Frequency of meaning use for ambiguous and unambiguous words

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When using verbal stimuli, researchers usually equate words on frequency of use. However, for some ambiguous words (e.g., *ball* as a round object or a formal dance), frequency counts fail to distinguish how often a particular meaning is used. This study evaluates the use of ratings to estimate meaning frequency. Analyses show that ratings correlate highly with word frequency counts when orthographic and meaning frequencies should converge, are not unduly influenced by semantic factors, and may provide a better measure of relative meaning dominance than the word association task does. Furthermore, the ratings allow researchers to equate or manipulate frequency of meaning use for ambiguous and unambiguous words. Ratings for 211 words are reported.

Lexically ambiguous words are widely used in psycholinguistic research. In word recognition studies, homonyms,¹ such as (baseball and vampire) *bat*, have been used to study context and frequency-of-meaning effects in lexical access (for a review, see Simpson, 1984, 1994), number-of-meanings effects (e.g., Millis & Button, 1989; Rubenstein, Garfield, & Millikan, 1970), summation of priming (Balota & Paul, 1996), and other issues. Homophones, such as *steel* and *steal*, have been used to explore orthographic priming effects (e.g., Grainger & Ferrand, 1994) and to test the influence of phonology on visual word recognition processes (e.g., Fleming, 1993; Jared & Seidenberg, 1991; Van Orden, 1987). Homographs with different pronunciations, such as *wind*, pronounced as /waɪnd/ or /wind/, have also been used to study these questions (e.g., Kawamoto & Zemblidge, 1992). In word production research, homonyms and homophones have been used to investigate open- versus closed-class vocabulary differences (Dell, 1990), the locus of word frequency effects (Jescheniak & Levelt, 1994), the effect of phonological priming on word selection (Griffin, 1995), phonology's role in subject-verb agreement errors (Bock & Eberhard, 1993), and the relationship between lexical processing stages (Cutting & Ferreira, 1999). However, part of what makes ambiguous words interesting—namely, the association of a single form with multiple meanings—also makes

it difficult to equate them with unambiguous words on the important factor of frequency of meaning use.

Word frequency effects are ubiquitous in word recognition (see, e.g., Forster & Chambers, 1973) and production (see, e.g., Oldfield & Wingfield, 1965) tasks. Because of this, care is usually taken to match verbal stimuli and responses on frequency of use. For unambiguous words, estimating and controlling word frequency is fairly straightforward, because measures of phonological- and orthographic-form frequency are highly correlated, and both reflect the frequencies with which meanings are used. In other words, the frequencies of perceiving or producing the form *tent*, /tent/, and the meaning *temporary shelter for campers* are probably similar. Thus, an experimenter generally need not be concerned about which type of frequency may have the greatest influence in a task. However, for ambiguous words, orthographic, phonological, and meaning frequencies may vary. To take an extreme case, the form /rajt/ has a phonological-form frequency combining the uses of *rite*, *wright*, *write*, and *right*. Each orthographic form has its own frequency. For *rite*, *wright*, and *write*, orthographic-form frequency may correspond closely to the frequency with which their meanings are used. In contrast, the orthographic form *right* has meanings related to direction, correctness, politics, and privileges. If frequency of phonological form (e.g., /rajt/) is influential in a task, an orthographic frequency count (e.g., for *right* only) underestimates the use of /rajt/. Alternatively, if the frequency of meaning use (e.g., the directional *right*) is the most important index of use in a task, orthographic frequency (which covers all *rights*) overestimates use of any one meaning of *right*. Naturally, all types of frequency may be relevant in a task, in which case a measure of each is important.

Fortunately, there are frequency counts that provide estimates for each orthographic form and grammatical class of a word in speech or text (e.g., the CELEX database; Baayen, Piepenbrock, & van Rijn, 1993; Francis &

The norming study was conducted at the University of Illinois at Urbana-Champaign while the author was supported by a National Science Foundation Fellowship. The research was made possible, in part, by grants from the National Institutes of Health (R01-HD21011) and the National Science Foundation (SBR 94-11627). Thanks to Kathryn Bock, Victor Ferreira, Leslie Twilley, an anonymous reviewer, and, especially, Gary Dell for suggestions in the preparation of this manuscript and to Urbano Chaidze and Edyta Kania for their hard work and patience in data entry. Correspondence concerning this article should be sent to Z. M. Griffin, Department of Psychology, Stanford University, Jordan Hall, Bldg. 420, Stanford, CA 94305-2130 (e-mail: griffin@psych.stanford.edu).

Kučera, 1982). Some of these databases provide separate counts for each meaning of homophones (*do* and *dew*), homographs of different grammatical classes (/wajnd/ and /wind/), and homonyms of different grammatical classes (the noun and verb meanings of *watch*). Combining these separate counts for each spelling and grammatical class offers a way to estimate orthographic or phonological frequency. Meaning frequency is a different matter. With one exception (Lorge, 1949; Lorge & Thorndike, 1938), frequency counts do not differentiate between the different meanings of homonyms that share grammatical class, such as *ball* (meaning a round object or a formal dance), and these are perhaps the most commonly used ambiguous words in experiments.

