NORMAL AND IMPAIRED PROCESSING IN QUASI-REGULAR DOMAINS OF LANGUAGE: THE CASE OF ENGLISH PAST-TENSE VERBS

Karalyn Patterson*, Matthew A. Lambon Ralph*, Helen Bird*, John R. Hodges* and James L. McClelland**

* MRC Cognition & Brain Sciences Unit, Cambridge CB2 2EF U.K.
** CNBC, Carnegie Mellon University, Pittsburgh PA 15213, USA

ABSTRACT

In most if not all languages, there are domains in which the relationship between one form of a word and another can be described as quasi-regular [1]. This means that, across the whole relevant vocabulary, there is substantial but imperfect consistency in the nature of the transformation linking the two forms. Quasi-regularity may apply between the same word forms in different modalities, as in the spoken and written versions of words, and also between different morphological forms of the same word root. In many languages, some aspects of verb morphology have this feature. The majority of English verbs, for example, are transformed to past tense by simply adding \textit{ed} to the present tense form (e.g., \textit{talk} \rightarrow \textit{talked}). The remainder, which include some of the most commonly used verbs in the language, form their past tenses in an atypical way (e.g., \textit{speak} \rightarrow \textit{spoke}; \textit{think} \rightarrow \textit{thought}; \textit{have} \rightarrow \textit{had}).

According to one widely held theory about language, the nature of processing for regular (and novel) vs. irregular transformations differs so fundamentally as to require two completely separate mechanisms. In the realm of the English past-tense, this theory has been most thoroughly described by Pinker [2]. An alternative view, most recently developed by Joanisse & Seidenberg [3], proposes that all types of past-tense transformation are achieved by a single distributed, constraint-satisfaction process recruiting activation of the phonological and semantic representations of words.

Among various forms of empirical evidence pertinent to this theoretical debate, attention has recently turned to the performance of neurological patients with acquired language impairments. One popular paradigm assesses generation of the past-tense in a sentence frame preceded by the present tense of the same verb (‘\textit{oday I speak to my friend; yesterday I ___ to my friend}’). Previous evidence is reviewed and new evidence presented here for a double dissociation in this task, with some types of aphasic patients achieving greater success on regular and novel verbs whereas others show an advantage for irregular verbs. Although the dual-mechanism theory predicts this double dissociation, such a pattern of results can also be well explained by a single constraint-satisfaction process. The crucial proposal here is that disruption to semantic representations has a disproportionate impact on the processing of irregular forms, and that disruption to phonological processing is more detrimental to success with regular forms. The semantic and phonological capabilities of patients with the two sides of the dissociation therefore become salient evidence in this debate. Additional features of the evidence, such as the nature of the patients’ errors, seem to favour the constraint-satisfaction approach.

1. THE PREVAILING THEORY: TWO SEPARATE MECHANISMS

A central aspect of human language is the ability to transform a word in some controlled fashion. In the domain of verb morphology, if a normal speaker of English is offered the present tense of a verb (such as \textit{blink} or \textit{think}), he or she can readily translate this into its past-tense form \textit{blinked} and \textit{thought}, respectively. The question addressed here is whether the processes involved in the transformation from \textit{blink} to \textit{blinked} and from \textit{think} to \textit{thought} are so fundamentally different as to require two separate mechanisms, operating on different principles and based on the functioning of separate neural regions. The prevailing view, laid out in detail by Pinker [2], is that a generative rule system is responsible for performance on the roughly 85\% of existing English verbs that form the past tense by simply tacking \textit{ed} on to the present-tense root. The same rule system is argued to apply to novel items: new verbs (like \textit{fax}) or nonwords that can be treated like verbs. On the other hand, the two-mechanism theory claims that an irregular past tense form like \textit{thought}, which cannot be generated by rule from \textit{think}, is stored as a separate lexical entry and activated via an associative network linking the present and past forms.

