

Chris Frith - selected references

- 1 Shea, N., Boldt, A., Bang, D., Yeung, N., Heyes, C., & Frith, C. D. (2014). Supra-personal cognitive control and metacognition. *Trends in Cognitive Sciences*, 18, 186-193.
Notes: The human mind is extraordinary in its ability not merely to respond to events as they unfold but also to adapt its own operation in pursuit of its agenda. This 'cognitive control' can be achieved through simple interactions among sensorimotor processes, and through interactions in which one sensorimotor process represents a property of another in an implicit, unconscious way. So why does the human mind also represent properties of cognitive processes in an explicit way, enabling us to think and say 'I'm sure' or 'I'm doubtful'? We suggest that 'system 2 metacognition' is for supra-personal cognitive control. It allows metacognitive information to be broadcast, and thereby to coordinate the sensorimotor systems of two or more agents involved in a shared task
- 2 Ma, Y., Bang, D., Wang, C., Allen, M., Frith, C., Roepstorff, A. et al. (2014). Sociocultural patterning of neural activity during self-reflection. *Soc.Cogn Affect.Neurosci.*, 9, 73-80.
Notes: Western cultures encourage self-construals independent of social contexts, whereas East Asian cultures foster interdependent self-construals that rely on how others perceive the self. How are culturally specific self-construals mediated by the human brain? Using functional magnetic resonance imaging, we monitored neural responses from adults in East Asian (Chinese) and Western (Danish) cultural contexts during judgments of social, mental and physical attributes of themselves and public figures to assess cultural influences on self-referential processing of personal attributes in different dimensions. We found that judgments of self vs a public figure elicited greater activation in the medial prefrontal cortex (mPFC) in Danish than in Chinese participants regardless of attribute dimensions for judgments. However, self-judgments of social attributes induced greater activity in the temporoparietal junction (TPJ) in Chinese than in Danish participants. Moreover, the group difference in TPJ activity was mediated by a measure of a cultural value (i.e. interdependence of self-construal). Our findings suggest that individuals in different sociocultural contexts may learn and/or adopt distinct strategies for self-reflection by changing the weight of the mPFC and TPJ in the social brain network
- 3 Konvalinka, I., Bauer, M., Stahlhut, C., Hansen, L. K., Roepstorff, A., & Frith, C. D. (2014). Frontal alpha oscillations distinguish leaders from followers: multivariate decoding of mutually interacting brains. *NeuroImage*, 94, 79-88.
Notes: Successful social interactions rely upon the abilities of two or more people to mutually exchange information in real-time, while simultaneously adapting to one another. The neural basis of social cognition has mostly been investigated in isolated individuals, and more recently using two-person

paradigms to quantify the neuronal dynamics underlying social interaction. While several studies have shown the relevance of understanding complementary and mutually adaptive processes, the neural mechanisms underlying such coordinative behavioral patterns during joint action remain largely unknown. Here, we employed a synchronized finger-tapping task while measuring dual-EEG from pairs of human participants who either mutually adjusted to each other in an interactive task or followed a computer metronome. Neurophysiologically, the interactive condition was characterized by a stronger suppression of alpha and low-beta oscillations over motor and frontal areas in contrast to the non-interactive computer condition. A multivariate analysis of two-brain activity to classify interactive versus non-interactive trials revealed asymmetric patterns of the frontal alpha-suppression in each pair, during both task anticipation and execution, such that only one member showed the frontal component. Analysis of the behavioral data showed that this distinction coincided with the leader-follower relationship in 8/9 pairs, with the leaders characterized by the stronger frontal alpha-suppression. This suggests that leaders invest more resources in prospective planning and control. Hence our results show that the spontaneous emergence of leader-follower relationships in dyadic interactions can be predicted from EEG recordings of brain activity prior to and during interaction. Furthermore, this emphasizes the importance of investigating complementarity in joint action

- 4 Heyes, C. M. & Frith, C. D. (2014). The cultural evolution of mind reading. *Science*, 344, 1243091.

Notes: It is not just a manner of speaking: "Mind reading," or working out what others are thinking and feeling, is markedly similar to print reading. Both of these distinctly human skills recover meaning from signs, depend on dedicated cortical areas, are subject to genetically heritable disorders, show cultural variation around a universal core, and regulate how people behave. But when it comes to development, the evidence is conflicting. Some studies show that, like learning to read print, learning to read minds is a long, hard process that depends on tuition. Others indicate that even very young, nonliterate infants are already capable of mind reading. Here, we propose a resolution to this conflict. We suggest that infants are equipped with neurocognitive mechanisms that yield accurate expectations about behavior ("automatic" or "implicit" mind reading), whereas "explicit" mind reading, like literacy, is a culturally inherited skill; it is passed from one generation to the next by verbal instruction

- 5 Frith, C. D. (2014). Action, agency and responsibility. *Neuropsychologia*, 55, 137-142.