Typically, researchers rely on dominance from word association norms to determine the relative frequency of different meanings for same-class homonyms (i.e., *ball* is more commonly used for a round object than for a formal dance; see, e.g., Cutting & Ferreira, 1999; Onifer & Swinney, 1981). Several sets of word association norms have been published to aid researchers in determining dominance and in manipulating the relative frequencies of homonym meanings (e.g., Cramer, 1970; Gorfein, Viviani, & Leddo, 1982; Kausler & Kollasch, 1970; Nelson, McEvoy, Walling, & Wheeler, 1980; Twilley, Dixon, Taylor, & Clark, 1994). However, such norms are inadequate for matching a homonym's meaning frequency to that of an unambiguous word, because there is no equivalent measure in word associations for these. Furthermore, the relationship between associative dominance and actual meaning frequency is unclear.

In a study of word associations to unambiguous words, de Groot (1989) found that there were more word association responses to words of high imageability than to words of low imageability and that it took less time to generate an associate to a highly imageable word. The effect of stimulus-word frequency on the speed and number of associations was considerably weaker and, in some experiments, completely absent. This raises the possibility that dominance in word association norms for ambiguous words may be more influenced by the relative imageability of the meanings than by their relative frequency. Consider the homophone *can*. In Nelson et al.'s (1980) association norms, 29 responses were associated to the container meaning, whereas only 8 responses were related to the ability meaning. In contrast, Francis and Kučera (1982) list the modal auxiliary (which is associated with the ability meaning) as having a frequency of 2,192 occurrences per million, whereas the noun (container meaning) has a frequency of 12. Thus, there may be a nonmonotonic relationship between associative dominance and meaning frequency, particularly when meanings differ in imageability or in the richness of their semantic features (Kausler & Kollasch, 1970). This raises the possibility that findings of processing differences between dominant and subordinate homonym meanings (cf. Simpson, 1994) may be attributable to imageability, rather than to meaning frequency.

Past studies (e.g., Carroll, 1971; Shapiro, 1969; Tryk, 1968) have shown that subjective frequency ratings for orthographic forms correlate highly with objective frequency measures in general. One goal of the present study was to validate the use of such ratings as estimates of meaning frequency. Another goal was to compare the obtained ratings of meaning frequency with dominance measures from word association norms and frequency counts, in order to validate the use of ratings as measures of relative meaning frequency for ambiguous words. As an integral part of this effort, over 200 words were normed. Participants were asked to rate words according to how often they used the words' meanings in speech. Ratings were collected for homonyms of same and different grammatical classes, for homophones, and for unambiguous words. The inclusion of various types of ambiguous words allowed comparisons to be made between objective and subjective measures that would not otherwise be possible. For example, homophones are ambiguous when presented auditorily, so word associations may be collected for them (G. G. Galbraith & Taschman, 1969). Because each homophone meaning has a distinct spelling, word frequency counts should correspond to meaning frequencies, allowing comparison between measures of meaning dominance from frequency counts, those from frequency ratings, and those from word associations. The frequency ratings for all words are presented in the Appendix.

METHOD

Participants

Twenty-four students at the University of Illinois at Urbana-Champaign participated to fulfill a requirement for an introductory psychology course. They were all native speakers of American English.

Apparatus

A Macintosh Quadra 800 with a 17-in. monitor was used to present the stimuli and record the ratings.

Materials

Although linguistic tests for ambiguity exist, they are unreliable (Geeraerts, 1993). Rather than being strictly ambiguous or unambiguous, words appear to lie on a continuum with a single meaning at one end, multiple unrelated meanings at the other, and clusters of more-or-less related senses in the middle (see, e.g., Tuggy, 1993). Thus, determining the number of distinct meanings that a word possesses relies ultimately on subjective criteria. The author imposed a final classification on each word, using her own intuition after norming was completed. Because some words were only recognized as ambiguous at this point, a few ambiguous words received ratings for only one meaning. The normed items consisted of 119 ambiguous, 73 unambiguous, and 20 questionably unambiguous words. The unambiguous words were chosen to provide potential controls for ambiguous stimuli matched in grammatical class, phonological length, and initial phoneme. The questionable items were not included in comparisons between word types. Some of these words were homophonous with inflected words (e.g., *new-knew*, *pause-paws*), and some had secondary meanings only in technical vocabularies (e.g., *phone* as used in phonology and *pan* meaning to rotate a camera). A few excluded items had subordinate meanings that seemed unlikely to be in the average vocabulary (e.g., the homonym *nap* (a downy surface) and the homophone *heart* (homophonous with *hart*, a deer).

Figure 1 illustrates the classification of the words used in this study, along with examples of each. Words that are ambiguous in multiple ways were assigned to the category that best reflected this—in other words, the rightmost appropriate category in Figure 1. For example, *plane* is homophonous with *plain*, which makes it a homophone, but it also has meanings that share the same spelling and grammatical class, so it was analyzed as a same-class homonym. Of the ambiguous words, 62 were homophones (i.e., sharing sound but not spelling). Among these were 29 word pairs, 2 words homophonous with words in other ambiguity categories, and 2 words with homophones that were not rated. There were 31 items classified as different grammatical class homonyms (11 pairs at the same level of ambiguity, 2 homophonous with words in other groups, 7 alone), and 25 items were considered to be same grammatical class homonyms (12 pairs, 1 alone). A short definition was written for each word, based loosely on its definition in *Webster's New World Dictionary of American English* (1991).

