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Is There a Dual System for Regular Inflections?

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A central question in morphological research is whether there are whole-word representations for regularly inflected forms. A series of four lexical decision experiments addressed this question by looking at whole-word frequency effects across a range of frequency values with constant stem-cluster frequencies. Frequency effects were only found for inflected forms above a threshold of about 6 per million, whereas such effects were found for morphologically simple controls in all frequency ranges. We discuss these data in the context of two kinds of dual models and in relation to competition models proposed within the connectionist literature.

Key Words: dual system; connectionism; inflection; morphology; lexical access.

The idea of a dual model for inflectional morphology has emerged within two distinct lines of research in psycholinguistics. One kind of dual model is known as the rule-associative model, reflecting the different kinds of representations for regular and irregular inflections (Pinker, 1991). The second kind of dual model characterizes lexical access for morphologically complex words as via either a whole-word route or a compositional route (e.g., Caramazza, Laudanna, & Romani, 1988).

Pinker's rule-associative model claims that the generation of regular inflections involves the concatenation of an affix with a variable representing the syntactic category of the stem (e.g., V+ed). Irregular inflections are stored as whole words in associative memory and generalization occurs on the basis of similarity to clusters of existing forms. The strong version of this model proposes that regularly inflected words are never stored in memory. However, it is conceded that ''. . . prior storage of regulars is possible . . . but

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generalization never depends on prior storage of a similar form'' (Prasada & Pinker, 1993, p. 9).

The second kind of dual model focuses on lexical access rather than generalization. Access to morphologically complex words occurs either through a whole-word route or a compositional route. These two routes are said to work in parallel and in competition. The whole-word access route is faster unless the item frequency of the complex word is very low. In that case, the compositional route wins out and the whole-word representation is not accessed. If low-frequency inflected forms are not accessed via the whole word route, then they should not exhibit whole-word frequency effects in lexical access. Such effects should be restricted to inflected forms with frequencies above a particular threshold. To date, there has not been any evidence that such a frequency threshold exists, and therefore the location of the threshold has never been specified. The present experiments were designed to determine whether there are frequency effects for regularly inflected words and whether there is a threshold for such effects.

If a frequency threshold is found for regular inflections, this does not provide unequivocal evidence for a dual model. Several connectionist models, using single associative networks, have been successful in accounting for discontinuities in data without recourse to rule systems. For example, in Bybee's (1995) connectionist model of morphology, there is competition between lexical strength (based on frequency of the complex form itself) and lexical connections (based on the strength of connections to other words that share phonological segments with the complex form). There is no distinct representation of morphology within this system and thus no compositional route to lexical access. Like the dual access models, Bybee's model predicts a threshold for frequency effects as lexical strength takes over from lexical connections in accessing a complex form. Unlike the dual access models, Bybee makes a distinct prediction concerning the number of inflectional variants associated with a particular stem cluster. If an inflected form is part of a paradigm that contains many inflectional variants—as in the case of verbs—then this will increase the connection strength for that item over its lexical strength. For an inflectional paradigm containing only a few variants—as in the case of nouns—the lexical strength should be more significant than its connection strength. The model predicts that whole-word frequency effects should be stronger for inflected nouns than for inflected verbs. This prediction distinguishes Bybee's model from existing dual models and will therefore be tested using data from the present set of experiments.

In the present experiments, we attempted to find out if there was a frequency effect for regularly inflected nouns and verbs and whether there was a threshold value below which the frequency effect disappears. Previous attempts to find frequency effects for regular inflections have treated frequency as a categorical variable (high vs low) (Burani, Salmaso, & Caramazza, 1984; Prasada, Pinker, & Snyder, 1990; Taft, 1979). In the present studies,

we wanted to examine whole-word frequency effects across a range of values, while keeping stem-cluster frequency (i.e., frequency of stem plus inflectional variants) constant.

The specific questions to be addressed are: (1) Is there a frequency effect for regularly inflected words? (2) If so, is there a frequency threshold below which such effects are not found? (3) If so, is the region below the frequency threshold sufficiently well differentiated to allow one to find frequency effects when normal (simple) words are being considered? (4) Are there interactions between the size of the frequency effects and the syntactic category of the items?

