What is preexisting strength? Predicting free association probabilities, similarity ratings, and cued recall probabilities

DOUGLAS L. NELSON

University of South Florida, Tampa, Florida

GUNVOR M. DYRDAL

University of Oslo, Oslo, Norway

and

LEILANI B. GOODMON

University of South Florida, Tampa, Florida

Measuring lexical knowledge poses a challenge to the study of the influence of preexisting knowledge on the retrieval of new memories. Many tasks focus on word pairs, but words are embedded in associative networks, so how should preexisting pair strength be measured? It has been measured by free association, similarity ratings, and co-occurrence statistics. Researchers interpret free association response probabilities as unbiased estimates of forward cue-to-target strength. In Study 1, analyses of large free association and extralist cued recall databases indicate that this interpretation is incorrect. Competitor and backward strengths bias free association probabilities, and as with other recall tasks, preexisting strength is described by a ratio rule. In Study 2, associative similarity ratings are predicted by forward and backward, but not by competitor, strength. Preexisting strength is not a unitary construct, because its measurement varies with method. Furthermore, free association probabilities predict extralist cued recall better than do ratings and co-occurrence statistics. The measure that most closely matches the criterion task may provide the best estimate of the identity of preexisting strength.

How do we use preexisting knowledge in remembering what has been newly experienced? The initial step in answering this question often involves estimating what people know. This rationale underlies contemporary work on the effects of expertise, printed frequency, concreteness, associative strength, and other variables linked to prior knowledge. In these studies, the variable of interest is measured, and then items representing different levels of the variable are selected and manipulated under experimental conditions of interest. The purpose of this article is to advance our understanding of free association and similarity ratings as measures of preexisting strength between word pairs. Strength has been measured with free association probabilities (Cramer, 1968), similarity ratings (e.g., Kammann, 1968), and recently, co-occurrence statistics (Landauer & Dumais, 1997). We emphasize issues related to free association, but the larger issue is whether the method used to index strength matters.

We focus on word pairs because of the importance of this unit of analysis in research. Measuring lexical knowledge is a challenge because words are embedded in associative networks (Steyvers & Tenenbaum, 2005). Measuring the strength of the connection between any single pair raises problems, because links involving related words may affect the estimate. Figure 1 shows two associated words, A and B, and illustrates the complexity of the issue. The first problem is to determine whether A and B are linked, and this problem has been solved for generations by using free association (Bahrick, 1970; Cramer, 1968; Glaze, 1928). Subjects are given words and are asked to produce the first related word that comes to mind. If A produces B, the two words are said to be *associated*, and the degree of association is indexed as a probability by dividing B's production frequency by sample size. Theoretically, A has a directional forward link to B that has been created by prior experience, called *forward strength*.

This tradition treats free association probability as an unbiased estimate of forward strength. However, in free association, cue words such as A also produce other words as associates. In the figure, A produces B, C, D, and E, and when these words are independently normed in free association, A and B can be linked in many ways. For example, B has a backward link to A, because it pro-

This research was supported by Grant MH16360 from the National Institute of Mental Health to D.L.N. We especially thank Cathy McEvoy and the reviewers for their comments. Correspondence concerning this article should be addressed to D. L. Nelson, Department of Psychology, PCD 4118G, University of South Florida, Tampa, FL 33620-8200 (e-mail: dnelson2@chuma1.cas.usf.edu).

Figure 1. Two associated words, A and B, and the types of links that affect cued recall and that have the potential to affect free association and associative similarity ratings. F, forward; B, backward; C, competitor; M, mediated; SA, shared associate; AA, associate to associate; AT, associate to target.

duces A as an associate. In addition, Associates C and D indirectly link Words A and B because they provide mediating and shared associate connections, respectively. Also note that A produces E and that E is not linked to B. Associates such as E are important because they provide likely competitors for response selection. The presence of Associate E may affect the likelihood of producing B as a response. Finally, note that B is linked to associates other than those involving A, including F, G, H, and I.