The classification of words for this study was validated against entries in *Webster's Dictionary* (1991) by counting the number of entries of the same grammatical class per orthographic form. As was expected, words classified as same-class homonyms had the highest mean number of entries ($M = 1.56$)² per spelling and grammatical class. Words that were unambiguous (1.14) and homophones (1.19) had somewhat fewer entries than did different-class homonyms (1.32). The differences between same-class homonyms and other ambiguity categories were evaluated with one-tailed unpaired *t* tests. These comparisons indicated that same-class homonyms had significantly more entries than did unambiguous words and homophones [$t(96) = 3.92, p < .0001$, and $t(85) = 2.81, p < .005$, respectively] and marginally more than did different-class homonyms [$t(54) = 1.30, p < .10$]. The *t* tests support the characterization of the same-class homonyms included in this study as possessing more meanings per form and grammatical class than the other categories did. Because word frequency counts typically follow the organization of dictionaries, except in distinguishing between meanings within the same grammatical class and spelling, frequency counts should be less representative of meaning use for same-class homonyms than for other words. Therefore, insofar as ratings are based on meaning frequency, the correlation between ratings and counts should be lower for same-class homonyms than for other words.

Procedure and Design

With the use of a variant of standard psychophysical rating tasks (Carroll, 1971; Shapiro, 1969), participants were asked to rate how often they typically said a word, using a particular meaning. They were told to rate meaning use relative to the other items in a list. The instructions were very similar to those of Carroll, except that the participants were asked to estimate frequency of spoken use, rather than written use, and frequency of meaning rather than form. The critical part of the instructions read as follows.

[W]e want to find out how often you say certain words. Suppose that the word "milk" has a value of 100 representing how often you say it. We would like you to give numbers to other words in such a way that the numbers give your own impression of how often you use them in speaking. Thus, if a word seems twenty times as frequent as another, you would give it a number twenty times as large. If, on the other hand, it seems only half as frequent, give it a number only one-half as large. You may use fractions, decimals, or whole numbers, but not negative numbers. Only use zero if you never have used a word. ... Next to each word is a definition. When you decide how often you say a word we want you to think of the meaning of the word that is in the definition.

As in Carroll (1971), the word in the instructions (*milk*) was only used as an example, and participants were allowed to set their own criteria. Every participant was presented with five practice items, selected to represent a wide frequency range, in random order. Definitions appeared next to all the words, so that the intended meaning would be clear. Two lists of items were constructed in such a way that members of ambiguous word pairs appeared on different lists. As a reliability check, 11 words appeared on both lists with either identical definitions or minor changes in wording. Most of these were unambiguous or excluded questionable words, and one was a homonym (*rash*). Other than these, words were not repeated with the same definition or intended meaning. Each participant saw both lists, and the order of list presentation was counterbalanced across participants. Between lists, the participants performed a short, unrelated norming task that took about 5 min to complete. One list contained 113 items, and the other 109. Within each list, word order was a different random sequence for each participant. Approximately 22 items were visible at a time. The participants entered their ratings with a number keypad and used arrow keys to move up and down the lists.

Figure 1. Diagram and examples of word categories used in this study.

Scoring

For each word that a participant rated, a *z* score based on the rating's deviation from the participant's mean rating was calculated. This is similar to the method used by Carroll (1971), except that ratings were also log-transformed in Carroll's study. For each item, a median *z* score was calculated by taking the median score across participants.

RESULTS AND DISCUSSION

There was a great deal of variety in the scales used by participants in estimating frequency of meaning use. One participant found 0–30 to be a sufficiently broad range, whereas another used numbers ranging from 10^{-12} to 10^7 . The distribution of median *z* scores for the 222 rated words is shown in the top panel of Figure 2, and for comparison, the distribution of spoken frequency counts from CELEX (Baayen et al., 1993) for the same words is shown in the bottom panel. The mean of the median *z* scores was -0.090 , with a standard deviation of 0.436 . The homophone *no* received the highest median *z* score

(2.312), and the unambiguous word *reef* received the lowest (-0.690).

Rating Meaning Use Versus Form Use

Two different analyses were employed to determine whether the participants were rating meaning frequency rather than orthographic-form frequency. In the first, the median *z* scores for the 11 repeated words were compared with the median *z* scores for the 11 different-class homonym pairs. If the participants did not attend to definitions, there should have been as little variability between the first and the second ratings given to a homonym, such as *watch*, as there was for the first and the second ratings given to an unambiguous word, such as *tent*. Note that this is a conservative test, because equivalent rating differences were also predicted if the homonyms had similar meaning frequencies. The absolute differences between median *z* scores for homonym pairs (0.209) were greater than those for repeated words (0.108). This difference was marginally significant in an unpaired one-tailed *t* test [$t(20) = 1.68, p < .06$].

In the second analysis, correlations were calculated between median *z* scores and objective measures of frequency. Objective frequency counts conflate meanings for same-class homonyms. Thus, if median *z* scores reflect meaning frequencies, ratings for same-class homonyms should have lower correlations than those for other word types. Alternatively, if the participants ignored the definitions and rated orthographic frequency, median *z* scores for different-class homonyms (which have their orthographic-form frequencies divided among grammatical classes) should show the lowest correlations with frequency counts. Frequency counts for members of other word types are not systematically divided between different grammatical classes.