Notes: In a series of experiments Marc Jeannerod revealed that we have very little awareness of the details and causes of our actions. We are, however, vividly aware of being in control of our actions and this gives us a sense of responsibility. These feelings arise, first, from intentional binding which creates a perception of agency, linking an intentional action to its outcome and, second,

from the counterfactual reasoning that we could have chosen some other action. These feelings of responsibility play a critical role in creating social cohesion since they allow people to be held to account for deliberate antisocial behaviour. Jeannerod's studies also showed that we are unaware of how little we know about our actions and so are happy to make up stories about the nature and causes of our behaviour. These stories often do not correspond with the underlying cognitive and neural processes, but they can be changed through instructions and through discussion with others. Our experience of responsibility for action emerges during our upbringing through exposure to our culture. This creates consensus about the causes of behaviour, but not necessarily accuracy

- 6 Frith, C. D. (2012). The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society.B: Biological Sciences*, 367, 2213-2223.

Notes: Metacognition concerns the processes by which we monitor and control our own cognitive processes. It can also be applied to others, in which case it is known as mentalizing. Both kinds of metacognition have implicit and explicit forms, where implicit means automatic and without awareness. Implicit metacognition enables us to adopt a we-mode, through which we automatically take account of the knowledge and intentions of others. Adoption of this mode enhances joint action. Explicit metacognition enables us to reflect on and justify our behaviour to others. However, access to the underlying processes is very limited for both self and others and our reports on our own and others' intentions can be very inaccurate. On the other hand, recent experiments have shown that, through discussions of our perceptual experiences with others, we can detect sensory signals more accurately, even in the absence of objective feedback. Through our willingness to discuss with others the reasons for our actions and perceptions, we overcome our lack of direct access to the underlying cognitive processes. This creates the potential for us to build more accurate accounts of the world and of ourselves. I suggest, therefore, that explicit metacognition is a uniquely human ability that has evolved through its enhancement of collaborative decision-making

- 7 Frith, C. D. & Frith, U. (2012). Mechanisms of social cognition. *Annual Review of Psychology*, 63, 287-313.

Notes: Social animals including humans share a range of social mechanisms that are automatic and implicit and enable learning by observation. Learning from others includes imitation of actions and mirroring of emotions. Learning about others, such as their group membership and reputation, is crucial for social interactions that depend on trust. For accurate prediction of others' changeable dispositions, mentalizing is required, i.e., tracking of intentions, desires, and beliefs. Implicit mentalizing is present in infants less than one year old as well as in some nonhuman species. Explicit mentalizing is a meta-cognitive process and enhances the ability to learn about the world through self-monitoring and reflection, and may be uniquely human.

Meta-cognitive processes can also exert control over automatic behavior, for instance, when short-term gains oppose long-term aims or when selfish and prosocial interests collide. We suggest that they also underlie the ability to explicitly share experiences with other agents, as in reflective discussion and teaching. These are key in increasing the accuracy of the models of the world that we construct

- 8 Konvalinka, I., Vuust, P., Roepstorff, A., & Frith, C. D. (2010). Follow you, follow me: Continuous mutual prediction and adaptation in joint tapping.

Q.J.Exp.Psychol.(Colchester.), 1-11.

Notes: To study the mechanisms of coordination that are fundamental to successful interactions we carried out a joint finger tapping experiment in which pairs of participants were asked to maintain a given beat while synchronizing to an auditory signal coming from the other person or the computer. When both were hearing each other, the pair became a coupled, mutually and continuously adaptive unit of two "hyper-followers", with their intertap intervals (ITIs) oscillating in opposite directions on a tap-to-tap basis. There was thus no evidence for the emergence of a leader-follower strategy. We also found that dyads were equally good at synchronizing with the irregular, but responsive other as with the predictable, unresponsive computer. However, they performed worse when the "other" was both irregular and unresponsive. We thus propose that interpersonal coordination is facilitated by the mutual abilities to (a) predict the other's subsequent action and (b) adapt accordingly on a millisecond timescale

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- 9 Frith, U. & Frith, C. (2010). The social brain: allowing humans to boldly go where no other species has been. *Philosophical Transactions of the Royal Society.B: Biological Sciences*, 365, 165-176.

Notes: The biological basis of complex human social interaction and communication has been illuminated through a coming together of various methods and disciplines. Among these are comparative studies of other species, studies of disorders of social cognition and developmental psychology. The use of neuroimaging and computational models has given weight to speculations about the evolution of social behaviour and culture in human societies. We highlight some networks of the social brain relevant to two-person interactions and consider the social signals between interacting partners that activate these networks. We make a case for distinguishing between signals that automatically trigger interaction and cooperation and ostensive signals that are used deliberately. We suggest that this ostensive signalling is needed for 'closing the loop' in two-person interactions, where the partners each know that they have the intention to communicate. The use of deliberate social signals can serve to increase reputation and trust and facilitates teaching. This is likely to be a critical factor in the steep cultural ascent of mankind