Frequency, Competition and Lexical Representation

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Abstract

An important issue in recent work on lexical representation is whether inflected past tense forms are represented as single units or in morphologically decomposed form, and whether this varies according to the regularity of the forms involved. We investigated this by looking at competitor effects between homophonic past tense forms (*paced/paste*, *made/maid*) where we varied the relative frequencies of the past tense form and its homophonic competitor. In particular, if regular forms are represented in morphologicaly decomposed form, as is widely argued, and irregular forms are listed as single units, this should lead to contrasting effects. To investigate this we used two tasks - writing to dictation and cross modal priming to compare frequency effects for regular and irregular forms. The results for both type of experiment were highly consistent, showing parallel effects of frequency for both regular and irregular forms. We discuss the implications of this for claims about the lexical representation of morphologically complex forms.

Introduction

An important issue in recent work on lexical representation is whether inflected past tense forms are represented as single units or in morphologically decomposed form, and whether this varies according to the regularity and irregularity of the forms involved. Although the subject remains controversial, at least one influential account does assume that lexical storage varies as a function of regularity, with regular verbs represented in a morphologically decomposed form and irregular past tense forms lexically represented as single units, either in an unstructured list, or, more recently, in a network-based associative memory (e.g., Prasada & Pinker, 1993).

On the decomposition account, frequency effects should also vary with regularity. Such effects may be found in irregular past tense verbs, since these exist as separate lexical items. It would be incoherent, however, to assume that the frequency of a regular past tense form should have any influence on its lexical representation or access, since no such item is stored. And indeed, there are experimental results that suggest that frequency effects are found in irregular past tenses, but not in the regulars. In separate experiments, Prasada, Pinker, and Snyder (1990) and Seidenberg and Bruck (1990) presented subjects with verb stems and asked them to name the corresponding past tense form as rapidly as possible. Both experiments showed that frequency of the verb stem influenced naming latencies for both regular and irregular verbs. Importantly, however, there was a reliable effect of past tense frequency only for irregular verbs, with longer naming latencies for low frequency than for high frequency items. These results are consistent with the claim that lexical representation is influenced by regularity: On this account the irregular forms are produced after a search through the lexicon for the appropriate past tense, and, on the assumption that frequency affects access time, the more frequent past tense items are more rapidly accessed. For the regular verbs, on the other hand, only the stem is stored and consequently only stem frequency influences search time. Once the verb stem has been accessed, the addition of the past tense suffix takes a constant amount of time across verbs, so no differences due to past tense frequency are expected.

But while these data are consistent with the decomposition account, they are also open to a very different interpretation. In a recent paper Daugherty and Seidenberg (in press) have shown that the same pattern of effects occurs in a connectionist model, for reasons having to do with how such networks learn. Briefly put, their account is this: In connectionist networks using the back-propagation learning algorithm, the goal of learning is to find the set of connection weights that will produce the most accurate output to each input. Both token frequency and pattern consistency (or type frequency) have strong effects on the sorts of weight changes that occur. For frequent patterns, this is due to the fact that they are presented to the network many times during training, and a weight change that reduces error (the difference between expected and obtained output) on one presentation of the pattern entails error reduction on all other presentations - therefore, a weight change that improves performance on a frequent pattern leads to a large reduction in error. For consistent patterns the effect is due to the fact that a weight change that leads to lower error on one mapping will reduce error on all patterns are consistent with it. Thus, for example, a weight change that reduces the error on the mapping *jump* -> *jumped* will also reduce error on mappings like *look* -> *looked* or *like* -> *liked*, since these items share a consistent form of inflection.

What this means for the current problem is that the learning of regular past tense forms does not rely entirely on the presentation frequency of that word, since each regular verb benefits from the learning of the other regular items. But learning the past tense of an exception word like *take* or *give* relies heavily on presentations of the word itself, so correct performance is highly dependent on word frequency. As a result, item frequency matters strongly for irregular items, but has much weaker consequences for regulars. This was the pattern found in the experimental data.

