, reaching, holding etc. There are two major types of mirror neurons: *strictly congruent* and *broadly congruent*. Some mirror neurons show a strict correspondence between the observed and the executed motor act. Others show a correspondence in the goal of the observed and the executed, but not in the precise movements to achieve the goal (Fogassi et al 2005). If a mirror neuron is strictly congruent it means the observed action and the executed action have virtually identical neural activation. If a mirror neuron is broadly congruent, then the observed and executed acts have overlapping though not identical neural activity. Most of the mirror neurons (70%) seem to be broadly congruent (Rizzolatti & Sinigaglia 2008, 82-84). Finding a strictly congruent mirror neuron is a task for single-cell recording, and in the myriad of neurons very difficult to detect. Finding broadly congruent neurons can be done by techniques like functional magnetic resonance imaging (fMRI), which has been done extensively on human brains.<sup>5</sup> There is a

question, of course, as to whether we should apply the term ‘*mirror neuron*’ to a neuron that is not strictly congruent. This is perhaps why neuroscientists have come to speak of a mirror neuron *system* (MNS), which reflects congruent activity in the same brain region when observing and executing. Upon philosophical scrutiny we might argue that only a system with properties which *appears* to be like mirror neurons has been detected in humans, since there has only been one single-cell recording of what is regarded as mirror neurons in humans (we will return to scepticism regarding mirror neurons below).<sup>6</sup> This aside, what are mirror neurons good for? What is their function?

At first glance we might believe mirror neurons would benefit imitation of other animals’ movements, and hence be beneficial to learning (see below). Rizzolatti and Sinigaglia (2008, 94-97) argue that imitation is involved in the construction of a motor image used in a preparatory stage. The macaque monkey has mirror neurons but does not imitate; only higher primates do. Mirror neurons must hence have an earlier evolutionary origin and another *primary function*, namely *action understanding*: mirror neurons code the goal of actions/motor acts. Since mirror neurons have both visual and motor properties, visual information and motor knowledge can be coordinated. The motor knowledge we possess can be used when observing others. Rizzolatti and Sinigaglia (2008, 106) claim motor knowledge is “of fundamental importance for building a basic intentional cognition”. The mirror neuron system provides the mechanism where an animal combines visual inputs with its motor knowledge to differentiate types of actions, and hence understand the actions of another animal. It means that we do not have to reflect explicitly upon another animal’s actions, but rather can understand directly and make responses quickly if needed. But what do we know about mirror neurons in humans? Is the MNS responsible for the athletic ability of “reading the game”? And is the MNS different in humans and in monkeys?<sup>7</sup>

### **Mirroring in humans**

Electrophysiological techniques like electroencephalography (EEG)<sup>8</sup> have been used on humans to support the claim that there is a MNS in humans as well as in monkeys. In addition, there have been several brain imaging studies (like fMRI) supporting the existence of a MNS in humans, and more is coming all the time (see e.g. Molenberghs et al 2012). Brain imaging localizes brain areas and circuits involved in the MNS, so that it is possible to find *where* the human MNS is. Cytoarchitectonic – the cellular makeup of a structure - differences in the human and monkey brain make areas functional and spatial un-identical, but

at least brain imaging might make us able to know where to start looking when new technology comes knocking. With fMRI (and similar brain imaging techniques), there can only be evidence of a mirror neuron *system*, and the neurons involved cannot be claimed to be anything more than broadly congruent.<sup>9</sup> We are not even sure what the homologue of macaque F5 is, but Rizzolatti & Sinigaglia (2008, 121) suggest it is Brodmann's area 44 (BA 44). Others (see e.g. Morin & Grèzes 2008) have suggested BA 6. Empirical evidence shows that compared to monkeys, the human MNS has more cortical space, responds also to non-object related arm movements and codes temporal aspects of individual movements (Rizzolatti & Sinigaglia 2008, 115-118, 124). This probably means that the human MNS has more fine-grained action understanding, and may even have other functions. What might they be?

Although macaque monkeys do not imitate, humans do. Might the MNS be involved in imitation, and the transmission from observing actions to learning motor and sporting skills (see Hurley & Chater 2005)? Research on mirror neurons is putting its mark on imitation learning for the sport sciences, nicely reviewed by Vogt and Thomaschke (2007). Rizzolatti and Sinigaglia argue that “the mirror system is involved in the imitation of acts already present in the observer's motor repertoire, suggesting an immediate motor translation of the observed action” (2008, 143). They imply that mirror neurons are involved in imitation, but *not* in *learning* completely new movement patterns. In addition to the MNS we must have a control system that inhibits motor movements. If not, we would replicate every movement we observed. So, if we are to learn by imitation, mirror neurons might be a necessary but not sufficient condition (Rizzolatti & Sinigaglia 2008, 148-153).

