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## Naming Tools and Using Rules: Evidence That a Frontal/Basal-Ganglia System Underlies both Motor Skill Knowledge and Grammatical Rule Use

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We investigated the hypothesis that two well-studied brain systems (see Feinberg & Farah, 1997) underlie the lexicon/grammar dichotomy (Ullman et al., 1997). In this view, frontal/basal-ganglia circuitry implicated in the learning and expression of motor and cognitive skills also underlie the acquisition and use of grammatical rules, and temporal-lobe circuits implicated in the learning and use of factual (conceptual) knowledge also underlie the learning and use of memorized words. The hypothesis predicts co-occurring word/rule and fact/skill double dissociations in patients with damage to one or the other system and similar degrees of impairment to words and facts and to skills and rules.

Lexicon and grammar, and conceptual and motor skill knowledge, were probed in patients with Parkinson's disease (PD) or Alzheimer's disease (AD). PD is associated with frontal/basal-ganglia damage, which may explain PD impairments at learning new and expressing established motor skills and at syntactic processing. In contrast, in (low-demented) PD patients there is typically little damage to temporal-lobe structures, and word and fact use remain relatively spared. AD is associated with temporal-lobe damage, which may explain AD impairments at learning new words and facts and at using established ones. In contrast, there is a relative sparing of frontal/basal-ganglia structures, learning new and using established motor and cognitive skills, and syntactic processing (see Feinberg & Farah, 1997).

Testing for grammar/lexicon dissociations has been problematic, because tasks probing lexicon and grammar usually differ in ways other than their use of the two capacities. Therefore grammar and lexicon were probed with English regular and irregular past tense. Regular forms (e.g., play–played) require an *-ed*-suffixation rule, whereas irregulars (dig–dug) undergo largely arbitrary transformations and are memorized in the lexicon. Crucially, regulars and irregulars are matched in complexity (one word), meaning (past), and syntax (tensed) (Pinker, 1991).

A previous study of regular and irregular past-tense processing in PD and AD patients probed motor skills with a task requiring skilled movement and facts with a fact retrieval task (Ullman et al., 1997). The predicted regular/irregular double dissociations and regular/skill and irregular/fact associations were obtained. However, the tasks probing skill and fact use differed in multiple ways other than the skill/fact distinction, precluding direct comparisons of the two types of knowledge.

In the present study the skill/fact distinction was tested by asking subjects to name pictures of two types of objects: (1) tools and other manipulated objects and (2) natural and man-made objects that are not normally manipulated. Knowledge of both types depends upon factual information (e.g., what a tool is used for), but only manipulated objects involve motor skill knowledge (i.e., how to use them). The naming of both object types has been linked to temporal-lobe structures, but only naming tools is associated with left frontal motor regions (e.g., Damasio et al., 1996; Martin et al., 1996).

*Method.* Twenty-six low-demented PD and 21 AD patients were asked to produce past tenses of 16 irregular, 20 regular, and 20 novel (plag-plagged) verbs and to name pictures of 22 manipulated objects (e.g., pencil) and of 20 natural and man-made objects that are not normally manipulated (e.g., beaver, house). They were also asked to carry out skilled movements with left and right limbs and to orally retrieve factual knowledge about the real world.

*Results.* Across the 26 PD patients, right-side motor skill deficits correlated significantly with errors inflecting novel and regular ( $p < .01$ ) but not irregular (n.s.) verbs (in all correlations, dementia scores partialled out and  $p$  values one-tailed). Novel and regular verb inflection correlated with performance at naming manipulated ( $p < .05$ ) but not nonmanipulated (n.s.) objects. In contrast, irregular verb inflection correlated with performance at naming both object types ( $p < .005$ ).

Across the 24 AD patients, fact-retrieval deficits correlated significantly with errors inflecting irregulars ( $p < .05$ ), but not regulars or novel verbs (n.s.). Irregular verb inflection correlated with naming errors of both object types ( $p < .05$ ), whereas regular and novel verb errors correlated with neither (n.s.). The lack of a correlation between *-ed* suffixation and manipulated object naming suggests that the variance in the latter in AD is better explained by its dependence on conceptual than on motor skill knowledge, as is indeed confirmed by the correlation between manipulated object naming and fact retrieval ( $p < .05$ ).

Subsets of the PD patients with the most severe right-side motor skill deficits, and of the AD patients with the most severe fact-retrieval deficits, were selected for further analysis. For these subsets, interactions were found between PD/AD, on the one hand, and Regular/Irregular Inflection, Novel/Irregular Inflection, and Manipulated/Nonmanipulated Object Naming on the other ( $p \leq .05$ ). The PD patients made more errors at producing regular

and novel verbs than irregular verbs and at naming manipulated than non-manipulated objects. The AD patients showed the opposite pattern.

*Conclusion.* The results link grammatical rule use in *-ed* suffixation to motor skill expression, to motor skill knowledge in naming tools, and to left frontal/basal-ganglia circuits. They link memorized word use in the production of irregular past tense forms to fact retrieval, to conceptual knowledge in naming objects, and to temporal-lobe regions. The findings support the view that the distinction between a frontal/basal-ganglia “procedural memory” system for motor and cognitive skills, and a temporal-lobe “declarative memory” system for conceptual knowledge, extends to grammar and lexicon.

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