Recent evidence germane to this debate has come from neuropsychology, in the form of dissociations in the performance of adults with brain lesions that disrupt language processes. For example, Ullman et al. [4] tested various groups of neurological patients on the sentence-frame generation task mentioned in the abstract. The performance of some patients, with either Alzheimer's disease or aphasia from a posterior left-hemisphere stroke, was significantly better on regular and novel verb forms than on irregular items. An aphasic patient with a
left anterior lesion exhibited the opposite pattern: an advantage for generating the past tense of irregular verbs relative to both existing regular and novel forms. This evidence for a double dissociation is clearly compatible with the dual mechanism view [2,4,5,6]. There is, however, another theory which dispenses with the need for two separate mechanisms yet also fits the evidence for a double dissociation, and furthermore seems to provide a more satisfactory account of additional aspects of the patients’ performance.

2. A CONSTRAINT-SATISFACTION NEURAL-NET ACCOUNT OF MORPHOLOGICAL PROCESSING

In this framework, which has been implemented as a connectionist model [3], production of the past-tense form of a verb from a present-tense probe corresponds to generating a phonological output from a specification of the phonology of the present tense, plus a partial semantic specification prompted by the instruction to produce the verb in its past tense. Adult speakers of English have acquired the knowledge that enables them to perform the transformation task from a vocabulary consisting of both regular and irregular forms. The assumption is that this learning results in a network that uses one common set of distributed phonological input and output representations and connections between these, and that is therefore sensitive to the systematicity of the present-past relationship across the vocabulary as a whole. Given that the great majority of English verbs form their past by addition of \textit{ed}, the transformation process will be strongly biased towards the regular inflection. Three factors help counteract this tendency.

First, as in all connectionist networks, learning is modulated by frequency of experience with specific patterns. Individual high-frequency irregular verbs (\textit{do}→\textit{did}, \textit{have}→\textit{had}) will therefore be well learned and suffer scarcely any interference from the many regularly inflected verbs. Secondly, a number of irregular verbs fall into clusters with respect to the relationship between present and past form. Processing of these items will benefit from the support of their neighbours, on a smaller scale than the pervasive regularity of \textit{ed}, but with more specific impact because of the high degree of phonological similarity within each cluster (e.g., \textit{know}→\textit{knew}, \textit{blow}→\textit{blew}, \textit{throw}→\textit{threw}). The third factor is interactive support from semantic representations. Language processing is characterized by constant and bi-directional communication between semantic and phonological components of the system, supporting both speech production and comprehension. Owing to the automatic nature of interactive activation between phonological and semantic representations, input from semantic knowledge about the word will enter the process of transforming a present-tense verb to its past for all verbs. The claim, however, is that lower-frequency irregular verbs \cite{2} the set of items least efficiently processed by the direct phonological transformation process —come to depend on this additional semantic source of constraint to a greater degree than do regular or higher-frequency verbs. The neuropsychological prediction is, therefore, that semantically impaired patients will reveal a selective deficit on irregular past tenses, especially for less common verbs.

On the other side of the dissociation, although competent phonological processing is central to all tasks and materials for speech production, the prediction is that phonological impairments will result in disproportionate difficulty with regular and especially novel past-tense forms. The phonological distinction between present- and past-tense regular forms (like \textit{talk} and \textit{talked}) is subtle; as Pinker puts it, \textit{\ldots} he delicate tongue-tip that graces the end of a [past-tense] regular form may escape a listener and be omitted when he reproduces it” \cite[p.19]{2}. Also, regular past-tense verbs commonly end in consonant clusters that are difficult to articulate (e.g., \textit{grabbed}, \textit{hoped}, \textit{judged}), whereas most irregular past-tense forms terminate in a phonetically much more simple fashion (e.g., \textit{ate}, \textit{wore}, \textit{spoke}).