The subject of observational learning is also of interest to sport science, and mirror neurons might play a role here too (see e.g. Lago-Rodríguez et al 2014; Stefan et al 2005; Van Gog et al 2009), although Rizzolatti downplays this part. If the MNS does in fact contribute to observational learning, it would appear to be beneficial whenever we are observing experts on the driving range, swinging a racket or throwing/catching a ball. Neuroscientific research on mirror neurons might thus change or influence both instruction and learning protocols in sport and elsewhere: knowledge about how much (or how little) practice (5, 10 or 20 repetitions of a movement sequence) it takes to cause synaptic growth (see Kandel 2006) would be immensely beneficial. Rizzolatti does not *deny* that the MNS impacts learning; he is merely claiming that learning is not the primary function of the MNS. The main reason is that mirror neuron activity is increased by already present (motor) knowledge, so mirror neurons do not

seem to be involved in learning movements from scratch. Mirror neuron activity might modify or enhance skills and motor knowledge though. Maybe we should say that learning enhances the MNS more than vice versa; learning a wide repertoire of movements seems to increase activity in the MNS. We will see later that an enhanced MNS has the consequence of recognizing subtle differences in actions, so learning motor skills through physical practice and mirror neuron activity are certainly connected. If a goalie is a skilled penalty shooter, then this seems to be beneficial to understanding what another penalty shooter is going to do. The possibility of a save might be higher. If it is action understanding and not learning that is the primary function of mirror neurons, we might claim that mirror neurons contribute more to a philosophical than a pedagogical theory. But there are voices arguing that mirror neurons do not play a role in action understanding at all. Let us listen to one of the loudest and sharpest.<sup>10</sup>

### **Hickok's critique - and some answers**

We must be cautious not to be seduced by motor theories, be they of language, perception or cognition. As philosophers of sport, it is of course easy to be against intellectualism (see e.g. Noë 2005) and embrace theories which emphasize the importance of embodiment and motor action. Perhaps we are too easily led astray by say the philosophy of Merleau-Ponty, the ecological psychology of Gibson, or in this case the mirror neuron theory of action understanding. Philosophers of sport would be good sports if they were the most skeptical of such accounts. We must not forget that there is overwhelming empirical evidence that cognition can be dissociated from body and movement (see e.g. Milner & Goodale 1995). This is perhaps one of many reasons why most of traditional philosophy is still occupied with theories not involving body or movement. It is a sound endeavor therefore to scrutinize the mirror neuron theory of action understanding; *especially* if we favor it and feel that a motor theory (of e.g. cognition) just is *it*. In the following then, I will present some serious objections to the mirror neuron theory of action understanding. I will also give some comments on how/whether these objections can be met. This part will also hopefully give us a deeper understanding of the MNS and the theory of action understanding.

Gregory Hickok (2009; 2014) raises some difficulties for the mirror neuron theory of action understanding, all of which stem from skepticism towards any motor/embodied theory (Hickok, 1229). Hickok's problems are based mainly on a critique of inferring mirror neurons

from (macaque) monkeys to humans. I will briefly present some general objections before moving to seven particular problems.<sup>11</sup>

Hickok (2009, 1230-31) initially complains that it is not clear what ‘action understanding’ means in different texts, by the same or different writers, and in different experiments. This is of course a problem, but not particularly for Rizzolatti and other mirror neuron proponents. This is a problem that encounters any enterprise in its infancy. Nor should we forget that philosophers have argued for centuries, and probably always will, about the meaning of concepts like ‘action’ and ‘intention’. In the philosophy of sport we are still arguing about what skill is, and what kind of knowledge a skill is (see e.g. Birch 2016; Breivik 2014). We should not demand too much of semantics in the neuro-department, but like Hickok we should urge for consistency. In Rizzolatti and Sinigaglia’s pivotal book they take ‘action understanding’ to mean “to immediately recognize a specific type of action in the observed ‘motor events’”, “movements take on meaning for the observer” who “*perceives the meaning* of these ‘motor events’ and *interprets them* in terms of an *intentional act*” (2008, 97-98). Action understanding must thus be understood as perceiving and interpreting motor events as intentional acts; as recognizing and differentiating between classes of actions by coding goals. The MNS is regarded as a direct neural mechanism doing this so we can use observations to respond in the most appropriate manner, *without* explicit, conceptual or reflective thought. Rizzolatti and Fogassi (2014) call this ‘automatic understanding’: an understanding without inference. Embodied theories of cognition which lack conceptual content are what Hickok generally opposes. Hickok does not deny the existence of mirror neurons *per se*; he denies that their (primary) function is action understanding.

Hickok (2009, 1231-33) first argues though, that the function of mirror neurons is not action understanding in monkeys either: there is simply *lack of evidence* for such a claim. If the core claim of the mirror neuron theory is undermined, there really isn’t much left. Hickok’s hypothesis is that lesions to F5 in monkeys should disrupt action recognition. But this kind of evidence is scarce or variable. It also follows that if one does have action understanding when F5 is impaired, then mirror neurons are not the sole mechanism for action understanding. Hickok argues there are indeed ways to represent and understand actions without the brain areas of the MNS, and that only a small percentage (15%) of the mirror neurons in F5 seem to code the meaning/goal of a motor act. This would also indicate that action understanding is not the only thing the MNS is involved in, but it might still involve the highest amount of mirror neurons for any one particular function. This does not mean that

mirror neurons are not involved in action understanding. It is merely to say that there might be different ways to, and other areas involved in, action understanding. This is Hickok's second objection.