Each link shown in the figure represents a type of connection that affects the probability of extralist cued recall (Nelson, McKinney, Gee, & Janczura, 1998; Nelson, Schreiber, & McEvoy, 1992). In this task, subjects study a list of words such as B and then are given words such as A as test cues to help them recall the studied words. The assumption underlying cued recall research has been that free association estimates forward A-to-B strength (e.g., Nelson, McEvoy, & Dennis, 2000), but given embeddedness, free association may provide a biased estimate of forward strength if it is influenced by closely related links.

The present studies determine whether related links affect free association probabilities and associative similarity ratings. In Study 1, free association probabilities for thousands of word pairs provided the dependent measure (Nelson, McEvoy, & Schreiber, 1999), and the strengths of the types of links depicted in Figure 1 were entered as predictors of these probabilities in a simultaneous multiple regression analysis. Forward strength is the latent variable that underlies these probabilities and could not be included as a predictor because, by tradition, free association probability is forward strength. The purpose of our analysis was to determine the extent of the bias produced by related links and, if any, which links contributed.

If free association probabilities provide an unbiased estimate of forward strengths, related links would have no influence, and the regression would not be significant. In the second part of Study 1, forward strength and a new index of preexisting strength were evaluated as predictors using extralist cued recall as the criterion task. In Study 2, associative similarity ratings for 1,016 word pairs were collected, and the links depicted in Figure 1 were entered as predictors of these ratings. As in the first study, the purpose was to determine whether the ratings were affected by these links. In the second part of Study 2, free association probabilities and similarity ratings were directly compared as predictors of cued recall.

STUDY 1

Predicting Free Association Probabilities

The links used as predictors of the free association probabilities in the regression analyses are identified and defined in Table 1. Along with backward strength and mediated strength, three features related to each target response—target competitor strength, target activation strength, and target frequency—were included. Most important, cue competitor strength was included as a predictor. Associates of a cue that fail to link a given cue–target pairing within two associative steps may compete with the target and reduce its chances of selection. Cue competitor strength is determined by summing the strengths of the individual associates in the set and subtracting forward strength, mediated strength, and shared associate strength (Nelson & Zhang, 2000). Idiosyncratic responses are not included in the initial sum, because they are unreliable.

Two general classes of interpretations guided our expectations. The *mean forward strength* explanation assumes that the strength of any given associate is deter-

Table 1
Definitions of Features

Feature	Definition
Forward strength	Probability that a cue word produces a target in discrete free association—e.g., apple→orange.
Backward strength	Probability that a target produces its cue word in discrete free association—e.g., orange→apple.
Mediated strength	Mediators indirectly link a cue word to a target—e.g., apple→ <i>tree</i> →orange.
Cue competitor strength	Summed strength of the cue's associates that fail to link a cue–target pair within two associative steps—e.g., apple→orange and worm, but worm does not produce orange and orange does not produce worm. Worm is a competing associate for the apple–orange pair because it is neither a mediator nor a shared associate.
Target competitor strength	Summed strength of the target's associates that fail to link a cue–target pair within two associative steps.
Target activation strength	Indexes the connectivity of the associates in the target's set and is equal to the sum of the individual strengths of its associate-to-associate and associate-to-target links.
Target frequency	Log (.5 + printed frequency of occurrence per million words).

mined by a distribution of values (see Nelson et al., 2000, p. 893, for more details). For example, for the cue BRUSH, the word COMB is not represented by a single strength but by a distribution of strengths, and free association probabilities estimate the mean of the strength distribution for this associate. This explanation assumes that competitors, as well as other types of links, have no effect, because free association probabilities provide unbiased estimates of forward strength.