In summary, according to this connectionist view of lexical and morphological processing, there is one complex set of procedures by which the speaker produces the past tense of a verb; the same procedures operate whether the past tense has a regular or an irregular relationship to the present-tense form. The reason for the observed neuropsychological double dissociation between regular and irregular verbs is not that there are two separate mechanisms, independently vulnerable to brain lesion, but rather that the semantic and phonological processing recruited for both verb types play somewhat different roles. Selective disruption to one or other of these two elementary components of the language system will therefore have differential consequences for the regular and irregular forms. What is the evidence?

3. WHO HAS TROUBLE WITH IRREGULAR VERBS?

PATIENTS WITH SEMANTIC DEMENTIA

Semantic dementia (SD), which results from a degenerative brain disease, is a cognitive syndrome whose hallmark is a progressive deterioration of semantic memory \cite{7}. The disorder is consistently associated with atrophy in the anterior, inferior, lateral region of the temporal lobe, sometimes just on one side initially but invariably involving bilateral temporal atrophy with disease progression. These patients’ speech production consists of well-formed sentences, without phonological errors, but with a severe anomia: a difficulty in producing names of people, places, objects and concepts. This word-finding difficulty is followed in prominence by impaired word comprehension \cite{8}. Deterioration in both the production and comprehension of content-word vocabulary is significantly modulated by word frequency, with less common words being more vulnerable \cite{9}.

Over the last few years of our research programme, eight SD cases have succeeded in completing three different verbs tasks
relevant to the current issue. (i) Past-tense generation: Each of 100 familiar verbs (25 in each of the four conditions formed by crossing regular/irregular with high/low frequency) was presented first in a sentence in its present tense (e.g., I talk to my friend” or “I speak to my friend”) in simultaneous spoken and written form; the patient then immediately heard and saw a sentence demanding the past tense of the target verb (e.g., I ________ to my friend”) and was asked to supply the missing word. (ii) Past-tense recognition: The patients were provided with the same 100 sentence pairs, but for the second sentence in each pair, they were offered a choice between the correct past-tense and an incorrect form. For irregular verbs, the incorrect foil was always the regularized form (e.g., esterday I spoke...); for regular verbs, pseudo-irregular foils were constructed by altering the present tense targets in ways similar to those relating existing irregular past tenses to their present forms (e.g., save → sove, analogous to drive → drove). (iii) Verb comprehension: The single-word present tense of each of the 100 verbs was given, simultaneously in spoken and written form, along with two response choices, one an approximate synonym of the target word and the other unrelated in meaning, and the patients were asked to choose the word most similar in meaning.

These results, although establishing the clearest evidence to date for this dissociation, do not discriminate between the two-mechanism and the connectionist models: both can account for the frequency-by-regularity interaction. More informative are two further aspects of the patients’ performance. First, individual patients’ success on irregular verbs in both the generation and recognition tasks was significantly predicted by the degree of their semantic deficit as measured by the synonym task with the same 100 (present-tense) target verbs. For past-tense generation, the slope of the function relating performance on these two tasks was a steep 0.88 for irregular verbs but a nearly flat 0.08 for regular verbs. For recognition, scores were converted to d’ measures by treating choices of the -ed form for regular verbs as hits and choices of the -ed form for irregular verbs as false positives. The relationship between this measure of past-tense knowledge and semantic comprehension (also treated as a d score) was dramatic: r=0.93, t=0.87, slope=0.86. The finding that a patient’s degree of deficit on irregular verbs was strongly correlated with, and therefore predicted by, his or her own synonym performance is a clear prediction from our framework. If, as we understand it, the dual mechanism view treats lexical entries and word meaning as separate representations, then it is not clear how this theory accounts for the observed relationship between knowing the meaning of an irregular verb and being able to produce or recognize its correct past-tense form.

