Journal Club

Editor's Note: These short, critical reviews of recent papers in the *Journal*, written exclusively by graduate students or postdoctoral fellows, are intended to summarize the important findings of the paper and provide additional insight and commentary. For more information on the format and purpose of the Journal Club, please see http://www.jneurosci.org/misc/ifa_features.shtml.

A Step Forward for Mirror Neurons? Investigating the Functional Link between Action Execution and Action Observation in Limb Apraxia

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Review of Pazzaglia et al. (http://www.jneurosci.org/cgi/content/full/28/12/3030)

Increasing evidence suggests that action execution and action observation are encoded by the same brain regions. This renders motor events central to the question of self and nonself discrimination (Georgieff and Jeannerod, 1998). In humans, it is widely assumed that mirror neurons link action observation and action execution networks. These neurons respond during action execution and action observation and have been found in macaque premotor and inferior parietal cortices (di Pellegrino et al., 1992; Rizzolatti et al., 1996).

The evidence for human mirror neurons is far from conclusive. Nevertheless, the presence of a general action "mirroring" system is well established (Dinstein et al., 2008). Human brains encode action execution and action observation in a remarkably similar way (Rizzolatti and Craighero, 2004), but what purpose this system serves remains unclear. It has been proposed that it is involved in action recognition, action imitation, understanding of action and emotion, imitation, and the developmental and evolutionary acquisition of language. However, it is possible that coupling of the two networks is a functionless consequence of motor development. For example, during development, Hebbian coupling may link neurons that fire during action execution to those that respond during action perception.

In a recent study published in *The Journal of Neuroscience*, Pazzaglia et al. (2008) demonstrate that patients with limb apraxia, a specific deficit in executing skilled limb movements or gestures, also display a deficit in recognizing observed gestures. This study expands on previous studies (Rothi et al., 1985; Cubelli et al., 2006) by including a more detailed lesion analysis. Forty-one patients with brain damage were assessed for limb apraxia by using two tests of gesture performance that tested for different subtypes of apraxia. One test assessed patients' ability to associate the correct action for a given object, and another tested the ability to sequence accurately a connected series of actions. Patients scoring below a predetermined level were diagnosed as having limb apraxia and were assessed for gesture-recognition deficits. Of the 21 patients diagnosed with apraxia, 56% had a gesture-recognition deficit. The lesion analysis indicated that patients with limb apraxia and a perceptual deficit tended to have lesions in inferior frontal areas, whereas apraxic patients with intact perception tended to have parietal lesions. Thus, compensation appears to be possible for patients with parietal lesions but not for those with frontal lesions.

In combination with previous studies, these data provide persuasive evidence that some motor deficits observed in limb apraxia transfer to perceptual modalities. Not only do the lesions that predict gesture-recognition deficits overlap with those implicated in the mirror-neuron network, these data indicate that, to some extent, the neural networks that match action execution and observation also serve to support action discrimination. The authors interpret this loosely as "gesture comprehension"; however, we would argue that their test of gesture recognition does not assess understanding of the action, only whether the action is correctly performed.

Patients with limb apraxia can be subdivided into distinct subtypes. There is debate as to the terminology defining these subtypes. We define a deficit in the temporal and spatial sequencing of an action as ideomotor apraxia. A loss of object knowledge and content errors (inappropriate use of tools) are considered to impair the conceptual system, which encompasses ideational and conceptual apraxia (Leiguarda and Marsden, 2000). Regardless of the terminology, the fact remains that the subtypes of limb apraxia are quite different and, we argue, may be associated with separate pathologies. It is unfortunate then that Pazzaglia et al. (2008) did

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not discriminate between the two types of limb apraxia (ideomotor and conceptual/ideational) in the gesture-recognition test or lesion-mapping analysis. With 21 patients, this was probably to avoid a substantial drop in power. But because a dissociation between subtypes of apraxia has implications for the study of potential mirror neurons in the human brain, this is confounding.

A subset of limb apraxia patients have specific deficits in the ability to associate objects with the appropriate action (conceptual or ideational). Canonical neurons are a subset of motor neurons in premotor cortex that respond during both the process of action execution and the process of observing an object. These cells therefore provide a neuronal link between an action and an object. Macaque studies have indicated that object information is encoded in neurons residing in anterior intraparietal area, which project to F5 of the premotor cortex, a debated homolog to human Brodmann area 44, in which it is thought that potential action representations are stored. It is possible, then, that damage to this network is involved in the deficits observed in patients with conceptual/ideational apraxia.

Conversely, ideomotor apraxia is characterized by intact object knowledge but inability to generate a motor representation. Patients can indicate what an object is and identify the associated action, but their motor schema is affected spatially and temporally. Given that these patients are able to match objects to actions, transitive or object-directed actions are performed more accurately than intransitive or nonobject-directed actions. Presumably, this is because these patients can extract information about the object (affordances) to guide the action in a manner that conceptual or ideational patients cannot. Therefore, we suggest that the gesture-recognition deficit may differ between patients with conceptual/ideational apraxia and those with ideomotor apraxia.

An additional confusion in the study by Pazzaglia et al. (2008) is that of language abilities: right-brain-damaged patients scored better on language comprehension than left-brain-damaged (LBD) patients, and of the LBD patients, those without apraxia performed better than those with it. The authors address this by including training sessions and by demonstrating that gesture-recognition scores did not correlate with language-comprehension scores. The inclusion of a control group with similarly low scores on language comprehension but no gesture-recognition deficits would have made the findings more persuasive, demonstrating a dissociation between language deficits and gesture-recognition tasks. Alternatively, the inclusion of a non-gesture-related visual task could have been used to assess whether these patients were specifically impaired in gesture recognition rather than language or a more general aspect of visual scene analysis.

It is clear that language and action processing and production are extremely closely linked. For example, it can be very difficult to clinically dissociate patients with aphasia, speech apraxia, and even dysarthria, all of which have been associated with lesions in inferior frontal gyrus. More troublesome, therefore, is the lack of discussion of language-production abilities in these patients. Limb apraxia is often accompanied by speech-production deficits, including unreliable yes/no responses, especially at the acute stage immediately after stroke. This calls into question the ability of these patients to respond appropriately in the gesture-recognition task.

Last, to further investigate the function of the matching system, it would be interesting to determine how tightly coupled the human action-execution and perception networks are. If this matching system subserves action recognition, action understanding, or even empathy, the coupling must be highly congruent. For instance, one would expect actions affected in the execution condition (e.g., executing a hand wave) to be specifically affected in the gesture-recognition task (recognizing a hand wave). The alternative would suggest that the matching system is too general to subserve the matching of specific observed actions to their motor counterpart for action recognition. For this reason, it would be useful to have information pertaining to each individual's performance across action-execution and action-recognition tasks on an action-specific basis.

The data presented by Pazzaglia et al. (2008) provide exciting evidence for a functional link between action observation and action execution in the human brain, the implications of which are widespread for both speech and limb apraxia. Furthermore, this provides a neurobiological rationale for established rehabilitation techniques and a framework for further development. Taken independently of the previous literature, there are confusions that render these data inconclusive. Without a more detailed assessment of language production and comprehension and the separation of subtypes of limb apraxia, we must rely on previous studies to judge the validity of these findings. Nonetheless, these findings confirm previous work and provide an insight into how lesion mapping may be used in the future for the differential diagnosis of apraxia subtypes.

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