Available online at www.sciencedirect.com
SCIENCE DIRECT®
ACADEMIC PRESS
Consciousness and Cognition 11 (2002) 481–487
Consciousness and Cognition
www.academicpress.com

Attention to action and awareness of other minds

Chris Frith*

Wellcome Department of Imaging Neuroscience, Institute of Neurology, University College London, 12 Queen Square, London WC1N 3BG, UK

Received 3 July 2002

Abstract

We have only limited awareness of the system by which we control our actions and this limited awareness does not seem to be concerned with the control of action. Awareness of choosing one action rather than another comes after the choice has been made, while awareness of initiating an action occurs before the movement has begun. These temporal differences bind together in consciousness the intention to act and the consequences of the action. This creates our sense of agency. Activity in the anterior cingulate cortex and medial prefrontal cortex is associated with awareness of our own actions and also occurs when we think about the actions of others. I propose that the mechanism underlying awareness of how our own intentions lead to actions can also be used to represent the intentions that underlie the actions of others. This common system enables us to communicate mental states and thereby share our experiences.

1. Awareness of action

Will, the sense of being in control of our own actions is a major component of consciousness (along with emotion and cognition). But are we aware of all aspects of our own actions? Milner and Goodale (1995) have intensively studied a patient, known as DF, who demonstrates a striking lack of awareness of certain aspects of her own action. As a result of damage to her inferior temporal lobe DF suffers from

* Fax: +44-207-813-1420.
E-mail address: cfrith@fil.ion.ucl.ac.uk.

1053-8100/02/$ - see front matter
PII: S1053-8100(02)00022-3

form agnosia. In other words, she is unable to perceive the shapes of things. She cannot distinguish a square from an oblong and cannot report the orientation of a slot. On the other hand, when she picks up a square or puts her hand through a slot she orients her hand and forms her grasp appropriately. DF is able to use information about the shapes of objects to guide reaching and grasping movements, but she is not aware of this information. This unconscious guidance system is not unique to patients. It is simply revealed more starkly in the case of DF by the damage to the system that normally brings certain kinds of information into consciousness. A number of studies have shown that we all can make rapid and accurate grasping movements without being aware of the information that is being used to control these movements (Pisella et al., 2000). In some cases, we are not even aware of having made the movement.

This unconscious and rapid system for controlling movements is particularly involved in making corrections to actions that are already underway. These are automatic responses driven by our environment rather than by our will. By definition, we must be aware of our willed actions and yet there is evidence that this awareness is too late for any involvement in the selection of the action. In Libet's much discussed experiment (Libet, Gleason, Wright, & Pearl, 1983) subjects made the willed action of lifting a finger, 'whenever they felt the urge to so so.' The time at which they felt the urge to make the action occurred some 100s of milliseconds after the first detectable changes in brain activity (the beginning of the EEG readiness potential). This result has been replicated by Haggard, Newman, and Magno (1999) who have also extended the finding to show that the time of awareness of the urge to act is correlated with the time of onset of the lateralised component of the readiness potential (Haggard & Eimer, 1999). This is the time at which the brain activity ceases to be centrally located and shifts towards the side of the brain that will control the movement, contra-lateral to the hand that will move. This observation suggests that we are not aware of the movement we have selected until that movement has been precisely specified.

If awareness comes after movement selection then presumably this awareness has no role in making that selection. This principle of awareness coming after the event does not just to apply to the very simple responses studied in these experiments, but also to the selection of complex actions (Bargh & Chartrand, 1999; Velmans, 1991). Indeed it has been argued that we are never conscious of cognitive processes, but only of the results of those processes (Nisbett & Wilson, 1977). If consciousness has no role to play in the short-term control of our actions, then what role does it play? Why does our subjective experience so strongly suggest that we are in control of our actions?

Libet also measured the time at which his subjects were aware of initiating their actions. This is a distinct and later event from the time of the first awareness of the urge to act. In contrast to the awareness of the urge, which is late, the awareness of the initiation to act is early. The time at which we think we initiate the act occurs some 80 ms before the limb actually starts to move. This result has also been replicated by Haggard et al. (1999). Note that any sensory feedback that results from the movement of a limb will occur a further 100 ms or so after the movement has actually started. Thus, the awareness of initiating the movement is much too early to be based on any of the sensations associated with the movement. What we are aware of must be based on predicted rather than actual sensations. We are very surprised if the actual sensations do not match those we predicted, as when we pick up an object that is much lighter than we anticipated. Furthermore, if the difference between predicted and actual sensations are small then it is the predicted sensations that dominate our awareness.