The objective frequency measures were taken from Francis and Kučera (1982) and the CELEX database (Baayen et al., 1993). Although they are somewhat old, the Francis and Kučera counts (abbreviated F&K) were included because they are still often used by researchers. Another measure of written frequency was taken from CELEX, which is based on a much larger (more than 16 million words) and more recent database than that of Francis and Kučera. CELEX also provides a measure of spoken frequency, based mostly on British English sources and a relatively small sample (1.3 million words). The frequencies corresponding to the grammatical class implied by the words' definitions were used. Correlations were calculated using base-10 logarithms of these counts in occurrences per million plus one. Words with no occurrences in a database thus received a log frequency of zero. The three counts are highly correlated [log written and log spoken CELEX, $r(211) = .94$; log written CELEX and log F&K, $r(211) = .94$; log spoken CELEX and log F&K, $r(211) = .89, ps < .0001$], but all three were used, because of their differences in sample sizes and sources. The log-transform of frequency counts is commonly used in studies of reaction time to words (Oldfield & Wingfield, 1965).

Figure 2. Top panel: distribution of median *z* scores for all ratings of meaning frequency. Bottom panel: distribution of log spoken frequency counts from CELEX for the same words.

For calculating correlations with meaning ratings, there was no reason a priori to prefer log-transforms to untransformed counts, but both produced a similar pattern of results, with the log-transformed counts showing slightly stronger correlations with ratings.

Pooling over word types, there was a significant relation between rated meaning frequency and measures of frequency from various corpora (only the first z score was included for repeated items). Ratings correlated moderately with log frequencies [$r(211) = .62$ with log F&K, $r(211) = .66$ with log written CELEX, and $r(211) = .68$ with log spoken CELEX, p s < .0001]. Table 1 displays the correlations between ratings and these frequency measures, broken down by word type. The Appendix lists the median z scores of individual words alphabetically by word type.

Correlations between ratings of meaning frequency and frequency counts were fairly high and uniformly significant for all word types except homonyms of the same grammatical class. The hypothesis that the participants solely rated frequency of orthographic form predicted that different-class homonyms would have lower correlations with objective counts than would other words. However, only ratings for homophones correlated more highly with counts than ratings for different-class homonyms did, and the difference in correlations for the two word types was not significant. As would be predicted if the participants rated meaning frequency, correlations for same-class homonyms were lower than those for homophones ($z = 1.58, p < .06$; $z = 2.34, p < .01$; $z = 2.19, p < .02$, for log F&K, log written CELEX, and log spoken CELEX, respectively). Correlations for same-class homonyms were lower than those for different-class homonyms, although not approaching significance for one word count ($z = .86, p < .20$; $z = 1.88, p < .04$; $z = 1.48, p < .07$, for log F&K, log written CELEX, and log spoken CELEX, respectively). However, there was only one marginally significant difference between correlations for same-class homonyms and for unambiguous words ($z = 1.33, p < .10$, for log written CELEX).

Overall, lower correlations between meaning frequency ratings and frequency counts were found for same-class homonyms than for other word types, although the correlations for unambiguous words were lower than expected.

Table 1
Correlations Between Ratings and
Objective Frequency Measures

Word Type	Word Frequency Measure		
	Log F&K	Log Written	Log Spoken
Unambiguous	.61†	.63†	.64†
Homophone	.72†	.76†	.78†
Homonym, different class	.64†	.71†	.73†
Homonym, same class	.47*	.40	.47*

Note—F&K, Francis and Kučera (1982) frequency counts; written, CELEX occurrences per million in written corpus (Baayen, Piepenbrock, & van Rijn, 1993); spoken, CELEX occurrences per million in spoken corpus. * $p < .05$. † $p < .0005$.

However, it may be the case that ambiguous words have fewer senses per meaning than unambiguous words do, which would make it easier to estimate the meaning frequencies for ambiguous words. The number of subentries in *Webster's Dictionary* (1991) was calculated for each orthographic form. Consistent with the idea that ambiguous words may have fewer senses per meaning, homophones had a lower mean number of subentries per entry (9.0) than unambiguous words did (10.9). However, by this argument, different-class homonyms should have fewer subentries than do unambiguous words as well, and they did not, even when word class was taken into consideration (9.4 vs. 6.0 subentries).

The low correlations between ratings and counts for same-class homonyms were predicted, because frequency counts collapse across all meanings for such words and, therefore, overestimate the use of each meaning. The alternative possibility, that the participants were simply basing ratings on orthographic forms, found no support. That account incorrectly predicted that objective frequency counts for different-class homonyms that were divided by class (e.g., noun and verb *watch*) would not correlate highly with ratings. Moreover, the larger difference in ratings for different-class homonym pairs, relative to words repeated with the same meaning, further supports the claim that the participants rated frequency of meaning use rather than frequency of form use in this task.

The correlations between ratings and objective counts were smaller than those found by some previous researchers using similar methods. Carroll (1971) and Shapiro (1969) found correlations above .90 between subjective and objective frequency measures. However, there were a number of differences between this study and theirs that could account for the difference in correlations. Both Carroll and Shapiro used a greater range of word frequencies, their analyses were based on log transforms of ratings, and most important, neither were trying to elicit frequency of meaning use. In the present study, objective frequency counts showed correlations in the same range as those found by Tryk (1968) for estimated word use and for Howes's (1954) frequency rankings.