Secondly, as predicted by both theories, the most common error type in the generation task was a pure regularization error (e.g., fall → falled’); 73% of the patients’ errors were of this type. An additional substantial 23% of errors, however, followed one of the following three patterns. (i) a combination of the correct past transformation plus -ed (e.g., freeze → froze’d); (ii) vowel changes just like those that characterize the relationship between present and past tense for other real irregular verbs (e.g., slit → slit’, cf. sit → sat); (iii) reproduction of the present-tense form without any change. Virtually every instance of this final error type occurred in response to a present-tense verb that ends in /t/ (like eat) or /d/ (like grind), which is important because only /t/ and /d/ final verbs take no change as their correct irregular past-tense forms (e.g., let → let and bid → bid). These three error types seem more likely to arise from disruption of a system that has encoded both regular and exceptional exemplars in the same network than from loss of lexical knowledge for irregular verbs with resultant reliance on a simple rule-based mechanism.

![Figure 1](image_url) % Correct Generation of Past-Tense Verbs

**Figure 1:** % Correct Generation of Past-Tense Verbs

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4. WHO HAS TROUBLE WITH REGULAR VERBS? PATIENTS WITH BROCA’S APHASIA AND PHONOLOGICAL DEFICITS

In contrast to a reasonably full set of data for semantically impaired patients with an advantage for regular > irregular past-tense performance, we have only begun to acquire data on the opposite dissociation, irregular > regular. Previous studies by two-mechanism theorists [e.g., 4,5] have demonstrated this pattern in a small number of cases, all of whom had a Broca-type aphasia and thus could be expected to have phonological and/or articulatory deficits; but from the perspective of their theoretical position, a general phonological impairment would presumably be considered irrelevant to the verb tasks and
therefore was not evaluated. Our prediction is that, just as we have been able to “rade” the degree of failure at generating/recognizing the past tense of irregular verbs by the extent of semantic degradation in patients with semantic dementia, we will be able to grade the degree of difficulty with the past tense for regular and novel verbs by the extent of phonological impairment in patients with Broca’s aphasia. Pilot data indicate that, on the same set of materials used by Ullman et al. [4], some Broca’s aphasics are very significantly impaired at repeating the past tense of novel and real regular verbs (and better at the irregular past-tense forms), which at least suggests that regularly inflected verbs are difficult to articulate.

5. ENGLISH IS NOT THE ONLY LANGUAGE

As already noted, the majority of, if not all, languages have quasi-regular features. In many languages, for example, quasi-regularity characterizes the relationship between written and spoken forms of words; and translating from orthography to phonology is the other main arena (apart from inflectional morphology) in which there has been lively debate between dual-mechanism and constraint-satisfaction accounts. It has been a challenge to see how well theories developed to account for reading aloud in the quasi-regular vocabulary of alphabetic English [1] generalize to an orthography like Japanese kanji, which, despite operating on very different principles, is also quasi-regular. This challenge has been met with considerable success, in implemented connectionist models of kanji reading [10], patterns of accuracy and reaction times in kanji word and non-word reading by normal adults [11], and patterns of impaired kanji reading in neurological patients [12].

Japanese verb morphology is also a quasi-regular system, though more with reference to transformations like the negative and imperative forms of verbs than the past tense. Studies of accuracy in Japanese verb transformation tasks by aphasic patients with either semantic or phonological deficits will therefore prove another important testing ground for the kind of framework proposed here. Interestingly, there has been one such study [6] of inflectional verb morphology but of the way in which Japanese nominal forms are created by the addition of the suffix -sa or -mi to an adjectival stem [6]. A preference by several Japanese Broca’s aphasics for the suffix -mi in sentence contexts where normal speakers and other types of patients prefer the highly productive default suffix -sa was interpreted by Hagiwara et al. [6] as supporting the dual-mechanism theory. It is worth noting, however, that -sa and -mi apparently differ in pitch accent, and also that the nouns formed by -sa and -mi differ in semantic transparency. We remain optimistic that the kind of constraint satisfaction framework presented here, in which semantic and phonological processing interact in all speech-production tasks but offer differentially crucial support to different word types, will provide a powerful explanatory account for a wide variety of language tasks and languages.

5. REFERENCES


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