Fourneret and Jeannerod (1998) required subjects to move their hands forward to draw a vertical line on a computer screen. The subjects could not see their hands and so could not see that a distortion had been introduced by the computer. Thus, in one condition, to draw the vertical line on the screen, subjects had to move their hand, not forward, but 10° to the left. In other conditions, different degrees and directions of distortion were applied. The striking result was that subjects were not aware that they were not making the movements that they saw on the screen. Even when asked to repeat the movement they had just made without any visual feed back they still made the straight forward movement they thought they had made rather than the deviant movement that they had actually just performed. It would seem that as long the intended goal was obtained (in this case drawing a straight forward line) unexpected sensory feedback does not reach awareness. But what is the advantage of being aware of the expected position of our limbs rather then their actual position?

It is an accepted principle in engineering that, when there are delays in the system, it is desirable to make response selections on the basis of predicted consequences (the forward model, Miall & Wolpert, 1995). Direct sensory feedback arrives too late to be useful for movement guidance. There is evidence that such prediction also plays a role in the human motor control system (Desmurget & Grafton, 2000). However, there is nothing in this engineering account that requires that these representations of the future state of the motor system need to be conscious. Robotic devices make use of forward models in the absence of consciousness.

Why is it that, at the point that we initiate an act, we are aware of the future state of our motor system rather then its current state? I suggest that the answer relates to our sense of agency: the experience that we are in control of our own actions. This experience of control occurs because we feel that our actions are caused by our intentions. In the simple task used by Libet, we have the 'urge' to lift our finger and, as a result, we lift it. Our sense of being in control derives from the experience that our actions are caused by our intentions. When we perform an act that we did not intend, we experienced a loss of control. Wegner (2002) has persuasively argued that this experience of causation is based on the temporal contingency between the intention and the action. We first have the intention and then, shortly afterwards, the action occurs. Because of this close contingency we believe that we caused the action, but this belief can sometimes be false. If a volunteer finds her hand moving shortly after having the thought of moving her hand then she believes that she initiated the movement herself even though the movement was actually caused by someone else (Wegner & Wheatley, 1999). In other circumstance, the volunteer may falsely attribute the cause of their own movements to someone else. Thus, in a sense our experience of controlling our own actions is illusory. All we can actually experience is the contingency between thought and action.

Our experience of being in control of our actions depends critically on the temporal interval between the intention to act and the initiation of that act. By basing our awareness of initiating an action on the predicted rather than the actual sensory consequences, we move the awareness of initiation backward in time. The awareness of the action is closer in time to the awareness of the intention and our sense of being in control is enhanced. That the time between intention and action is shorter in awareness than it is in terms of brain activity is particular striking in Libet's experiment. Changes in brain activity (the readiness potential) can be detected up to 1 s before the urge to act is reported. Thus, the awareness of intention is moved foreward in time to be closer to the point of initiation. A similar point is made by the elegant experiment recently reported by Haggard, Clark, and Kalogeras (2002). This experiment demonstrates the binding together in awareness of actions and their consequences. When a voluntary action is followed by a tone the perception of the action and its consequence (the tone) are closer together in time than was actually the case. Thus, the action and its consequence are bound together. In contrast, when an involuntary action (a muscle twitch caused by transcranial magnetic stimulation) is followed by a tone, these events are pulled apart, with the twitch being perceived as occurring earlier and tone as occurring later.

Studies of the awareness of action show that there are many aspects of motor control of which we are not aware. In many circumstances, the selection and control of action can occur perfectly well without awareness. Awareness of action seems not be relevant to the control of action, but to our beliefs about this control. We are aware of those aspects of our actions, which enhance our experience of being in control. We experience that our actions are caused by our intentions. But why is it so important to feel that we are in control of our actions when this experience has such little effect on the actual control of action?

2. Neural correlates of awareness of action

We may get clues about the function of awareness of action by studying the neural correlates of this awareness. The basic experimental paradigm is to try and keep the action the same while varying awareness. In one study reported by Jueptner et al. (1997), subjects learned a choice reaction time task in which there were four stimuli corresponding to four keys. The stimuli came on in a sequence, which repeated exactly every eight trials. As subjects learned this sequence, their responses became faster. After many minutes of practice they could perform this task without attending to their actions. This automaticity was confirmed by showing that they could do something else at the same time without reaction times being slowed (Passingham, 1996). At the beginning of practice much activity was observed in frontal cortex, but this activity returned to resting levels once the task had become automatic. After their performance had become automatic volunteers were also scanned in a condition where they were instructed to think about their performance. In comparison to performance without thought activity was seen in the anterior cingulate cortex (ACC, posterior rostral cingulate zone to be more precise) and in dorsolateral prefrontal cortex (DLPFC). Similar results have been obtained when the comparison is made between learning motor tasks with and without awareness (Grafton, Hazeltine, & Ivry, 1995; Hazeltine, Grafton, & Ivry, 1997). Awareness of learning a skill is associated with activity in ACC. Haggard and Magno (1999) have shown that transcranial magnetic stimulation (TMS) over this brain region delays the awareness of initiating an action. In contrast, TSM over primary motor cortex delays the actual initiation of the action, but not the awareness of the initiation.