GENERAL DESIGN OF EXPERIMENTS 1 THROUGH 4

Participants

Participants for all experiments were recruited from the Psychology subject pool at the University of Pittsburgh. There were 30, 30, 27, and 26 participants for Experiments 1 through 4, respectively.

Design

Visual lexical decision task was used in all experiments. Participants saw a fixation cross on a computer screen followed by a stimulus item. They responded as to whether it was a word by pressing one of two keys with reaction times and accuracy recorded by the computer. Since accuracy was above 95% for all experiments, there were no effects for this measure, and only RTs for correct responses are reported in this paper. Test items in Experiments 1–3 included equal numbers of inflected nouns and verbs (see Table 1 for numbers). Stem-cluster frequency was held constant across items, whereas whole-word frequency of the inflected form varied evenly across the log scale. Log frequency values were calculated from the Francis and Kučera (1982) word count. Experiments 2 and 4 included uninflected adjectives, which were matched to the inflected nouns and verbs for mean length and whole-word frequency. Distractors included simple real words (nouns and verbs), simple nonwords, and inflected nonwords. All distractors were matched on length to the main items and real-word distractors

TABLE 1
Items Used in Experiments 1 through 4

	Inflected nouns and verbs			Simple adjectives		Distractors (*n*)		
Expt.	Cluster freq.	Inflected freq.	*n*	Item freq.	*n*	SRW	SNW	INW
1	49–60	0–44	68			68	68	68
2	49–60	0–6	50	0–6	50	30	80	50
3	25–31	0–24	94			94	94	94
4				0–24	94	94	188	

Note. SRW, simple real words; SNW, simple nonwords; INW, inflected nonwords; *n* = number of items. There were equal numbers of nouns and verbs in the inflected and SRW categories.

were matched on item and cluster frequency to main items; nonwords were generated from real words by altering one letter to produce a pronounceable string.

In each experiment, word length, syntactic category, neighborhood frequency, cluster frequency, and item frequency were analyzed as variables. Materials were designed so that these variables were not intercorrelated. When variables unrelated to the hypotheses were significant, they were factored out of the analysis. Details of cluster and item frequency values and number of items for each of the experiments are presented in Table 1. Results of the individual experiments are reported below; headings represent approximate cluster and item frequency values for each experiment. Multiple regressions on the five variables were carried out for item analyses. For subject analyses, we used hierarchical linear modeling. Individual slope coefficients for each of the five variables were calculated, then mean coefficients across subjects were tested to see if they were significantly different from zero.

EXPERIMENT 1

In this experiment, cluster frequency = 50 and word frequency = 0–50. In this frequency range, we found strong frequency effects for both subject and item analyses [$F1(1, 29) = 33.5$, $p < .0001$; $F2(1, 67) = 10.9$, $p < .005$; Min$F'(1, 96) = 8.24$, $p < .01$]. The results indicate that there is storage of regularly inflected forms, but they do not address the question of whether there is a threshold for this frequency effect. We therefore did a median split on the log frequency values and divided the items between those below and above the median frequency of 6 per million. The result of this separation was that the lower frequency items did not show evidence of a frequency effect (subjects: $p = .3$; items: $p = .8$), whereas the items with frequencies above 6 did show significant effects [$F1(1, 29) = 16.7$, $p < .0005$; $F2(1, 37) = 6$, $p < .005$; Min$F'(1, 60) = 4.41$, $p < .05$].

These data provide initial support for the existence of a threshold for frequency effects for regularly inflected words. However, it is possible that the lack of frequency effects in the 0–6 range may have been due to range compression or a floor effect. In addition, frequency estimates in the lower ranges may be inaccurate due to sampling error. In the next experiment, we examined whether frequency effects could be found in the 0–6 range when simple forms were tested. To do this, we chose adjectives, which lack clear inflectional paradigms and therefore would not show confounds of differences in cluster frequency.[1] In addition, we wanted to do a prospective study in which we demonstrated that their was no frequency effect in the 0–6 range for inflected items since previous findings had been post hoc.

