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## Cognitive Neuroscience: Distinguishing Self from Other

**Neurons in medial frontal cortex have been found to distinguish between whether an animal or its partner is responding on a turn-taking task, but are they really the basis of a social learning mechanism?**

Stephanie Burnett and Masud Husain

Isn't it irritating when people cannot wait their turn and interrupt? The ability to 'take turns', whether during a conversation or other cooperative activity, is a fundamental requirement for successful social interactions. At just a few months of age, human infants show evidence of engaging in interactions with their caregiver, including taking their turn [1]. Social development continues through childhood and adolescence, with emerging awareness of a social concept of self as viewed by other people [2]. Such abilities are considered to be evidence for neural mechanisms that distinguish between 'self' and 'other'.

By contrast, an ever-expanding literature on 'mirror neurons' — neurons that respond *similarly* to actions of self and other — has shifted attention to brain mechanisms that do not distinguish between whether we perform an act, or someone else does. Much has been written about the possible functions of such mirror neurons [3–5], but evidence for single neurons involved in the converse function of distinguishing self from other has, until recently, been conspicuously absent [6]. A primate electrophysiology study [7] published recently in *Current Biology* provides novel evidence for a role of the medial frontal cortex in differentiating self from other's action during a turn-taking task in which it is imperative not to interrupt.

Yoshida *et al.* [7] trained two macaques to perform a rewarded task. On each trial, one animal was assigned the role of actor, and the other was an

observer. Roles alternated every two trials. During each trial, the actor made a choice between a green or yellow illuminated button, the position of which could swap randomly; whereas the observer simply held down a red button for the duration of the trial. Both animals received a juice reward if the actor made the 'correct' choice, and both animals could see the other's actions. The button colour that was rewarded remained constant for several trials, but reward contingencies switched without warning every so often. So now the animal whose turn it was to act had to switch to choosing the alternative coloured button. Thus, reward expectation was constant across animals on a given trial, and the experimenters were able to identify agent-specific neural signals.

Recordings were made from medial frontal cortex during actor and observer trials. In line with a recent human electrophysiology study [8], mirror neurons were observed that fired similarly to a green or yellow choice made by either animal. But, in addition, the authors observed 'partner neurons'. These fired selectively to a choice made by the partner and, in the main, remained unmoved during the choices of self. The authors argue that partner neurons provide a neural substrate for self–other differentiation which enables social learning in the task.

Recordings were made in two adjacent sites, the pre-supplementary motor area (pre-SMA) and the cingulate sulcus, with partner neurons being encountered more frequently in the pre-SMA. Yoshida *et al.* [7] speculate that these neurons might play a critical

role in social learning. Indeed, studies of Theory of Mind — the attribution to others of mental states that account for their behavior, for example, 'my partner believes the green button will be rewarded' — have implicated medial frontal regions, together with the temporoparietal junction, in this function in humans [9–11]. The authors suggest that connections between multisensory superior temporal sulcus (STS) and pre-SMA might form a brain network involved in assigning agency.

Focal damage to the STS in humans can lead to unusual syndromes, for example loss of possession of one's own arm [12], perhaps consistent with a role for agency. However, the medial frontal areas that are considered to be important for Theory of Mind in humans are located far more anteriorly (rostral) to the pre-SMA [9]. Furthermore, their precise contribution is unclear as bilateral lesions to them can leave Theory of Mind intact [13].

Nevertheless, the proposed function of partner neurons in assigning agency to other versus self would be a necessary first step in the assignment of discrete mental states to other — wherever that might be computed in the brain. In this way they might be considered precursors to a social agency or social learning system. But is self–other differentiation, or indeed 'social learning', the best way to consider such activity? The precise role of the pre-SMA is far from clear and it has been implicated in several different types of function [14–18].

Converging lines of evidence from single unit recordings in macaques, as well as human functional neuroimaging and lesion studies, has led to the proposal that the pre-SMA represents complex condition–action associations [18]. These contain links between stimulus and response which can be described as multiple, conditional or poorly specified, and of course may depend upon previous experiences and their outcomes — positive or negative.

In the turn-taking task, the conditions and appropriate actions which led to rewards were learnt by the monkeys. Both animals had to be clear whose turn it was because this condition would determine whether they made a choice action or not, and both animals monitored whether the actor's response was rewarded. Moreover, if the reward contingencies switched such that the actor's choice was unrewarded, both animals had to note this condition because it would mean the next turn-taker should alter their response from previous choices. Thus, it was crucial to distinguish whether it was the self or other's turn, and map which was the appropriate response in the current trial context.

Yoshida *et al.* [7] found that a small number (<5%) of partner neurons were selective for the target button colour — the goal of the partner's action in the current trial — while one-third encoded the spatial location of the goal. Importantly, some 40% of partner neurons also responded differently on error trials, compared to correct ones. Thus, apart from distinguishing self from other, activity within this population of neurons also held a rich set of information about current trial context.

Viewed from this perspective, partner neurons might be considered to be part of the neural system involved in encoding condition-action relationships which, in this particular paradigm, depended upon differentiating self from other, among other variables. An interesting question is whether the same neurons might encode different condition-action relationships if a single monkey was trained on a different protocol that did

not require distinguishing self from other, or even turn-taking. Are these neurons part of a general purpose system that maps and remaps appropriate actions to different contexts, regardless of their social implications? Answering such a question would require an ambitious and challenging experimental design, but would seem to be crucial for a better theoretical understanding of the role of the pre-SMA.

Moreover, these findings highlight one of the challenges for 'social neuroscience'. Social behaviour requires understanding appropriate responses, conditional upon the current context, which often also depends upon previous contexts. Encoding such condition-action rules might be important for many aspects of an animal's survival and aren't necessarily specific to any 'social' brain system. Thus, distinguishing what is truly social in neural terms and what is built on underlying circuits that subserve more general brain functions is not always easy (see also [11]). In this regard, the research presented by Yoshida *et al.* [7] provides an important and provocative contribution, though one that raises as many questions as it answers.

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## Climate: Baselines for the Biological Effects of Environmental Change

Establishing biological baselines requires access to organisms which lived earlier in, or before, the present episode of anthropogenic change. Specimens of a bryozoan collected on Scott's Antarctic expeditions, and subsequently, provide clear evidence of recent increases in growth rate after 80 years of constancy.

John A. Raven

Studies of how organisms have responded to the continuing

environmental changes that began some two centuries ago require access to biological specimens that provide data from which growth rates

(for example) can be estimated. One such source is organisms that are still alive, e.g. annual rings of trees with secondary thickening. Here the thickness of the rings indicates the growth rate of the tree, although not necessarily the environmental factor altering the growth rate. Similar principles apply to growth rings in the shells of long-lived bivalve molluscs. For organisms with shorter life-spans relative to the period under investigation, data are available from fossils in well-dated sediments,