ACC is not only activated when we attend to our own actions. It is also activated, possibly in a slightly more anterior region (anterior rostral cingulate zone), when we attend to other features of our mental state including pain (Rainville, Duncan, Price, Carrier, & Bushnell, 1997), thoughts (McGuire, Paulesu, Frackowiak, & Frith, 1996), and emotions (Lane, Fink, Chua, & Dolan, 1997). And adjacent to this region, but more anterior and inferior and spreading into medial prefrontal cortex, we find a region, which is consistently activated when we think about the mental states of others. In most of these studies volunteers were presented scenarios in the form of written stories (Fletcher et al., 1995; Gallagher et al., 2000; Vogeley et al., 2001), cartoon strips (Brunet, Sarfate, Hardy-Baylé, & Decety, 2000) or animated displays (Castelli, Happé, Frith, & Frith, 2000) and then asked to describe the beliefs and intentions of the agents in the scenarios. However, the same region is also activated in studies in which the volunteer is scanned while interacting in real time with another person (Gallagher, Jack, Roepstorff, & Frith, 2002; McCabe, Houser, Ryan, Smith, & Trouard, 2001). In the study reported by Gallagher et al. volunteers were scanned while playing the child's game 'stone–paper–scissors.' Success in this game depends upon predicting what your opponent is going to do next. So what has predicting what someone is going to do next got to do with their beliefs and desires? To make such predictions we take 'an intentional stance' (Dennett, 1987). We assume that other peoples' actions are determined by their beliefs and desires. We try to infer their beliefs and desires to predict what their actions will be.

Thus one of the brain regions involved in representing the mental states of others is certainly adjacent to and probably overlaps with a region involved in the representation of our own mental states. Furthermore, both these regions are adjacent to a region of ACC which is activated when we attend to our own actions. These observations suggest that there is a relationship between the requirement to predict the actions of others and the representation of our own mental states. Such a relationship is implied by simulation theory (Goldman, 1989), the idea that we 'read' the mental states of others by imaging ourselves in their circumstances and discovering what this feels like. However, I am suggesting that the causality is the other way round. We start with a representation of the person's mental state and, from that we predict what they will do. The critical requirement is the sense of agency, that actions are caused by intentions based on beliefs and desires. Perhaps the sense of agency that springs from our conscious experience of our own actions is critical for taking an intentional stance towards the behaviour of others (Frith & Frith, 1999). The 'illusion' of our own will allows us to perceive will in others.

2.1. The evolution of consciousness?

The ability to represent the mental states of others and to take an intentional stance towards their behaviour is very highly developed in humans. Indeed, it is often erroneously applied to lower animals and even inanimate objects. However, this ability seems to be absent in monkeys (Cheney & Seyfarth, 1990) and is only found in a very primitive form in great apes (De Waal, 1992). How did this ability evolve? Perhaps the evolutionary pressure came from the advantage of being able to predict the behaviour of others. Representing the hypothetical mental states of others is good way of making such predictions. Such representations can be made of our own mental states also. A common format for representing mental states that applies to our own as well as others opens up the possibility for communication. I can tell you what it is like to be me and vice versa. We can share our experiences. This, of course, is what consciousness is all about.

References

Bargh, J. A., & Chartrand, T. L. (1999). The unbearable automaticity of being. *American Psychologist, 54*, 462–479.

Brunet, E., Sarfate, Y., Hardy-Baylé, M. C., & Decety, J. (2000). A PET investigation of the attribution of intentions with a non-verbal task. *NeuroImage, 11*, 157–166.

Castelli, F., Happé, F., Frith, U., & Frith, C. D. (2000). Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns. *NeuroImage, 12*, 314–325.

Cheney, D. L., & Seyfarth, R. M. (1990). *How monkeys see the world: Inside the mind of another species*. USA: Chicago University Press.

Dennett, D. C. (1987). *The intentional stance*. Cambridge, MA: MIT Press.

Desmurget, M., & Grafton, S. (2000). Forward modelling allows feedback control for fast reaching movements. *Trends in Cognitive Sciences, 4*, 423–431.

De Waal, F. B. M. (1992). Intentional deception in primates. *Evolution of Anthropology, 1*, 86–92.