Hickok (2009, 1233) argues that the existence of *other mechanisms for action understanding* suggests that it might be difficult to distinguish action understanding from object understanding. Cells in the superior temporal sulcus (STS) do not have motor properties, but have been found to be involved in action understanding. There might be a circuit coming from STS to F5 suggesting that action understanding is achieved primarily through perceptual object recognition and leaving mirror neurons to a mere executive motor command. That there are other areas involved in action understanding is perhaps not the greatest threat to the mirror neuron theory of action understanding. It is commonly accepted that neuronal activity is widely distributed in the brain (see e.g. Baars 1997), that different brain areas work in parallel and loops (see e.g. Edelman 1992; 2006) and that this differs even at an individual level (see e.g. Changeux 2004). The mirror neuron theory simply claims that mirror neurons (perhaps amongst many) are indeed involved in action understanding, and at some level even primary (for mouth/hand grasping/gripping).

The third problem is that mirror neurons have been found in *other locations than F5*. That there are mirror neurons outside F5 does not in itself weaken the mirror neuron theory of action understanding. It is an empirical question as to whether the functional properties of mirror neurons are also to be found elsewhere. If so, fine. That might just be an indication that several types of cells in the brain have other functions, properties or connections than scientists originally believed. We are perhaps beginning to see that the brain is not organized neatly, but is complex to the degree neuroscientist Edelman (1992, 29) calls an ever-changing, intricate jungle.

The fourth problem confronts the grounds for *inferring from macaque to human*. Hickok (2009, 1234-1235) argues we have to consider at least three possibilities concerning mirror neurons in monkeys and humans: 1) Mirror neurons do not exist in humans, 2) Mirror neurons are exactly the same in monkeys and humans, 3) Mirror neurons in humans have evolved to be involved in higher-order cognition. The first two possibilities have not been ruled out empirically, and it is therefore a sound scientific attitude to hold one of these possibilities, according to Hickok. After all, the single-cell recordings on humans by Mukamel et al (2010) do not set out to *falsify* the existence of mirror neurons. This is not to say that the mirror neuron theory of action understanding regarding monkeys is false. But if



one adopts the third possibility, which according to Hickok mirror neuron proponents too often do, it is not necessarily true regarding humans.<sup>12</sup> That there is a difference between mirror neurons in humans and monkeys is due to a general difference between these species. Neuroscientists working within evolutionary theory (see e.g. Gazzaniga et al 2002, ch. 14) agree that the neural networks and pathways in humans are somehow pruned (see Edelman 1992, 2006), epigenetic (see Changeux 2004), and make new connections and synaptic growth at a completely different level than any other primate, including chimpanzees, gorillas and macaques (see LeDoux 2002, ch. 3-4). This is evident in our relatively long (social) learning phase, compared to other mammals and primates. Even our gene expression changes throughout life to a great degree (Kandel 2006), and this is a necessary requirement for our formidable ability to adapt and learn (by synaptic plasticity), both in daily life and sport. Our human nature is a nature of nurturing, and so is perhaps the MNS (Calvo-Merino et al 2005, 1246-48; Rizzolatti & Sinigaglia 2008, 130). As we have seen, mirror neurons are linked to the F5 in macaque monkeys and it is not clear what the equivalent brain area is in humans. Hickok soundly questions the empirical basis for extrapolating the existence of a MNS to humans. This problem might be resolved in the (nearby) future if/when more single-cell (or similar) recordings are gathered from humans. Until then, we will basically only have brain imaging like fMRI showing (increased) brain activity in brain regions *supposedly* having mirror neurons. Hickok is of course right when he warns to make claims about functional properties across species when location does not hold across species. But that does not mean there isn't a MNS for action understanding in humans.

The fifth and sixth problems raise the question whether *the mirror neuron system can be dissociated from action understanding* in humans. Hickok (2009, 1235-37) argues that the MNS is not a *necessary* requirement for action understanding in humans, since other brain areas without mirror neuron properties are also involved in action understanding, and that we are indeed capable of understanding actions we have never performed ourselves (without having motor knowledge of a certain action). The mirror neuron theory implies that if one cannot produce types of actions, one will also have trouble understanding those actions. But this does not seem to be the case, since even people born with serious movement deficiencies seem perfectly qualified to understand the actions of others. Hickok also points to the absurdity of mirroring in the literal sense: we would produce the same movement we observe *if* neuronal events were in fact truly mirrored. This would be counterproductive; meeting a basketball lay-up with a lay-up and not a block. At some point then, action observation,

understanding and production must come apart. That would make the mirror neuron system's properties and functions appear meaningless. Although important, this critique is not as devastating to the mirror neuron theory of action understanding as it seems.