The Influence of Semantic Factors on Ratings

Earlier studies have found strong effects of semantic factors, such as concreteness, on word association latencies and the number of associates generated (Brown, 1971; Cattell, 1889/1947; Cramer, 1968; de Groot, 1989). These researchers have also noted the ability of such semantic factors to mask or eliminate frequency effects in word associations. Insofar as sensitivity to semantic factors may be common to all subjective measures, they could influence frequency ratings, as well as word associations. Although it is easier to generate associations to concrete words than to abstract ones, past studies of frequency estimation have shown that abstract words are rated higher in frequency than are concrete words (R. C. Galbraith & Underwood, 1973). The next set of analyses

evaluates the influence of semantic factors on ratings of meaning frequency.

Correlations between frequency ratings and various measures available from the MRC Psycholinguistic Database (Coltheart, 1981) were calculated. Unfortunately, it was not possible to correlate MRC measures with frequency ratings for homonyms, because the database does not distinguish between different grammatical classes or meanings for the same form. Thus, comparisons were only appropriate for unambiguous words and homophones. As a control for the possible inclusion of words for which frequency and semantic factors were in fact correlated, correlations were also calculated for objective word frequency measures. If abstract word meanings were systematically rated higher in frequency than were concrete meanings, ratings would show greater negative correlations with factors such as concreteness than objective frequencies would. Correlations for each semantic factor with frequency ratings and with log F&K are shown in Table 2.

The frequency measures showed similar negative correlations with concreteness and imageability ratings from combined sources (Gilhooly & Logie, 1980; Pavio, Yuille, & Madigan, 1968; Toglia & Battig, 1978). The correlations were stronger for homophones, probably because homophones had greater variability than did unambiguous words in all measures. There were no significant differences between the correlations with each semantic factor for frequency ratings and log F&K (all z s < 1). Ratings of meaning frequency appear no more related to semantic factors than are objective frequency measures. This suggests that frequency ratings were not biased by the concreteness or imageability of words.

Measures of Meaning Dominance

Next, the frequency ratings, objective frequency counts, and associative dominance were compared as measures of relative meaning frequency for ambiguous words. Currently, the standard method of determining the dominant or high-frequency meaning of a homonym is to select the meaning that receives the greatest proportion of word associations (see, e.g., Hino & Lupker, 1996; Onifer & Swinney, 1981). Homonym meanings are considered equibased or fairly equal in frequency if two meanings produce nearly equal numbers of associations (see, e.g., Rayner & Duffy, 1986). However, concrete word meanings may be more likely to generate associates than are abstract meanings, diminishing the influence of mean-

ing frequency in associative dominance (Brown, 1971; Cramer, 1968; de Groot, 1989). If ratings of meaning frequency truly reflect frequency of meaning use, the ratings may provide an alternative and, perhaps, superior measure of meaning dominance.

Analyses were performed on dominance measures for homophones, such as *steal* and *steel*, rather than for homonyms.³ Because the separate meanings of homophones are identified by spelling, objective frequency counts were expected to reflect meaning frequencies quite well. A measure of associative dominance came from G. G. Galbraith and Taschman's (1969) collection of word associations to auditorily presented homophones. For the 18 homophone pairs for which there were both frequency ratings and associations, the higher and the lower frequency members were determined on the basis of each measure. Associative dominance had a low level of correspondence with meaning dominance, on the basis of objective frequency measures. Associative dominance agreed with dominance in the written CELEX database for 11 of 18 pairs. For 10 of 18 pairs, associative dominance agreed with dominance in spoken CELEX and F&K. These patterns did not differ significantly from chance, according to sign tests. Dominance in word associations agreed no better with estimates of meaning dominance based on frequency ratings (10 of 18). In contrast, dominance in frequency ratings matched dominance measures based on objective measures more often than would be expected by chance (15 of 18 with written CELEX, 14 of 18 with spoken CELEX, and 16 of 18 with F&K, p s < .02). So, for the same set of homophones, objective frequency counts and ratings of meaning frequency showed a high level of agreement, whereas associative dominance agreed only at chance levels with meaning dominance, as measured in frequency counts and ratings.

Next, the differences between homophone pairs in a variety of measures were calculated, and correlations between differences were examined. Rather than simply indicating how often measures of dominance agreed with one another, the correlations between differences indicate the degree to which measures agree in magnitude of dominance. Insofar as dominance in word associations is associated with greater frequency of use, differences between the homophone pairs in proportion of associates generated should correlate positively with differences in frequency. Insofar as differences between homophone pairs in word associations are due to concreteness of the meanings or imageability, such differences should correlate positively with word association differences. The same logic holds for ratings of meaning frequency. The upper portion of Table 3 shows the correlations between word association differences and other measures of frequency and semantic factors. For comparison, the correlations for written CELEX frequency in millions and its log are shown below for the same items. The correlations were calculated for all homophone pairs in G. G. Galbraith and Taschman's (1969) norms. Out of a maximum of 88, values for both homophone meanings could be ob-

Table 2
Correlations Between Frequency Measures and
Semantic Word Information From the MRC Database

Measure	Unambiguous			Homophone		
	Rating	Log F&K	N	Rating	Log F&K	N
Concreteness	-.23	-.31*	60	-.56†	-.68†	52
Imageability	-.15	-.29	62	-.51†	-.54†	53

Note—F&K, Francis and Kučera (1982) frequency counts. * p < .05, † p < .0005.