Since they are consistent with both the decomposition and the connectionist accounts, the naming data do not decide between the two possibilities. In the current paper we will present the results of two new experiments, using two different types of task, which show that under appropriate testing conditions frequency effects can be found in both regular and irregular verbs. We will then show that general principles of learning embodied in connectionist models can adequately account for these new data.

Experiments

In this work we use two tasks - writing to dictation and cross-modal repetition priming - to look at competitor effects between homophonic past tense forms such as paced/paste or made/maid. In both experiments we varied the relative frequencies of the past tense form and its homophonic competitor, to determine whether this led to contrasting effects for the regular and irregular verbs. On the decomposition account, relative frequency should have an effect in the irregular past tense verbs, but not in the regulars. If all past tense forms are represented in a similar fashion, on the other hand, there should be parallel effects of frequency for both regular and irregular forms.

Experiment 1: Dictation

In this experiment subjects heard a list of words presented on tape, and were instructed to write a phrase or a sentence containing each word as they heard it. There was a short pause after the presentation of each word to allow the subjects to write.
Test items in the experiment were 40 regular and 39 irregular past tense verbs, each with a second (monomorphemic) reading. Both regulars and irregulars were divided into three groups according to the frequency of the past tense (PT) reading relative to its homophone (HP). Frequencies were calculated throughout using the LOB norms (Johansson & Hofland, 1989)

1. ***PT greater***. Items where the frequency of the past tense form was higher than the frequency of the homophonic reading. (e.g. *allowed/aloud, made/maid*)

2. ***Approximately equal***. Items where the frequency of the past tense did not differ from the frequency of the homophone. (*ducked/duct, heard/herd*)

3. ***HP greater***. Items where the frequency of the homophone was higher than the frequency of the past tense reading. (*fined/find, ate/eight*)

A further 40 non-homophonous monomorphemic nouns and verbs were included as fillers.

Twenty-one subjects, all university-age native speakers of British English, completed the test. In presenting the results we will focus on the proportion of past tense responses to the test items. The mean proportion of past tense responses for each verb type is given in Table 1.

TABLE 1. Mean proportion of past tense responses, Experiment One

	Regular	Irregular
PT greater	0.78 (n=9)	0.73 (n=15)
Approx. Equal	0.42 (n=14)	0.78 (n=9)
HP greater	0.20 (n=17)	0.44 (n=15)

An overall analysis of variance gave a main effect of frequency group ($F2(2,73) = 16.3$, $p < 0.001$). Post hoc tests showed significant differences among all frequency groups: There were significantly more past tense responses in the PT Greater group than in either the HP Greater group ($p < 0.01$) or the Approximately Equal group ($p < 0.05$). There were also significantly more past tense responses in the Approximately Equal group than in the HP Greater group ($p < 0.01$).

ANOVAs carried out separately on the two verb types, regular and irregular, showed the same pattern of results. In both cases there was a main effect of frequency group (for the regular verbs, $F2(2,37) = 17$, $p < 0.001$; for the irregulars, $F2(2,36) = 5.1$, $p < 0.05$), with significantly more past tense responses to the PT Greater and Approximately Equal groups than to the HP Greater group.

Summary

The experiment shows a strong effect of past tense frequency that is highly consistent across regular and irregular verbs. These results are most simply explained by an account that says that the subjects, operating under time pressure, wrote the first item to be accessed when the homophone was heard. The most frequent of the homophone readings would be accessed first, and indeed the subjects reliably did choose the more frequent of the two. What is surprising about these results, though, is that this was the case not only for the irregular past tense verbs, which are non-controversially assumed to be represented in the lexicon, but for the regular past tenses as well. These results are expected in the network account, which assumes that regular and irregular verbs are subject to the same treatment, but more difficult to explain under the assumptions of the decomposition account.