That action observation, understanding and production *can* come apart both intellectually and neurally, does not disprove that mirror neurons have both visual and motor properties. It is just to say that many brain areas and circuits work together. This fact is appreciated by Rizzolatti and Sinigaglia (2008b; 2010). Their claim is that mirror neurons might be a platform from which we can have more efficient and fine grained understandings of actions. Without the MNS, fast and fine grained understanding of motor goals might be impaired. Rizzolatti and colleagues have never argued that mirror neurons fire identically on a group level. That would indeed be counterproductive. Mirror neurons are, as stated above, more or less congruent. We have activity in the motor cortex just by visualizing movements (and strongly congruent as well, see e.g. Jeannerod & Frak 1999), but the neural activity is not strictly *identical*, because at some level we also have inhibition. Interestingly, Mukamel et al's (2010) single- cell recording of mirror neurons in humans found inhibitory activity in mirror neurons.<sup>13</sup> They argue mirror neurons work as a control mechanism to differentiate the actions of others from those of oneself, and as such inhibit unwanted imitation or action. If we didn't have such a mechanism, we could never visualize, fantasize, or imagine without producing movements. Mirror neurons help us both to understand the goal of an action, *and* come up with an appropriate response. The final responsive (motor) action is the sum of several events going on, not only the firing of mirror neurons. In this way, action understanding and production both can and cannot come apart. Without the MNS, a goalie might not have the time to react appropriately when say a hockey shot is fired. This is in fact a problem for the serial information processing theorist, like Hickok seems to be. Given the time course of neuronal events, there simply isn't time for the brain to first calculate an outcome, and then come up with responses if a puck or a tennis ball travels fast enough (see Milton et al 2008, 44-47). The mirror neuron theory might explain how we are able to respond appropriately then, contrary to Hickok's suggestion that mirror neurons would produce identical actions.

Hickok's (2009, 1237-38) seventh problem concerns the *location of F5 in humans*. If F5 is analogue to BA 44/6, then damage to this latter region should cause impaired action understanding. But that does not seem to be the case. Since the exact location(s) of the MNS in humans is not established, this is no broadside to the theory and I will leave it at that. We

may summarize Hickok's important critique by urging ourselves not to jump to conclusions, especially when empirical evidence is (relatively) sparse, and activity in the MNS *might not* indicate action understanding. Whether we like it or not, we must also recognize the possibility that action understanding, abstract representation and thought seem to work quite well in humans without motor knowledge, skills or maybe even a MNS. Neither must we forget that there *is* a huge amount of evidence (see e.g. Gallese et al 2009, 105; Rizzolatti & Sinigaglia 2010) supporting the mirror neuron theory of action understanding – and more. Mukamel et al's (2010) single-cell recording suggests mirror neurons exist in several human brain areas: hippocampus, parahippocampal gyrus, entorhinal cortex and supplementary motor area. They suggest mirror neurons are involved in memory functions, inhibition of imitation, self-recognition and emotional understanding. Let us continue our discussion with the following attitude: suppose the mirror neuron theory of action understanding is true; what then? What would this mean for philosophy in general and philosophy of sport in particular?

### **Philosophical implications**

There are several important philosophical consequences if we take the mirror neuron theory of action understanding to be true. One implication of mirror neurons is questioning the intuitive view held by many analytical philosophers that the causal chain of intentional action goes from a desire/belief (in the brain) to the arm in a serial order. Single-cell recordings show that in reaching and grasping for food the arm moves without any *declarative* intention, and contractions in the hand may start before movement of the shoulder (Rizzolatti & Sinigaglia 2008, 21-25). That is to say, motor actions are intentional in themselves, *and* information processing theories are undermined. This paves way for two consequences I will focus on here:

1) Motor actions are intentional and thus cognitive. Epistemology cannot stick to the idea that knowing how (motor knowledge) without propositional content is not proper knowledge.

2) The mirror neuron theory of action understanding supports a motor theory of mind. A consequence for the philosophy of mind should be an increased interest in the moving body, motor action and sport.

I will briefly elaborate on these issues, and then try to relate them to more specific concerns in the philosophy of sport.

### **Motor actions are cognitive at their most fundamental level**

The view that the motor system is simply an executive system without any perceptive- or cognitive elements is challenged by the discovery of mirror neurons. Mirror neurons in the motor system are much more complex than classical cognitivism has recognized. Mirror neurons discriminate sensorial ‘information’ and code it on the basis of potential acts (gripping, reaching, bringing towards). To separate intention from movement is in this light perhaps a mistake. It is quite seldom (if at all) that we merely move our limbs randomly like autumn leaves; instead we are goal-directed. Without diverging into a discussion of the philosophy of action, we might say that we perform intentional actions, not mere mechanical movements.<sup>14</sup> The mirror neuron theory also aligns well with the phenomenological stance for which movement is crucial for cognition. As we have seen, some of the neurons in F5 discharge both when observing and performing motor actions: the motor and visual responses have the same functional meaning/goal. The consequences are crucial for philosophy, sport science and philosophy of sport: the mirror neuron theory supports the notion of movement as cognition (see Birch et al in press). The motor cortex of the brain is thus not merely executing movements, but intentional actions. With the discovery of neurons with both visual and motor properties, the distinctions between perception, cognition and movement are being more than bridged. They are being intertwined, perhaps even brought together as one. Rizzolatti and Sinigaglia claim that motor knowledge is necessary to understand the intention and goal of actions. The whole idea that actions and intentions are solely guided by declarative beliefs or desires is seriously wounded. Perhaps we should abolish the distinction between knowing that and knowing how all together (see e.g. Krakauer & Stanley 2013). This would truly change epistemology because analytic philosophy has hardly recognized knowing how as proper knowledge at all, sticking instead to propositional knowledge that can be given truth values. Maybe it’s not language after all, that is primary in everything that the so-called mind does.