Table 3
Word Association and Rated Frequency Differences for Homophone Pairs (e.g., *week/weak*)
Correlated With Differences Along Other Dimensions

Variable 1	Written	LogWritten	Spoken	LogSpoken	F&K	LogF&K	Conc	Image
Word association differences	.03	.55†	-.02	.47†	.00	.48†	.23*	.32†
Written CELEX		.44†	.96†	.48†	.96†	.43†	-.20	-.20
LogWritten CELEX			.31†	.92†	.49†	.93†	-.28*	-.13
Ratings of meaning frequencies	.49†	.56†	.54†	.48*	.50†	.60†	-.62†	-.50*
Written frequencies		.58†	.99†	.45*	1.00†	.52†	-.50*	-.55†
LogWritten frequencies			.62†	.94†	.57†	.94†	-.71†	-.60†

Note—Written, CELEX occurrences per million in written corpus; spoken, CELEX occurrences per million in spoken corpus; F&K, Francis and Kučera written frequency; conc, concreteness ratings; image, imageability ratings. For correlations with word association differences, $N = 78-87$; for correlations with rating differences, $N = 24-32$. * $p < .05$. † $p < .005$. ‡ $p < .0005$.

tained for 78–87 of the pairs. The lower portion of Table 3 shows correlations for differences in ratings of meaning frequency, written frequency, and its log. These were based on all homophonic pairs in the present norms, with 24 to 32 observations contributing to each correlation.

Both word association differences and rated frequency differences correlated significantly and positively with differences in log frequency, whereas only rated frequency differences correlated significantly with raw frequency differences. This difference in behavior appears primarily to be due to differences between function and content words that were often extreme in raw numbers but average when based on differences in log frequency. For example, more word associations were made to *eye* than to *I*, although *I* occurs 9,617 times more often per million words in the written CELEX database. No other word pair comes close to having such a large raw frequency difference, but the pair's difference in log written CELEX frequency is 1.26—for example, *gate/gait* and *symbol/cymbal*. Because response latencies typically reflect log frequency (Oldfield & Wingfield, 1965), this may be the more relevant measure of frequency. If so, word associations and frequency ratings would be equivalent in estimating differences in relative meaning frequency.

Both word association and frequency rating differences correlated significantly, albeit differently, with differences in concreteness and imageability ratings. Greater differences in concreteness and imageability correlated positively with differences in word association responses and negatively with differences in rated meaning frequency. For semantic factors, differences in frequency ratings patterned with differences in frequency counts,⁴ with no significant difference between their correlations with concreteness and imageability ($z_s < 0.6$, for comparisons with raw written frequency). In contrast, correlations with concreteness and imageability for word association differences differed significantly from correlations for frequency counts ($z = 2.67, p < .004$, for concreteness and raw written frequency; $z = 3.28, p < .0007$, for imageability and raw written frequency; $z = 2.84, p < .003$, for imageability and log written frequency). This further suggests that ratings of meaning frequency reflect frequency of use and are less biased by semantic factors than word associations are.

Summary and Conclusions

The first series of analyses converged on the conclusion that participants rated meaning frequency rather than form frequency. For words that possess approximately one meaning per form, ratings of meaning frequency correlated highly with objective frequency measures, as one would expect. The second set of analyses found that semantic factors had no greater correlations with ratings of meaning frequency than they did with objective frequency counts, although these same semantic factors often affect word associations (Brown, 1971; Cattell, 1889/1947; Cramer, 1968; de Groot, 1989). The final set of analyses compared ratings of meaning frequency and associative dominance as measures of meaning dominance for ambiguous words (i.e., which meaning of *ball* or *week/weak* is more common). For an identical group of homophones, frequency ratings agreed with dominance in objective frequency counts, whereas associative dominance did not. Also, differences in rated frequency for pairs of homophones correlated significantly with differences in raw and log frequency, showing correlation patterns with differences in semantic ratings similar to those for differences in objective frequency measures. In contrast, differences between proportion of related word associations showed positive correlations with differences in concreteness and imageability ratings, whereas differences in objective frequency measures did not.

In the past, proponents of subjective measures of word frequency or familiarity have argued that they may actually be more accurate than objective counts when considering infrequent words that are unlikely to appear in small samples (e.g., Carroll, 1971; Gernsbacher, 1984; Tryk, 1968). Now that frequency counts based on far larger corpora exist, there is less of a concern about sampling error for written word frequency counts. However, word frequency counts for *spoken* English are still based on relatively small samples (e.g., a quarter million in Howes, 1966; 1.3 million in CELEX) and are often from dialects spoken outside North America (as is the case for CELEX). For the words included in this study, spoken and written frequency counts were highly correlated, but this need not always be true. In any case, all of the currently available objective frequency counts fail to differentiate between homonyms belonging to the same grammatical class,

such as *ball*, meaning a round object or a formal dance. The exception is Lorge's (1949; Lorge & Thorndike, 1938) semantic count, which is not widely available, in addition to having a number of discrepancies. So, it often remains necessary to resort to subjective measures for estimating word frequency in speech and for determining the relative meaning frequencies of same-class homonyms.

I presented evidence that collecting ratings of meaning frequency allows researchers to overcome several of the problems associated with other frequency measures. Currently, when researchers attempt to equate ambiguous and unambiguous words on frequency, they use the frequencies of the orthographic forms (Rayner & Duffy, 1986) or familiarity ratings for forms (e.g., Hino & Lupker, 1996). As is demonstrated here, it is possible to tap frequency of meaning use rather than form use, thus overcoming a limitation of most objective frequency counts and allowing ambiguous and unambiguous words to be matched on meaning frequency. It should also be possible to collect ratings of sense frequency, thus providing a measure of relatively how often senses of polysemous words are used (e.g., *paper* as a single document, a substance, a periodical publication, etc.). In general, ratings of meaning frequency provide a way to more accurately estimate and manipulate meaning frequencies of ambiguous words, while allowing them to be equated with unambiguous words on frequency of meaning, orthographic form, phonological form, or all three.

