Empathy:

Direct understanding through mirror neurons

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Abstract:

The experience of direct empathy is a result of sensory input being processed through the mirror neuron system. This is similar to a low-grade version of the experience had by the target of the empathy – that is, whatever they feel, the empathizer feels also in a very literal (albeit subconscious) sense. Sensory input may be from any number of things, such as visual face recognition, voice, "body language", smell, etc., but here I only discuss the recognition – and corresponding empathic experience – of facial displays of emotion.

> "**Empathy** is the experiential recognizing and understanding of the states of mind, including beliefs, desires and particularly emotions of others without injecting your own. This concept is often characterized as the ability to "put oneself into another's shoes", or experiencing for oneself the outlook or emotions of another being within oneself. In this sense it might be described as a sort of emotional resonance." – Wikipedia: Empathy

In many ways, empathy is the most basic prerequisite to having social interactions, or indeed to any understanding of the outside world that is not purely solipsistic. While empathy has long been studied in clinical psychology and philosophy, it is only recently that research into its neurological basis has been done.

The origin of the word itself – coined from the Greek en- "in" + pathos "feeling" – gives a remarkably accurate clue. The key distinction in the experience of empathy – mirrored in its neurology – is that it is a *direct* feeling; that is, there are no conscious intermediate steps, such as thinking out analytically how someone must be feeling based on a folk-psychology theory of mind. This puts a curious requirement on the brain: it must be able to directly mirror the emotions of others. Normally, we conceive of neurons and their wiring being a purely self-contained system; this has given rise to purely theory-driven ideas of how one might have (analytical) empathy. And this was, indeed, the only way to plausibly explain how empathy might be 'wired'… until the discovery of mirror neurons.

While the underlying research for this was done in the early 1980s – primarily having to do with the motor system of the macaque monkey – it was not until the mid-'90s that the understanding of mirror neurons as such really came to fruition. One of the key pieces of research was that of Rizzolatti et al. (1996).

By recording the activity of certain neurons in the F5 area of the macaque monkey's brain (analogous to Broca's area in humans – which is responsible, among other things, for speech production and comprehension [Rizzolatti & Arbib]), the researchers were able to observe a very unusual pattern of activation. Namely, these neurons would fire only when the monkey either performed or observed certain specific hand movements. Moreover, different mirror neurons appeared to be specific to different movements or grips – e.g. one would fire only for a "precision grip" (like that of grasping a raisin), another for a particular kind of twisting motion, etc. These neurons did *not* fire above baseline when the monkey was merely observing food or hands (monkeys' or experimenters'), observing other movement than the one encoded, observing or doing an otherwise triggering action done with a tool, etc; nor was it dependent on reward gained or other situational conditions. It also did not fire during other parts of the movement – only that involving its particular grip or movement. It would, however, fire at almost the same rate whether the monkey itself was doing the encoded action, or it was watching another monkey do it, or even observing the human experimenters performing the same action. (See Fig. 1, from Gallese & Goldman.)

This basic pattern of activity has since been confirmed with numerous other studies both in macaques and in humans. There have also been studies demonstrating the existence of more general mirror neurons – such as ones that appear to encode for any activity involving a particular muscle group (e.g. thumb movement); ones that fire for particular *actions* (such as ripping paper) (Kohler et al.); even ones that appear to fire for particular *intent* (e.g. picking up a glass of water vs. mimicking the action with no actual glass) (Rizzolatti & Gentilucci).

The implications of this study are fairly revolutionary to the conception of the brain as a self-contained system that merely takes input and analyzes it dispassionately. In short, what it says is that part of your brain is, literally, acting in the same way as if *you yourself* were performing an action you are observing. That is, if you watch someone pick up an object, or watch them receive pain to some area of their body, or for that matter watch their face assume different indications of emotion, you will be mirroring this activity. (Fortunately for neurotypical people, there is also a system that ultimately inhibits this mirror-activity before it reaches the muscles – the disorder of which is called *echopraxia*. An interesting subject, but beyond the scope of this essay; see Rizzolatti (1999).)

Paul Ekman et al have demonstrated the other crucial link in this chain: that motor activity can have effects on the emotions. This came from a fairly extensive series of experiments into the facial expression of emotions (which relevantly include demonstrating that, at least for basic emotions, facial displays of emotions are cross-cultural [Ekman et al. 1987]). In their 1990 article, Levenson, Ekman & Friesen describe an experiment involving a "Directed Facial Action task". In this experiment, subjects were asked to move their facial muscles one by one, until they were made to assume a facial affect corresponding to particular emotions. E.g., for a Duchenne smile, this would involve contracting the *zygomaticus major* of the mouth, and the *orbicularis oculi* of the eyes. (The difference between a "genuine", i.e. Duchenne smile, and a voluntary one used for politeness, is that the *orbicularis oculi* is normally overlooked when giving the "fake" smile.) Meanwhile, certain autonomic processes were measured – heart rate, skin conductance, finger temperature, and somatic activity – and subjects were asked to report their subjective experience.

