Is there privileged access to semantics for mirror-neuron related verbs?

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INTRODUCTION

Rizzolatti et al. (1988) were the first to demonstrate the existence of mirror neurons in macaque ventral premotor cortex, area F5. Much evidence suggests that neurons in this region code for producing and comprehending complex goal-directed actions, but not elementary movements. Evidence for mirror neurons in humans has been amassed using a variety of different techniques (see Rizzolatti, Craighero, & Fiadiga, 2002, for a review). The fact that area F5 is homologous to the language-specialized Broca's area in humans (Rizzolatti & Arbib, 1998) has been source of much speculation, but few hard tests, among theorists of language evolution (see Stamenov & Gallese, eds, 2002). We report here on behavioral and fMRI data from an experiment designed to test the hypotheses that verbs related to mirror-neuron actions ('reach', 'grasp', 'tear' etc.) have privileged access to lexical semantics and that this access is modulated through Broca's area.

EXPERIMENT 1: fMRI

METHOD

We asked to subjects to undertake a go/no-go noun/verb decision task, manipulating whether the verbs were 'mirror-neuron-related' or not. A mirror-neuron related verb was defined as any verb that unambiguously implicated a well-defined hand-action– for example, 'grasp', 'pinch', wipe', and 'grind'. The mirror-neuron and non-mirror-neuron verbs were individually matched to each other and to two sets of nouns on several non-semantic lexical dimensions (see Table 1).

	LETTERS	PHONEMES	OFREQ	NODUPON	CONBG-PRODUCT	CONBP-PRODUCT
GRASPING	**4.9**	**3.7**	**17.2**	**6.5**	**4664.2**	**1489.0**
NONGRASPING	**4.9**	**3.8**	**17.6**	**6.7**	**4227.6**	**1461.8**
NONVERB1	**4.9**	**3.8**	**19.3**	**6.4**	**4718.6**	**1403.9**
NONVERB2	**4.9**	**3.8**	**16.2**	**6.3**	**4445.1**	**1348.7**

TABLE 1: STIMULUS CHARACTERISTICS

After ensuring that subjects knew the difference between a verb and a noun, they were asked to hit a button if the word they saw *could be* used as a verb, and not otherwise. Ten right-handed fluent English-speaking subjects undertook the task while undergoing fMRI scanning in a 1.5T Siemen's Sonata scanner. Thirty 4 mm oblique gradient-echo slices were obtained, covering the entire brain (TR = 5s, TE = 50ms, gap = 0 mm). The task was originally designed as a block designed task, but later analyzed as an event-related design (see Experiment 3 for behavioral replication without blocks). Each subject saw 10 blocks of 16 stimuli each. Half of the stimuli in each block were verbs, and half were matched nonverbs. Half of the blocks contained only grasping-verbs and the other half contained only (matched) nongrasping verbs. These were alternated. We alternated which block subjects saw first: half saw a grasping block first, and half saw a non-grasping block first. The blocks were constructed anew for each subject, so that no two subjects saw the same blocks. This eliminates the possibility that any activation could be attributed to any consistencies in the verb or non-verb stimuli other than semantic status, since no stimulus consistently appeared in the same block as any other stimulus.

RESULTS

Subjects made correct decisions for 95% of verbs. The behavioral results for correct decisions only are shown in Figure 1. Subjects were reliably faster at deciding that mirror-neuron-related verbs were verbs than they were at deciding that other verbs were verbs ($p < 0.02$).

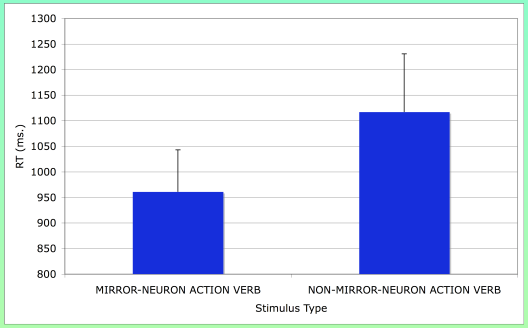

FIGURE 1: CORRECT DECISION RTs FOR VERBS (EXP. 1)

The imaging results for the verb category contrast are shown in Figure 2. Contrary to our original hypothesis, there was no significant differences between the two conditions in Broca's area. However, there were weakly reliable activation differences between the two conditions in the left anterior-inferior parietal lobe (Talairach coordinates: -47, -26, 28; $p < .001$, uncorrected; see Figure 2). This somatosensory association region has been associated with storage of tactile, proprioceptive, kinesthetic, and spatial knowledge, and damage in the region is associated with bilateral apraxia (Liepmann, 1900; Heilman, Rothi, & Valenstein, 1982). This BOLD activity is therefore plausibly related to the retrieval of 'praxicons' related to the movements referred to by the (apparently misnamed!) 'mirror-neuron related' verbs.

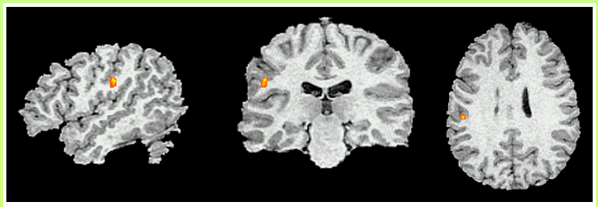

FIGURE 2: MIRROR-NEURON VERB - NON-MIRROR-NEURON VERB BOLD CONTRAST

EXPERIMENTS 2 & 3: REPLICATION

Because we had a small number of subjects and a block-design in Experiment 1, we replicated the identical experiment with more subjects and both a block-design newly randomized for each subject (Experiment 2; N = 39) and a fully-randomized design (Experiment 3; N = 41). As shown in Figure 3, both experiments replicated the behavioral finding in Experiment 1, of much faster decisions for grasping-type verbs than for matched verbs with different semantics ($p < 0.0001$ in both cases).

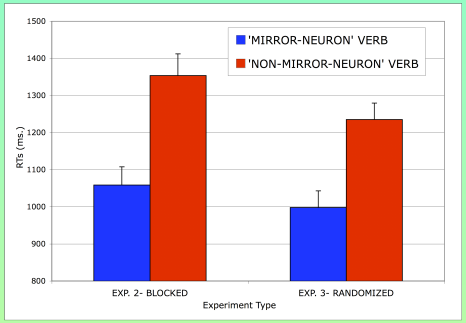

FIGURE 3: CORRECT DECISION RTs FOR VERBS (EXPS. 2 & 3)

CONCLUSION

Taken together, these imaging and behavioral results suggest that verbs related to specific hand gestures may have privileged access to semantics compared to other verbs. Subjects are much faster to make verb/noun decisions about such verbs. Imaging evidence suggests that these verbs differentially access a parietal lobe region that has been associated with storage and retrieval of practiced movements.

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