A second class of explanations assumes that free association probabilities are biased by all or by some of the links that bind word pairs together and those that drive them apart. The *intersection* explanation is the most complex bias model and incorporates all of the links depicted in Figure 1. The intersection explanation is based on the PIER2 model of extralist cued recall (Nelson et al., 1998), and it assumes that free association and extralist cued recall are variants of the same task. This approach assumes that free association probabilities are determined by computing the results of the intersection of the cue and its associates with the target and its associates. Free association probabilities are a function of the strength of the connections that bind the cue and the target together, relative to the strength of the competitors activated by both the cue and the target. In contrast, the *cue competition* explanation assumes that free association probabilities are biased by competition from other associates in the set activated by the cue word. Such competitors reduce the chances of producing a designated target by blocking access, with blocking directly determined by competitor strength. The cue competition explanation assumes that free association probability is determined by the forward strength of a given associate, relative to competing associates activated by the same cue.

Method

Subjects. Over 17 years, more than 6,000 subjects produced nearly three quarters of a million free association responses to

5,019 words. All were students in psychology courses and received course credit for service.

Procedure. Booklets contained a column of words on the left side of each page and a space for the response. The subjects were asked to write the first word that came to mind that was meaningfully related to or strongly associated with the presented word. They were asked to respond rapidly and to write legibly. Each booklet had four pages, with 30 words appearing on each page. The order of the pages was unsystematically randomized, and the task took approximately 20 min.

Materials. The free association norms for 72,176 cue–target pairs and 28 columns of additional data on the pairs are available on the Web and can be found in Nelson et al. (1999). Both the cues and the targets had to have a Use Code = 1 designation to qualify for inclusion. This designation is given to a word when its key associates have been independently normed, and with this as the only criterion, 48,572 pairs qualified. Downloading the norms, sorting them on the basis of Use Code, and then including only those with the Use Code = 1 for both the cue and the target determines the exact list of pairs. By downloading the associative features of interest here, data for each pairing become available, and summary statistics, as well as distributional characteristics, can be determined. The procedures used in summarizing the responses to each normed word and other details are available at the Web site.

Results and Discussion

Predicting free association probabilities. The results of the simultaneous multiple regression analysis and the associated correlation statistics are shown in Tables 2 and 3. The regression was significant, [$R = .50$; $F(6,48565) = 2,729.87$, $MS_{\text{res}} = 0.008$], accounting for 25.2% of the variance of the free association probabilities. Table 2 presents the standardized beta coefficients, the standard errors for these coefficients, and the resulting t statistics. For convenience, the strength indices are listed in order of size of the beta coefficients. Except for mediated strength, each index significantly predicted the free association probabilities, which is not surprising given the number of pairs. An unforced stepwise regression was used for estimating the proportion of variance explained by each type of link. In this analysis, the

Table 2
Predicting Free Association Probabilities
From Five Free Association Measures and Target Frequency

Feature	Standardized Beta	Standard Error	<i>t</i> Value	% Explained Variance
Cue competitor strength	-.42	.002	-87.33*	19.0
Backward strength	.27	.005	61.76*	4.9
Log (.5 + target frequency)	.06	.001	15.44*	0.6
Target competitor strength	.08	.002	15.48*	0.5
Target activation strength	.05	.0002	12.17*	0.2
Mediated strength	.01	.015	1.54	0.0

* $p < .01$.

strongest predictor enters first, and then the effects of the next strongest predictor enter next, and so on. The results of this analysis appear in the last column of Table 2, and they show that competitor and backward strengths explained 19% and 4.9% of the variance, respectively. The remaining indices taken together explained 1.3% of this variance. Estimates of forward strength in the free association task are biased, and they are biased primarily by competitor strength and, to a small degree, by backward strength. They are largely unaffected by mediated links and by links uniquely related to the target, including target competitor strength, target activation strength, and target frequency.

The zero-order correlations are shown below the diagonal in Table 3, and the partial correlations are shown above it. Partial correlations represent the correlation between two variables after correcting for the influence of the other predictors, and they serve as summary statistics for the regression analyses. The partial correlations shown in the first row indicate that free association probabilities were negatively correlated with cue competitor strength ($r = -.37$), positively correlated with backward strength ($r = .27$), and only weakly correlated with the remaining indices. Higher levels of forward strength are associated with weaker competitors and somewhat stronger backward links.