Fletcher, P., Happé, F., Frith, U., Baker, S. C., Dolan, D. J., Frackowiak, R. S. J., & Frith, C. D. (1995). Other minds in the brain: A functional imaging study of "theory of mind" in story comprehension. *Cognition, 57*, 109–128.

Fourneret, P., & Jeannerod, M. (1998). Limited conscious monitoring of motor performance in normal subjects. *Neuropsychologia, 36*, 1133–1140.

Frith, C. D., & Frith, U. (1999). Interacting minds – a biological basis. *Science, 286*, 1692–1695.

Gallagher, H. C., Happe, F., Brunswick, N., Fletcher, P. C., Frith, U., & Frith, C. D. (2000). Reading the mind in cartoons and stories: An fMRI study of 'theory of mind' in verbal and nonverbal tasks. *Neuropsychologia, 38*, 11–21.

Gallagher, H. C., Jack, A., Roepstorff, A., & Frith, C. D. (2002). Imaging the intentional stance. *NeuroImage, 16*, 814–821.

Goldman, A. (1989). Interpretation psychologized. *Mind Language, 4*, 161–185.

Grafton, S. T., Hazeltine, E., & Ivry, R. (1995). Functional mapping of sequence learning in normal humans. *Human Brain Mapping, 1*, 221–234.

Haggard, P., & Eimer, M. (1999). On the relation between brain potentials and awareness of voluntary movements. *Experimental Brain Research, 126*, 128–133.

Haggard, P., & Magno, E. (1999). Localising awareness of action with transcranial magnetic stimulation. *Experimental Brain Research, 127*, 102–107.

Haggard, P., Newman, C., & Magno, E. (1999). On the perceived time of voluntary actions. *British Journal Psychology, 90*, 291–303.

Haggard, P., Clark, S., & Kalogeras, J. (2002). Voluntary action and conscious awareness. *Nature Neuroscience, 5*, 382–385.

Hazeltine, E., Grafton, S. T., & Ivry, R. (1997). Attention and stimulus characteristics determine the locus of motor-sequence encoding. *Brain, 120*, 123–140.

Jueptner, M., Stephan, K. M., Frith, C. D., Brooks, D. J., Frackowiak, R. S., & Passingham, R. E. (1997). Anatomy of motor learning I Frontal cortex and attention to action. *Journal of Neurophysiology, 77*, 1313–1324.

Lane, R. D., Fink, G. R., Chua, P. M. L., & Dolan, R. J. (1997). Neural activation during selective attention to subjective emotional responses. *NeuroReport, 8*, 3969–3972.

Libet, B., Gleason, C. A., Wright, E. W., & Pearl, D. K. (1983). Time of conscious intention to act in relation to onset of cerebral activity (readiness potential): The unconscious initiation of a freely voluntary act. *Brain, 106*, 623–642.

McCabe, K., Houser, D., Ryan, L., Smith, V., & Trouard, T. (2001). A functional imaging study of cooperation in two-person reciprocal exchange. *PNAS, 98*, 11832–11835.

McGuire, P. K., Paulesu, E., Frackowiak, R. S. J., & Frith, C. D. (1996). Brain activity during stimulus independent thought. *NeuroReport, 7*, 2095–2099.

Miall, R. C., & Wolpert, D. M. (1995). An internal model for sensorimotor integration. *Science, 269*, 1880–1882.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford: University Press.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84*, 231–259.

Passingham, R. E. (1996). Attention to action. *Philosophical Transactions of Royal Society of London: B, 351*, 1423–1432.

Pisella, L., Gréa, H., Tilikete, C., Vighetto, A., Desmurget, M., & Rode, G., et al. (2000). An 'automatic pilot' for the hand in human posterior parietal cortex: Toward reinterpreting optic ataxia. *Nature Neuroscience, 3*, 729–736.

Rainville, P., Duncan, G. H., Price, D. D., Carrier, B., & Bushnell, M. C. (1997). Pain effect encoded in human anterior cingulate, but not somatosensory cortex. *Science, 277*, 968–971.

Velmans, M. (1991). Is human information processing conscious? *Behavioural and Brain Sciences, 14*, 651–726.

Vogeley, K., Bussfeld, P., Newen, A., Herrman, S., Happé, F., & Falkai, P., et al. (2001). Mind reading: Neural mechanisms of theory of mind and self-perspective. *NeuroImage, 14*, 170–181.

Wegner, D. M. (2002). *The illusion of conscious will*. Cambridge, MA: MIT Press.

Wegner, D. M., & Wheatley, T. (1999). Apparent mental causation – sources of the experience of will. *American Psychology, 54*, 480–492.