### **A motor theory of mind?**

Philosopher Alvin Goldman (2006) argues that mirror neurons might be the fundament for a simulation theory of mind. Goldman has collaborated with Vittorio Gallese, who is one of Rizzolatti’s closest research partners. Goldman attacks what he calls a theory-theory of

mind. His attack resembles Moe's (2005) critique of classical cognitivism and information processing theory. Goldman argues that understanding low-level emotions (disgust, fear, anger, surprise, sadness, happiness) is not something we do by means of reasoning (through theory, propositional content or information processing). Instead, evolution has brought forward a faster and more direct way of recognizing emotions, namely simulation. Goldman uses evidence from cognitive neuroscience to argue that if you have not experienced a basic emotion yourself, your recognition of such an emotion is heavily impaired. In contrast to Hickok's arguments above, Goldman refers to a vast number of lesion studies which show that persons with damage to brain areas (like the amygdala) involved in experiencing a type of emotion (like fear) have problems detecting facial expressions of that same type of emotion. This is an analogue to the work of Rizzolatti: if you cannot do, you cannot understand – if you cannot experience, you cannot recognize (see also Birch 2009). If we cannot reduce first-person experience to third-person description, this amounts to saying an experience cannot be known in any other way than by being there/doing it.<sup>15</sup> Rizzolatti and Sinigaglia (2008, 138) insist that mirror neurons give an observer a first person grasp of the motor goals and intentions of others that we have yet to find elsewhere. This is also to say that we might actually have a neurophysiological mechanism for what is known as phenomenal consciousness in analytic philosophy. In the philosophy of sport, Birch (2009) argues that phenomenal consciousness of how something feels is an essential part of sporting skills.<sup>16</sup> Goldman argues that the neurophysiological mechanism for understanding emotions is the same as understanding bodily actions.<sup>17</sup> This is why Goldman's work is interesting also to the philosophy of sport: understanding emotions and actions is essentially the same. And if so: knowledge of so-called mental states and motor knowledge is essentially also the same. If Goldman is right (and Hickok wrong), it puts motor knowledge on par with what has traditionally been called cognition and this insight may seriously undermine the (Cartesian) divide between body and mind. An empirically supported motor theory of mind has consequences for the philosophy of mind by questioning whether mind, the mental and cognition is something essentially different from body and motor action. Our body and motor actions then, might very well be the hub of our thoughts.

### **Mirror neurons in the philosophy of sport**

Motor theories of mind are not new to the philosophy of sport. What is new is the empirical foundation the discovery of mirror neurons provides (if Hickok's critiques can be met). Neuroscientific explanations of how the brain and the rest of the body work in conjunction with the world should be welcomed by philosophers of sport who have held similar philosophical views. Neuroscientific discoveries have implications ranging from learning protocols (in sport and elsewhere) to epistemological and metaphysical questions concerning the human body. In this article though, I will highlight a discussion recently brought up again by Hopsicker (2009). When Hopsicker extended the contributions made by Breivik (2007; 2014) and Moe (2005) on consciousness and knowledge in skilled motor behavior, he said it is those things we do not declare that deserve attention. As we have seen, mirror neurons function in the interplay between the non-declarative, intentionality and prior knowledge. In this section I will try to relate the discussion above on mirror neurons to the contributions by Breivik, Moe and Hopsicker.

To get a better grasp of intentional movements in sport, Moe first raised critiques against information processing theories held by cognitivists. Moe's arguments came from Dreyfus' (1992; 2002) anti-representational/anti-rule account and Searle's (1992) neurobiological theory of consciousness. Breivik criticized Dreyfus' view of absorbed coping. Breivik argues that Dreyfus treats the athlete as mostly mindless, and hence underestimates conscious attention in (elite) performance (see also Birch et al in press). Hopsicker follows Moe and Breivik by analyzing the 'background' and 'attention'. Hopsicker turns to Polanyi to "examine kinds of knowing and how our intellect operates at the tacit and focal levels during the learning and performance of complex motor activities" (2009, 76). I hope to make a contribution to this discussion by moving into the domain of contemporary neuroscience.

In the information processing theories Moe (2005) criticizes, the motor system is regarded as an executive system without any perceptual or cognitive elements. Since recordings of mirror neurons suggest that there is a *direct* link between seeing and doing, there is no *processing* of information in the way information processing theories describe. Rizzolatti and Sinigaglia (2008, x- xi, 3, 17-21) argue that we cannot any longer support the view that perception, cognition and movement are distinct modes. The neuroscience of mirror neurons gives heavy empirical artillery to Moe's (and Ilundàin-Agurruza 2014a; 2014b) arguments against information processing theories and (classical) cognitivism.<sup>18</sup>

In the discussion of mirror neurons above, we have seen that having motor knowledge is what makes the MNS efficient. Having motor knowledge and a mirror neuron system is certainly a great benefit in evolutionary terms. It means one gets a better prediction of what is going to happen, and a better possibility of making an efficient response. The link to sport is evident: having a well developed MNS and motor knowledge help us understand what an opponent is going to do: you are better at predicting the trajectory of a ball even if you have seen only a portion of the opponent's motion. We can even unmask tricks and concealed moves, as in a football dribble. As we have already seen, a grasp starts simultaneously as an arm reaches. When observing someone move, the mirror neurons in our brain coding for a goal directed and *intentional action* start firing at the first minor twitches of the other person. Mirror neurons combined with motor knowledge enable us to understand a motor action at an incredibly early stage (Rizzolatti & Sinigaglia 2008, 110-114). Without mirror neurons, the tennis ball served by Djokovic would probably be way behind Federer before his arm began to move. Thanks to the MNS, already in the throw up an expert begins to understand where the ball is coming and start a countermove. Motor knowledge is part of what Searle and Moe call 'the background', which again makes us both understand and produce intentional actions. Rizzolatti and Sinigaglia (2008, 124-125) also argue that human action understanding based on motor knowledge is done pre-reflectively and non-conceptually. The human MNS might be interpreted as *tacit* knowledge. As we shall see below, there are several reasons to believe that the MNS is trainable and different at individual level. The MNS then, plays a role in what Polanyi (1962) called 'personal knowledge'.