The result was that subjects in fact did generally experience the emotion represented by the result of their muscle-by-muscle movement, and their autonomic activity matched it. This was not explainable by the difficulty of the action (Levenson & Ekman 2002), and was not significantly affected by the subject's experience as an actor, their gender, whether the emotion generated was positive or negative, or the use of a mirror or the experimenter as a visual aid, and the subject was not initially aware of what emotion they were being guided into expressing (as their instructions were purely in terms of what muscles to contract, in order). The effect was increased when the facial movements made were closer to a strong display of emotion.

This, in combination with the mirror neuron system outlined above, gives us an account of the basic function of emotional empathy (at least when the target's face is visible). The emotion is registered on the target's face – in culturally-invariant ways that are very difficult to fully suppress (Ekman & Oster). This is then, purely as a configuration of muscles, mirrored in the mirror neuron system of the person experiencing empathy ("subject" for short). That is, a subset of the subject's motor system is acting as if the subject themselves were displaying that affect, with regulatory systems acting to inhibit it at the very final stages (before it would actually change their muscle movement). This, then – as demonstrated by Levenson et al – triggers (through as-yet unspecified means) the experience of that original emotion in the subject to some degree. Finally, the subject attributes this feeling to their interaction (and thus to the target), because of its paired association.

I would like to point out one gloss I just made: that of jumping from Levenson et al's demonstration of *full* motor movement leading to emotional and autonomic response, to an assertion that the *mirror neuron subset* of it would generate the same effect. Fortunately, this too has been covered by recent research.

Whalen et al. conducted a fairly simple experiment. They put subjects in an fMRI, and expose them to alternating stimuli: masked happy expressions, masked fearful expressions, and a fixation cross. The masking was done by showing the subject a random-order series consisting of a target fearful or happy expression for 33 msec, followed by a neutral one of the same person for 167 msec (so 200msec per trial in the series). (Ekman has discussed this as occurring in real life, and calls the phenomenon "microexpressions". [Frank & Ekman]) The subjects come out of the fMRI generally unaware of the fearful or happy expressions, and only aware of – and able to explicitly recognize – the neutral pictures. However, their blood oxygen level dependent (BOLD) signal in the amygdale – the part of the brain responsible for regulating fear – was significantly more active during the masked fear trials than the masked happy trials.

While this study did not look at the mirror neuron activity (nor at fMRI indications of happiness), this still indicates that the subjects were in fact mirroring the effects of the emotions displayed on the faces they were seeing. They would not have been experiencing fear *in response to* a fearful stimulus (as they might if the stimulus were e.g. anger); rather they were doing so *in empathy with* it; moreover, as they were not even aware of the existence of the fearful / happy stimulus, they could not have been executing an explicit "theory of mind"[i] and then "deciding" to be fearful in response.

This combination of research of course has numerous potentially valuable implications.

For one, it can help to describe group behavior – whether for species survival (e.g. group flight in response to a predator, by quickly propagating one individual's fearful response to the others) or for more negative behavior such as crowd violence in a mob (by similarly propagating more violent emotions).

For two, it can help to give a neurological means of understanding the question of why we believe in other minds (a question plaguing philosophers for some time now): empathy as described resolves this by giving, if not a logical justification, at least an explanation of why we *have the feeling* that other people do exist and probably have the same experience as we do.

Finally, this research will probably lead to new ways of addressing disorders such as autism and schizophrenia, and perhaps to ways for increasing the empathy of normal people.