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NOTES

1. Henceforth, words identical in spelling and sound will be called homonyms, those sharing spelling but not sound will be called homographs, and those sharing sound but not spelling will be homophones. The word ambiguous will be used to cover all of these words and to differentiate them from orthographic and phonological forms that only have related meanings.

2. Often, meanings that I found sufficiently unrelated to make them homonyms fell under one entry in the dictionary (e.g., *note* as in a message or as used in music, *chest* as a body part or as a box).

3. Ideally, same- and different-class homonym pairs could be compared in a similar fashion. Unfortunately, among the stimuli, there were only nine different-class pairs that association norms and frequency ratings had in common. Slightly more same-class pairs were shared, but those lacked objective counts for comparison. An attempt was made to use sense frequency counts from Lorge and Thorndike (Lorge, 1949; Lorge & Thorndike, 1938), but the low level of agreement within these counts, as reported by Rosenzweig and McNeill (1962), as well as between Lorge counts and CELEX counts for different-class pairs, made this an unattractive source.

4. Note that, in the present analyses, ratings never correlated significantly higher with concreteness or imageability than objective frequency measures did. This supports R. C. Galbraith and Underwood's (1973) idea that number of contexts rather than concreteness may have affected their frequency ratings. Use in a greater number of contexts has also been hypothesized as a reason why high-frequency words are produced more quickly and accurately than low-frequency words (Dell, 1990).

APPENDIX

Target	Definition	Median z Score	Target	Definition	Median z Score
Unambiguous Words					
age	length of existence	-0.07	mask	disguise for the face	-0.38
ax	instrument to chop wood	-0.54	moon	a satellite revolving around earth	-0.07
bake	to cook in an oven	-0.27	name	title	1.19
beak	a bird's mouth	-0.51	nose	something you breathe through	-0.10
beer	an alcoholic drink	0.62	paint	liquid color	-0.23
boat	a vessel for traveling on water	-0.41	patch	a cover for a hole	-0.56
boat	water vessel	-0.37	pose	to assume a position	-0.37
brag	to boast	-0.30	price	cost	0.18
burn	to injure with heat	-0.09	price	cost	0.41
candle	source of light	-0.46	prize	free gift	-0.21
captain	commander of a vessel	-0.51	pulse	the beating blood in arteries	-0.45
chalk	a powdery stick used for drawing	-0.45	reach	to attain; to extend toward a goal	-0.08
choose	to select	-0.11	reef	a formation in the ocean	-0.69
cut	an incision, a wound	-0.19	ride	a trip	-0.07
dark	dim, lacking light	0.48	sand	small rock particles	-0.42
deep	opposite of shallow	-0.24	say	to utter aloud, speak	1.01
deep	opposite of shallow	-0.34	scar	mark of a wound	-0.33
dent	a hollow in a surface	-0.41	scoop	a kind of spoon	-0.46
dent	a hollow, an indentation	-0.28	seat	a place to sit	0.09
dime	ten pennies	-0.07	shark	an animal that lives in the ocean	-0.47
dime	ten pennies	-0.12	show	a television program	0.37
floor	a level in a building	0.03	sick	ill	-0.04
frost	frozen moisture outside	-0.46	size	a measure of the space something occupies	-0.07
germs	bacteria, carriers of disease	-0.43	sky	the upper atmosphere, the heavens	-0.01
gulp	swallow	-0.50	soft	opposite of hard	0.04
hand	part of the arm below the wrist	0.53	soil	dirt	-0.39
hint	a clue	-0.38	song	a tune	0.65
hook	curved metal pin that holds things	-0.43	sour	a sharp, acid taste	-0.23
hunt	search; kill or catch for sport	-0.46	space	area between things; room	-0.08
job	employment	-0.01	spy	an undercover information gatherer	-0.51
land	real estate, property, ground	-0.20	stain	a permanent mark	-0.20

APPENDIX (Continued)