### **Nurturing a mirror neuron system**

The 'background' and the tacit knowledge discussed by Moe and Hopsicker are the result of experience. They are nurtured rather than the product of nature. When the MNS is considered the result of evolution it is perhaps easy to think of it as a static system rising from DNA structures which are not trainable.<sup>19</sup> But empirical evidence from sport-related studies actually supports another interpretation. In a fMRI study by Calvo-Merino et al (2005) on expert ballet dancers, experts in capoeira and non-expert control groups the following results emerged: the experts had stronger activation than non-experts in brain areas typically associated with the MNS when viewing videos of ballet and capoeira. But not only that: the expert ballet dancers had stronger activation when watching ballet than capoeira, and the

capoeira experts had stronger activation when watching capoeira than ballet. Both expert groups had stronger activation than the non-experts when watching videos of their non-expert domain. These findings suggest that a MNS is important for skillful motor behavior, and might be developed through training and experience. Similar results have been found in basketball players (Aglioti et al 2008), where also decision making abilities have been linked to the MNS. This kind of research shows how neuroscientific studies on mirror neurons is directly influencing sport science.<sup>20</sup> The trainability of the MNS (e.g. the difference between experts and novices) is also an answer to the problem raised by Hickok against motor knowledge as a necessary requirement for action understanding: action understanding is a matter of degree, and Calvo-Merino shows us that more/better motor knowledge enables a more fine grained (better) action understanding. Rizzolatti and Sinigaglia (2008, 136-138) argue that motor knowledge is decisive to *understand* the *meaning* of actions of others. Hence, it is suggested that motor knowledge is cognitive knowledge.<sup>21</sup> For sporting skills, it may also suggest the following: action understanding in team sports like volleyball, ice hockey and baseball, and individual sports like tennis or boxing (where we respond to the actions of an opponent) is enhanced by the MNS. Our sensitivity to another's motor goals and intentions is better if we have expertise in the specific motor area. For example, experts have stronger neural activity in the MNS and can predict the outcome of motor actions better than novices on the basis of observing only the initial motor action (see Lago-Rodríguez et al 2014). Mirror neurons are a part of skillful motor behavior, especially in sports where understanding of others' actions are important. As Rizzolatti's philosophical right hand, Sinigaglia (2009, 320) states: the MNS is trainable so that a wide platform of action production enables action understanding. Simply put: the more you can *do*, the more you *know*, making adequate (and creative) responses easier to come up with.<sup>22</sup> This might not come as a surprise to sporting people, but the mechanisms of the MNS give us insight into what goes on in the brain when we do come up with an adequate response. That is after all considerable scientific progress. Motor knowledge involved in action understanding is background knowledge, but it is also tacit knowledge: motor knowledge involved in action production and understanding does not have to be declarative, or rise to the conscious attention Breivik (2007) claims is *also* important in skillful motor behaviour. That we do not have direct declarative conscious access to the neurophysiological mechanisms of mirror neurons is not to say that athletes are nonconscious as Dreyfus claims. It is merely to say that consciousness is directly evident in the actions, if we catch Rizzolatti's drift about motor



actions being cognitive in themselves. Athletes do not have to make the background (Polanyi's subsidiary awareness) rise to conscious attention (Polanyi's focal awareness – being aware of the content of thought) because they *know* what they can *do*, and in this lies their ability also for action understanding and appropriate (or surprising) responses. The direct matching mechanisms of the MNS enable us to explain how we can be intentional, cognitive and conscious even though knowledge remains tacit and in the background. The obviously cognitive capacity of understanding intentional motor actions seems to be underpinned by trainable motor skills, which are also tacit and in the background.

Let us now sum up what all the hype is about, and what some consequences are (see also Kilner and Lemon 2013). First and foremost, mirror neurons have visual *and* motor properties. This again implies that both visual and motor responses have the same functional meaning; they have the same goal. In other words: the discharging of neurons is the same in a person hitting a home run, and in you observing that action. This is also to say that the motor system is not solely a final stage in the brain for execution, but a cognitive system in itself. Rizzolatti and Sinigaglia (2008, 50-51) describe this as “seeing with the hand”. If we relate this to debates on knowledge, skill, consciousness and intentionality by Birch, Breivik, Hopsicker, Ilundàin-Agurreza and Moe, we see that the properties of the MNS provide the possibility of an extended consciousness where the hand or the hammer “sees the nail” (Hopsicker, 79-80), and gives us a neurophysiological explanation of why we do not have to reflect declaratively when performing a skill. We do not need to have focal awareness or conscious attention on all the subsidiaries/background because there is a direct link between the object (the nail), the grasping of the hand, and the intention of hammering. The discovery that mirror neurons have visual and motor properties undermines the idea of distinct and serial processes in the brain. There is not a perceptual stage, then a cognitive stage and finally a motor stage. There are parallels, loops and sometimes perhaps only one thing. Rizzolatti and Sinigaglia's (2008, x- xi, 3, 17-21) empirically-based claim that there is a *direct* link between seeing and doing lends strong support to Moe's (and Ilundàin-Agurreza's) rejection of information processing theories and (classical) cognitivism. The unity of visual and motor functions in mirror neurons secures a fast and fluid understanding and production of intentional skillful actions. When we try to understand how to do, imitate, remember and reproduce, mirror neurons also seem to play a role. Mirror neurons are an important tacit component of our background knowledge in sport.