To demonstrate that the frequency effect is a robust one, we then ran a second experiment using a very different task.

Experiment 2: Lexical Decision

In the second experiment we used cross-modal repetition priming to compare the effects of frequency on the regular and irregular verbs. In this task the subject hears a spoken prime - for example, *spoke* - and immediately at the offset of this word sees a visual target - here, *speak* which is morphologically related to the prime. The subject makes a lexical decision response to this target, and the response time relative to that in a control condition (with the same target following an unrelated prime) is used to measure any priming effect (Marslen-Wilson, Tyler, Waksler, & Older, 1994).

In this experiment, as in experiment one, there were two classes of verbs, Regular and Irregular. In each verb class two thirds of the items consisted of past tense forms with unrelated homophones, as in Experiment 1. For comparison, a further third of the items had unambiguous past tense forms, as in pairs like *jumped/jump.*

Triplets were created for each verb, in which visual target was always the uninflected verb stem, while the prime was either the inflected present tense, the inflected past tense, or an unrelated control prime. Table 2 gives an example stimulus set.

TABLE 2. Example stimulus set, Experiment Two

		Primes		Target
		Present	Past	
Regular	hphone	paces	paced	PACE
	non-HP	jumps	jumped	JUMP
Irregular	hphone	speaks	spoke	SPEAK
	non-HP	sleeps	slept	SLEEP

As in Experiment One, verbs in the Homophone conditions were divided according to the relative frequency of the past tense and homophone readings into PT Greater, HP Greater, or Approximately Equal groups.

The controls were matched to the primes for frequency and syllable length, and the Homophone and Non-HP conditions were matched to each other for frequency. Three experimental versions were constructed so that each target word occurred only once for each subject. The experiment included a further 324 filler pairs, to reduce the relatedness proportion of prime/target pairs and to guarantee that the target was a non-word on 50% of the trials.

The results given below are for 45 subjects (15 in each version), all native speakers of British English. In presenting these results we will consider the test-control difference scores for the past tense primes, to determine whether the existence of a homophone, and the frequency relation of the two readings (as a past tense form or as an unrelated monomorphemic form) affected an inflected verb's ability to prime its stem. These scores are given in Table 3.

TABLE 3. Difference scores (test minus control) for Experiment Two

No-Homophone		Homophone		
Verb type	PT prime	Verb type	Frequency group	PT prime
Regular	51*	Regular	PT Greater	17
			Approx. Equal	6
			HP greater	-46(*)
Irregular	1	Irregular	PT greater	-5
			Approx. equal	2
			HP greater	-26*

Note that there is significant priming in the No-HP regular condition, but not in the HP condition[1]. Note also that verbs in the HP Greater groups showed interference relative to control. This was marginally significant in the regular verbs ($p < 0.1$) and significant in the irregulars ($p < 0.5$). Tests were then run comparing test/control differences following past tense primes for all frequency groups. These showed a significant difference between the PT greater and HP greater groups for the Regular verbs ($p < 0.05$), but not for the Irregular verbs

We next looked at the correlation between the relative frequency of a homophonic past tense form and its ability to prime its stem. This was done by correlating the test-control difference following the past tense prime with the difference in frequency between the past tense form and the competing homophone. This correlation was significant for all items ($R = -0.35$, $p < 0.01$) though not for the Irregular past tense verbs alone ($R = -0.22$, $p > 0.1$). Importantly, however, the correlation was significant for the Regular past tense verbs ($R= -0.52$, $p < 0.01$).

We also looked at the relationship between the size and the direction of priming effects and the frequency of the verb

[1] The absence of priming for the No-HP Irregular past tense forms replicates findings we have reported previously, showing that irregular past tense forms do not prime their stems (Marslen-Wilson, Hare, & Older, 1993)

stems. Although a decompositional account might not predict an effect of past tense frequency *per se* for regular verbs, it would predict effects on speed of access of the frequency of the verb stem itself. Since stem frequency (defined as the cumulative frequency of occurrence of a stem across all its inflectional variants) is highly correlated with past tense frequency, we used multiple regression analyses to determine the proper attribution of effects. These analyses showed that the dominant factor was indeed the frequency of the past tense form, and that stem frequency made only a marginal additional contribution, increasing R for regular verbs from .52 to .55. This means that the results cannot be attributed to variations in stem frequency across the three frequency groups.