Target	Definition	Median z Score	Target	Definition	Median z Score
stem	the main stalk of a plant	-0.53	poll	a survey	-0.52
string	a thin cord	-0.31	sale*	reduce price	-0.08
tent	a temporary shelter	-0.54	sight	vision	-0.21
tent	a temporary shelter	-0.56	site	a location	-0.46
thick	opposite of thin	-0.31	son	male child	-0.20
thin	opposite of fat	-0.08	sun	the star that the Earth revolves around	0.01
thorn	a sharp, pointed growth	-0.44	steal	to take without permission	-0.17
thumb	part of the hand	-0.27	steel	a metal	-0.43
tube	a slender pipe	-0.51	tea	a hot beverage	-0.26
war	armed conflict	-0.19	tee	golfball holder	-0.51
warm	a degree of heat	0.64	waist	between ribs and hips	-0.20
wet	moist	0.21	waste	unnecessary use	-0.18
wife	female spouse	-0.17	wait	to remain, to be ready	0.30
wing	what birds and planes use to fly	-0.41	weight	degree of heaviness	0.15
wise	knowledgeable, full of information	-0.22	way	direction	0.25
wise	knowledgeable, full of information	-0.46	weigh	to measure heaviness	-0.07
wish	to desire, express a want	0.18	weak	lack of strength	-0.07
wolf	a wild, dog-like animal	-0.51	week	seven days	0.78
	Homophones		write†	to inscribe; record in words	1.10
ad	a commercial	-0.19		Different-Class Homonyms	
add	to sum, put together	-0.06	ace*	usually the highest card in a deck	-0.25
be	to exist; to possess some quality	1.40	bail*	a deposit to get out of jail	-0.54
bee	an insect	-0.29	boil*	to heat water until bubbling	-0.39
brake	to slow down	-0.12	change	to alter	0.67
break	to shatter, come apart	-0.07	change	coins	0.36
cellar	basement	-0.53	check	a substitute for cash	-0.01
seller	someone who sells things	-0.47	check	to test, as in to double-check	-0.04
cent	one penny	-0.08	fair†	unbiased, even, just	-0.06
scent	an odor; smell	-0.22	fall*	to descend quickly, to drop	-0.07
chute	a funnel	-0.53	light	a source of illumination	0.65
shoot	to fire a gun	-0.31	light	opposite of heavy; lacking mass	0.08
dam	a blockage of water	-0.55	park	a recreational area	-0.08
damn	a swear word	0.16	park	to position a car	-0.07
dew	moisture formed on surfaces at night	-0.48	rash*	skin irritation	-0.50
do	to act, perform	1.39	rash*	skin irritation	-0.52
die	to cease living	0.07	right†	opposite of left	0.66
dye	substance for coloring fabric	-0.54	ring	jewelry worn on a finger	-0.23
fare†	bus ride fee	-0.50	ring	the sound a telephone makes	0.07
flour	ground grain used in baking	-0.42	safe	secure, not in danger	-0.09
flower	a blossom	-0.16	safe	a container for valuables	-0.37
genes	carriers of hereditary information	-0.26	shot*	what a gun fires	-0.27
jeans	denim pants	0.64	sign	to handwrite one's name	-0.05
hair	threadlike growths on people's heads	0.46	sign	a notice, a display of information	-0.05
hare	animal like a rabbit	-0.55	sink	to descend, move downwards	-0.37
heal	to cure, repair	-0.22	sink	a water basin	-0.20
heel	back part of the foot	-0.45	sock*	something worn under shoes	0.02
hear	to perceive through the ear	0.67	stick	a small branch	-0.25
here	in this place; location	0.99	stick	to adhere; to fasten something	-0.39
knead	to handle dough	-0.58	toast	browned bread	-0.22
need	to require	0.65	toast	to drink to someone's health	-0.43
know	to possess information about	1.31	watch	a timepiece, a small clock	0.20
no	refusal; negative vote	2.31	watch	to look at for a while	-0.07
mail	letters delivered by post office	0.74		Same-Class Homonyms	
male	counterpart to female	0.04	ball	round object used in games	-0.06
new*	opposite of old	0.32	ball	a formal dance	-0.69
none	complete absence	-0.07	bat	a flying creature	-0.58
nun	a religious woman	-0.55	bat	something used to hit a baseball	-0.22
pain	extreme discomfort, agony	0.11	bill	a draft of a proposed law	-0.39
pane	a sheet of glass in a window	-0.51	bill	a charge for services	-0.07
peace	calm; freedom from war	-0.09	capital	uppercase letter	-0.34
piece	a part of something	-0.06	capital	seat of government	-0.43
pole	a long rod	-0.43			

APPENDIX (Continued)

Target	Definition	Median z Score	Target	Definition	Median z Score
chest	a large wooden box-like container	-0.55	build	to construct	-0.25
chest	a body part	0.03	close	to shut	0.76
club	object used to hit things, such as golfballs	-0.33	head	part of the body above the neck	-0.07
club	an organization	-0.12	heart	a bodily organ or the shape of this organ	-0.05
date	a day of the year	0.49	man	male human	0.11
date	a romantic encounter; appointment	0.26	man	male human	0.44
feet	a measure of length or height	-0.04	meal	breakfast, lunch, or dinner	0.24
feet	part of the body below ankles	-0.10	mouth	oral cavity	0.02
letter	part of the alphabet	-0.08	nap	a short period of sleep	0.09
letter	a written message	0.00	neck	part of the body	-0.34
note	a certain tone or pitch in music	-0.24	pan	cooking utensil	-0.31
note	a short written communication	-0.09	pause	a time period during which nothing happens	-0.44
plain*	unadorned, not decorated or special	-0.20	phone	communication device	1.06
plane*	flying vehicle	-0.24	red	a bright color	0.03
run*	to move rapidly	0.65	rent	housing payment	-0.23
tie	clothing worn around the neck	-0.40	rent	payment for housing	-0.26
tie	a draw; a nondecisive outcome	-0.25	shoe	clothing worn on feet	0.25
Excluded Questionable Words			skate	to move on rollerblades	-0.37
bald	without hair	-0.38	tan	skin darkened by the sun	-0.16
bald	hairless	-0.38	world	the planet Earth	-0.07
bell	something that makes noise	-0.25			

Note—Homophones are presented in pairs in alphabetical order. *Indicates that the other meaning was not rated. †Indicates that the other meaning falls into a different category, either homophones or different-class homonyms.

(Manuscript received November 22, 1995;
revision accepted for publication May 7, 1998.)