Fig. 1, from Gallese & Goldman p. 494

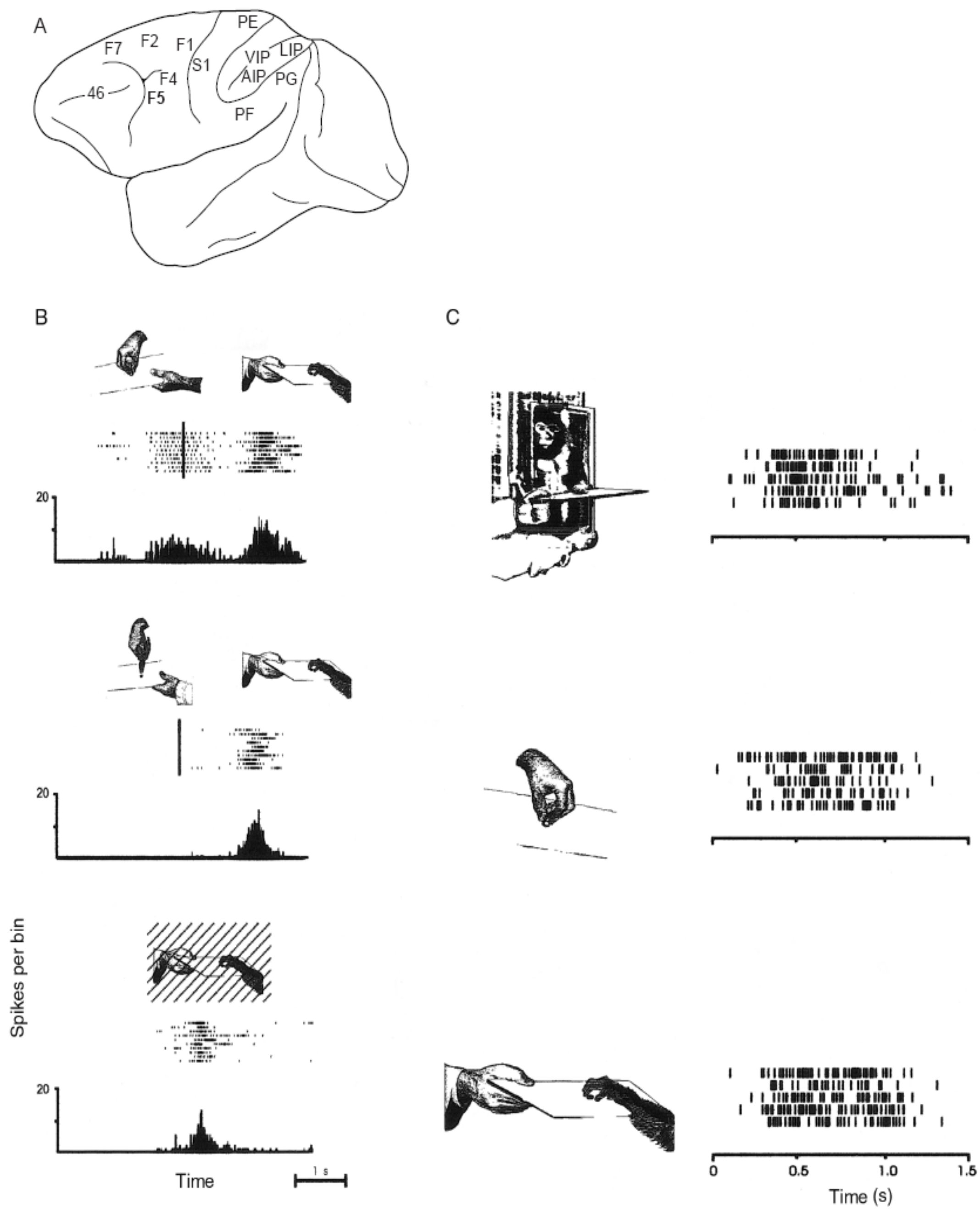

Fig. 1 Anatomical location and functional properties of mirror neurons. (A) Lateral view of the macaque brain showing the cytoarchitectonic parcellation of the agranular frontal cortex and of the posterior parietal cortex. Motor and premotor areas, indicated by the letter F, are defined according to Matelli *et al.*[2] Mirror neurons were all recorded from area F5 (shown in bold). **(B)** Visual and motor responses of a mirror neuron. In the upper part of each panel the behavioral context in which the neuron was studied is shown. In the lower part of each panel a series of consecutive rasters and the relative peristimulus response histograms are shown. In the upper panel the experimenter grasps a piece of food with his hand and moves it towards the monkey, who grasps it. The neuron discharges during grasping observation, is silent when the food is moved, and discharges again when the monkey grasps it. In the middle panel the experimenter grasps the food with a tool. Subsequent series of event as in the previous panel. During grasping observation the neuron is silent. In the lower panel the monkey grasps the food in complete darkness. In the upper and middle panels rasters and histograms are aligned (vertical bar) with the moment in which the experimenter grasps the food. In the lower panel alignment is with the beginning of the grasping movement. (Histograms bin width, 20 ms. Ordinates, spikes/bin. Abscissae, time.) **(C)** Visual and motor responses of a mirror neuron. In the upper panel the recorded monkey observes another monkey grasping food. In the middle panel the recorded monkey observes the experimenter grasping food. In the lower panel the recorded monkey actively grasps food. Each panel illustrates five consecutive trials. The spontaneous activity of the neuron was virtually absent. (Panels B and C are modified from Ref. 15.)

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[i] **Comment re. TOM:** While discussion of theories of theory of mind is beyond the scope of this paper, it may help to know that I believe in a meshed theory-theory / simulation-theory approach, with ST being the fundamental process and TT being an analytical extraction that happens downstream from it.