EXPERIMENT 2

In this experiment, inflected cluster frequency = 50, item frequency range = 0–6, and adjective frequency range = 0–6. As in the previous experiment,

[1] There is some disagreement as to whether *-er* and *-est* constitute inflectional variants of adjectives. However, since there was only one such form listed in Francis and Kucera (1982) based on the adjectives tested, this should not be a problem.

there was no frequency effect for inflected items in the 0–6 range. In fact the relation between frequency and RT was positive. For adjectives, there was a strong frequency effect [$F1(1, 29) = 20.19$, $p < .0005$; $F2(1, 49) = 7.5$, $p < .01$; Min$F'(1, 76) = 5.47$, $p < .05$], indicating that failure to find an effect for inflections was not a floor effect or the result of range compression or inaccurate frequency estimates.

One remaining issue is the arbitrariness of the threshold value. The value was chosen because it represented the log median value, not because of any theoretical or empirical considerations. Therefore, we wanted to see if the same difference between inflected items and adjectives could be obtained for a wider frequency range of 0–24.

EXPERIMENTS 3 AND 4

In Experiment 3, for inflected items: cluster frequency = 25, and item frequency = 0–24. In Experiment 4, adjective frequency = 0–24. In Experiments 3 and 4, inflected items and adjectives were tested separately to avoid any possible contamination and to allow a larger pool of items to be used. Both were tested in the 0–24 frequency range.

For the inflected items, there was a frequency effect that was significant by subjects [$F1(1, 26) = 16.1$, $p < .0005$] but not by items ($p = .1$). For adjectives, there was again a strong frequency effect in this range [$F1(1, 25) = 89.11$, $p < .0001$; $F2(1, 93) = 47.45$, $p < .0001$; Min $F'(1, 109) = 30.96$, $p < .0001$]. These results suggest that the 0–24 frequency range goes beyond the threshold for the storage of regularly inflected words. Reexamining these items with the 0–6 range, we find that the frequency effect again disappears for inflected forms (subjects: $p = .58$; items: $p = .56$) but remains for adjectives (subjects: $p < .01$; items: $p < .005$).

GENERAL DISCUSSION

These results clearly support the predictions of the dual-access model for regularly inflected words. Above the frequency threshold of about 6 per million, the whole-word route appears to win over the compositional route. However, we noted earlier that the same prediction of a frequency threshold can be made by Bybee's (1995) connectionist model, which does not invoke morphological decomposition. Unlike the dual model, Bybee's model predicted that nouns should show stronger whole-word frequency effects than verbs because nouns contain smaller inflectional clusters and therefore should have lower connection strengths, leaving a greater role for lexical strength in determining access. In testing for interactions between whole-word frequency and category (noun vs verb) across the experiments, we found no effects to be significant, whether we examined the complete frequency range or just the 0–6 range ($p > .27$ for all analyses). Therefore, the present data do not support this specific prediction that distinguishes

Bybee's model from the dual-access model. Other connectionist models have also been tested against the present data, and none of the specific predictions have been supported (Alegre & Gordon, 1999). We do not preclude the possibility that more targeted experiments could provide support for some kind of connectionist model. We simply note that the present results do not do so.

Since frequency effects are taken to indicate whole-word storage for regularly inflected forms, the present data do not support the strong version of Pinker's (1991) rule-associative model in which regular inflections are never stored. The weaker version of his theory allows for some storage of regular inflections, although such storage is not required for generalization. But if higher frequency regular inflections are stored, then why do they not take on the properties of associative memory and lead to gang effects in generalization (Prasada & Pinker, 1993)? Marslen-Wilson, Tyler, Waksler, and Older (1994) suggest that there is a distinction between access representations, which are modality specific and frequency sensitive, and central representations, which are abstract and modality neutral. It is possible that the domain of associative memory, where gang effects originate, is at the level of central representations. The frequency–threshold effects in the present study would thus be characteristic only of access representations, which are precisely the domain of the dual-access model. Whether frequency effects extend into central representations would require cross-modal techniques that would capture the frequency properties of this level of representation.

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