## So far and in the future

Let's say we take Goldman's simulation theory of mind to mean that understanding *emotion* is an understanding of bodily *action*. If read this way, understanding another's mind is understanding another's body, and vice versa. It is a view of an *extended* mind (see also Clark 2008) – extending the mind beyond brain to body and world. We understand both low level emotions and motor actions through bodily observation. Recognizing and understanding emotions and motor actions seem to presuppose the ability to experience the emotion/action. There is a link between the mirror neuron theory and the popular discussion of phenomenal consciousness (subjective experience; how something *feels*) and psychological consciousness (e.g. cognitive awareness and understanding; what consciousness *does*) (See Birch 2009; Cappuccio 2017; Chalmers 1996). We might wonder if biological creatures like humans could really have the one without the other. This is an important message to take home: if the neat distinction between phenomenal- and psychological consciousness is heavily undermined, then research on human cognition should/could not be continued without including the first person perspective of phenomenality, even when studying tasks like memory or visual attention. The same goes for research on skills and knowledge in sport (see Birch 2009). How something feels (see Nagel 1974) is an integrated part of remembering things, focusing on a task and making a decision (see also Damasio 1994). What Polanyi and Hopsicker call 'dwelling' (how subsidiaries merge into focal awareness) must be brought into the picture when studying human cognition, skill and intentionality. To study mere attention (Breivik's 'conscious attention' or Polanyi's focal awareness) then, without what Polanyi and Hopsicker have called tacit knowledge, Birch's usage of phenomenal consciousness and Searle's and Moe's 'background', simply does not make much sense. Why? There just wouldn't be any focal/conscious attention without the background/tacit knowledge. There would be no starting point, no idea of what to focus on, no shoulders for the eye's spotlight to rest upon. This philosophical point, brought forward again by Hopsicker has drastic consequences for research methodology and goals in, for example, (sport) psychology. We might say that the mirror neuron theory of action understanding supports Ilundáin-Agurreza's (2014a) demand for a more phenomenologically oriented methodology concerning both consciousness, skill and intentionality.<sup>23</sup>

If the interpretive and empirical challenges concerning the mirror neuron theory can be met, then it might be true that mirror neurons will eventually do for psychology what DNA

has done for biology. The consequences for sport science are perhaps just as enriching. We have seen that the discovery of mirror neurons has implications for imitation, learning, emotions, intentions and understanding. Moreover, the mirror neuron theory of action understanding presents us with a fundament for a philosophical theory with at least the following suggestions and intriguing ideas suited for further research: <sup>24</sup>

First and foremost, the mirror neuron theory of action understanding provides an empirically based ground for rejecting both a dualistic and an information processing view of the mind, intentionality and skill. Instead, the mirror neuron theory provides us with a view in which motor action is cognition in itself. This popular view in the philosophy of sport now suddenly has support from the most advanced neuroscience. The mirror neuron theory of action understanding is a motor theory of understanding the intentions of others. It is a theory of both how cognition and the body work, although the distinction between body and cognition might be eliminated, or at least: reconceptualised (see e.g. Ilundáin-Agurruza 2014b). Furthermore, the theory makes us see that cognitive skills and motor skills are at heart (or at neuron if you will) the same. It supports Breivik's claim that consciousness and skill are intertwined, and that skillful motor behaviour is not, as Dreyfus argues, mindless (see also Birch et al in press). Treating non-declarative motor actions as cognitive makes the distinction between knowing that and knowing how blurry. Attempts to reduce knowing how to knowing that (see Stanley & Williamson 2001; Birch 2016; Breivik 2014) are undermined. Finally (and more speculatively); if mirror neurons are important in social cognition, we might even have a neurotheory of ethics (see Rizzolatti & Sinigaglia 2008, ch. 7). Perhaps we have a neural mechanism underpinning empathy and Levinas' (1961) notion of 'the other'. This has implications for numerous ethical issues in the philosophy of sport: violence, sportsmanship, ethos and cheating. It is a long leap from the mechanism of mirror neurons to doping behaviour, but without recognizing emotions or reactions in the other it is perhaps difficult to establish a personal morality. Combining for example Jeffrey Fry's (2000; 2003) work on emotions and suffering and Goldman's simulation theory on the one side, with Rizzolatti's work on mirror neurons and LeDoux's (2002) work on the amygdala on the other, might be a start in such a direction.