Summary

As in the first experiment, the lexical decision experiment shows an effect of past tense frequency that is not limited to the Irregular verbs. For both Regular and Irregular verbs, the existence of a more frequent homophone leads to interference in the priming task. Furthermore, the degree to which a homophonic past tense form facilitates recognition of its stem correlates with the frequency of that form relative to its homophone. It is notable that this correlation is stronger in the Regular verbs than in the Irregulars.

A second point of interest is that while there is significant priming for Regular verbs in the non-Homophone condition, the facilitation effect is greatly reduced in the Homophone condition, even for those items in the PT Greater group. This suggests that frequency alone cannot account for our pattern of results, for the existence of a competing homophone appears to have an effect that is not eliminated by differences in frequency.

Discussion

The pattern of results found in these two experiments is clearly inconsistent with any account which assumes that frequency effects in the past tense must vary with the regularity of the verb. The pattern is consistent with current connectionist assumptions that both regular and irregular verbs are learned and processed in a similar fashion, however. Therefore, in the remainder of this paper we will call upon principles of connectionist learning to account for the details of our experimental results.

As discussed in the Introduction, both token frequency and pattern consistency have strong effects on learning in a network. Patterns that are consistent, in the sense they are subject to similar input-output mappings, benefit from the existence of their consistent neighbors. Thus, to take the example of a mapping from the form of a verb stem to the form of its inflected past, the fact that a network has learned to produce *sing* -> *sang* will aid it in producing *ring* -> *rang*, since these are phonologically similar inputs that inflect in the same way.

This is so because the same set of connection weights mediate between input and output for both forms. An important consequence, then, is that the opposite must also be true: connection weights that correctly produce the consistent patterns will lead to larger error on patterns that are inconsistent. Seidenberg (1992) shows that this aspect of the consistency effect can account for the fact that in naming experiments, regular verbs with irregular neighbors (such as *bake*, with the inconsistent neighbors *take* or *make*) have longer response latencies than regular verbs whose neighbors are all consistent. The basis of the explanation is that weight changes beneficial to *take* will increase the error on *bake*, and vice versa. Since the two items compete for how the weights will be set they take longer to learn than will a regular consistent item such as *jump*, and once learning is complete the error on regular inconsistent words like *bake* will be slightly higher than on other regular words.

In summary, in this type of network high frequency patterns are easier to learn than low frequency ones, and items with consistent neighbors are easier to learn than those with inconsistent neighbors (or no neighbors at all). In other work this difference in learnability has been correlated with speed of lexical processing (e.g. Seidenberg and McClelland, 1989). On the assumption that the correlation is correct, the network account makes certain predictions for our data.

Consider, first, that the recognition of a spoken word is a mapping task: the listener must match the perceived sound pattern to the correct lexical item. In a network, this task will be learned more efficiently for more frequent words, thus offering an explanation for the standard assumption that more frequent items are accessed more rapidly. In addition, the homophones are subject to the consistency effect in much the same way as the regular inconsistent verbs discussed above: Homophones have inconsistent neighbors, since in each case the form of the word can map to two dissimilar responses. In a network these items compete for how the weights are set, and their relative frequencies will play a role in which form would be most successful. Furthermore, even when learning is complete the total error on these items will be higher than on items that are not subject to such competition.

Thus the network learning account predicts that error (and therefore speed of access) will be higher for items with homophones than for those without, and that for the homophonous pairs, error will be lower on the form with the more frequent reading. This is the pattern of results obtained in our experiments, and argues in favor of the network account of these data.

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