The mirror neuron theory has far reaching consequences worth taking seriously in the philosophy of sport. From the fundamental theory of the body as a direct matching organism and not as a serially organized unit, to understanding and doing intentional motor behaviour and sharing emotions on the field; mirror neurons are pertinent for several aspects of sport.

With mirror neurons, Polanyi's and Searle's philosophy might also have found a neurophysiological fundament not easily swept under the carpet.

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<sup>1</sup> [http://www.edge.org/3rd\\_culture/ramachandran/ramachandran\\_p1.html](http://www.edge.org/3rd_culture/ramachandran/ramachandran_p1.html).

<sup>2</sup> A single-cell recording measures neural events (action potentials) in the brain by inserting electrodes into axons and/or dendrites.

<sup>3</sup> Primary motor cortex is often referred to as M1. Rizzolatti and Sinigaglia use F1.

<sup>4</sup> Rizzolatti and Fogassi (2014) distinguish between (mechanical) *movements* (the flexion of a finger), *motor act* (movements to achieve a specific goal: flexing a finger to grasp) and *action* (a series of linked motor acts: reaching, grasping and bringing food to the mouth to eat).

<sup>5</sup> fMRI measure changes in metabolism or blood flow in the active brain. With fMRI, imaging is focused on the magnetic properties of haemoglobin. The fMRI detectors measure the ratio of oxygenated to deoxygenated haemoglobin – called the blood oxygenation level dependent effect (BOLD). For a more extensive treatment of the methods of (cognitive) neuroscience, see Gazzaniga et al (2002, ch. 4).

<sup>6</sup> Mukamel et al (2010) recorded extracellular activity from 1177 neurons in 21 epileptic patients.

<sup>7</sup> As I have already stated, there is the problem of attaching mirror neurons in the strict sense to humans due to lack of single-cell recordings.

<sup>8</sup> EEG provides a continuous recording of overall brain activity through electrodes placed on the scalp, which measures large, active populations of neurons producing electric potentials (see Gazzaniga et al 2002, ch. 4).

<sup>9</sup> Brain imaging cannot distinguish between inhibitory and excitatory activity in neurons. This means that we can only see similar activation, but not what kind. Although spatial and temporal resolution in fMRI is increasing all the time, neither localization nor firing rate can be established at the level of identity by brain imaging techniques.

<sup>10</sup> Other objections have been raised by De Jaegher and Di Paolo (2007), and Hutto (2008). Sinigaglia (2009, 322-325) has tried to conciliate these objections. See also Csibra (2007).

<sup>11</sup> Hickok also objects to the lack of empirical support for a generalization of a mirror neuron system to speech recognition (problem number eight). This critique is mostly connected to theories linking mirror neurons and early language learning. It does not seem to be the most crucial issue for philosophy of sport, and will not be discussed here.

<sup>12</sup> Mukamel et al (2010) argue there is no denying the similarities between monkeys and humans regarding the matching mechanism of mirror neurons.

<sup>13</sup> See also Vigneswaran et al (2013).

<sup>14</sup> In discussing fine grained vs coarse grained individuation of actions, mirror neurons support a coarse grained approach; probably more coarse grained than say Davidson's account (see e.g. Davidson 1963).

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<sup>15</sup> An example: analytic philosophers have tried to resolve Jackson's (1986) 'knowledge argument' by claiming what Mary learns is a knowing how which is not considered knowledge, and hence Mary does not know anything new when seeing colours. This answer is perhaps excluded by the mirror neuron theory.

<sup>16</sup> See also Chalmers (1996).

<sup>17</sup> The same claim is raised by Rizzolatti and Sinigaglia (2008, 130, ch. 7). Mukamel et al (2010) found mirror neurons were active in both facial emotional expressions and hand grasping actions.

<sup>18</sup> I state 'classical' in parenthesis because connectionism might also be undermined by these discoveries. Evan Thompson (2007) holds that connectionism is a contemporary neuroscientific information processing theory.

<sup>19</sup> Evidence has suggested a mirror mechanism in infants as young as 6 months (Rizzolatti & Sinigaglia 2008, 327).

<sup>20</sup> An excellent review of neuroscientific research on sporting skills is provided by Yarrow et al (2009). They urge "neuroscientists to consider how their basic research might help to explain sporting skill" (Yarrow et al 2009, 585). We are probably only beginning to see the impact neuroscience is going to have on sport science and the philosophy of sport.

<sup>21</sup> There is a neuronal link between motor knowledge and motor memory (see Mukamel et al 2010) in Rizzolatti and Sinigaglia's (2008, 106-114) theory. For a discussion on memory, knowledge and skill, see Birch (2011).

<sup>22</sup> The neurophysiological explanation is: if you do not have the motor knowledge x, you will not have the neural network z necessary for producing motor action y, so when observing someone capable of y and having x and z, your brain cannot have strict congruent neural activity. You may have broad congruence, but of course the similarity will widen with the difference in x and z, which are (some of) the reasons you cannot do y.

<sup>23</sup> Although not treated in this article, Rizzolatti and Sinigaglia's (2008, ch. 3) philosophical considerations lean on Merleau-Ponty. This link should be most interesting to the philosophy of sport.

<sup>24</sup> The mirror neuron theory has philosophical relevance for both body and action. The theory argues for the body as the 'great reason' (Nietzsche 1961, "Of the Despisers of the Body").

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