Given the correlational nature of the data, these results must be interpreted with caution, but they are inconsistent with the mean forward strength and intersection explanations of free association probabilities. They are in-

consistent with the mean forward strength explanation because 25.2% of the variance in free association probability is produced by related links. They are inconsistent with the intersection explanation because most related links had negligible effects on these probabilities. Given a cue, response probability does not vary appreciably as a function of the target's features. Each of these variables affects extralist cued recall probabilities (Nelson & Zhang, 2000), but not the probabilities of free association. The free association task is not an extralist cuing task in disguise, and it can serve as an independent means for estimating preexisting strength.

The findings are most consistent with the competition explanation. In the norms, cues activate from 1 to 32 associates, in addition to the target, and these associates apparently reduce the probability of target selection. This finding is not just a constraint of the single-response free association task. Competitor strength is not equivalent to cue set size defined as the number of different associates to the cue (Nelson & Zhang, 2000). Competing associates consist only of those that fail to link the cue to the target within two associative steps. Cue competitor strength is determined by summing the strengths of the individual associates in the set minus the strengths of those having forward, mediated, and shared associate links (Nelson & Zhang, 2000).¹

Predicting cued recall. The cue competition explanation assumes that probability of free association is relative to the interference provided by competing associates. A ratio rule that expresses the influence of links that

Table 3
Zero Order Correlations (Below Diagonal) and Partial Correlations (Above Diagonal)
Between Free Association Probabilities, the Six Associative Features, and Frequency

Index	Fsg	QCsg	Bsg	TFreq	TCsg	TAsg	Msg
Free association probability (forward strength)	—	-.37	.27	.07	.07	.06	.01
Cue competitor strength	-.44	—	.04	.03	.35	-.14	-.33
Backward strength	.29	-.17	—	-.09	-.34	-.09	-.15
Log (.5 + frequency)	.01	.06	-.20	—	.20	.09	.12
Target competitor strength	-.20	.44	-.40	.26	—	.12	-.13
Target activation strength	.09	-.14	-.13	.14	.10	—	.04
Mediated strength	.17	-.43	-.06	.09	-.22	.11	—

Note—Fsg, forward strength; QCsg, cue competitor strength; Bsg, backward strength; TFreq, log (.5 + target frequency); TCsg, target competitor strength; Tasg, target activation strength; Msg, mediated strength.

strengthen a word pair, relative to those that reduce it, may provide a better index of preexisting strength than do raw free association probabilities. We incorporated the effects of backward and cue competitor strength because both sources influence free association probabilities. Preexisting strength for a given A–B word pairing was defined as the sum of forward and backward strength (Fsg + Bsg) relative to cue competitor strength (QCsg):

$$\text{Preexisting} = \frac{\text{Fsg} + \text{Bsg}}{\text{Fsg} + \text{Bsg} + \text{QCsg}}.$$

The application of this rule to individual pairs resulted in some substantial changes. For example, for BROOK–RIVER, forward strength is .16, backward strength is .02, cue competitor strength is .01, and ratio rule index of preexisting strength is .93. By the free association index, the pair is weakly related at .16, but by the ratio rule, the pair is strongly related at .93. This difference arises because competitor strength is very weak for this pair. Many of BROOK's associates have mediated links to river—for example, BROOK–*stream*–RIVER—that subtract from competition. When the free association probabilities were subtracted from the probabilities determined by the ratio rule, the results showed that free association values underestimated the ratio rule by an average probability of .25 ($SD = .19$). On average, competitor strength acts to reduce the estimate of preexisting strength obtained in the free association task to a large degree.

The question is whether raw free association probabilities or the ratio rule provides the most valid index of preexisting strength. To evaluate this question, we used extralist cuing as the criterion task. In this task, individual words are studied (e.g., RIVER), and recall is then prompted by cues that were unavailable during study (e.g., BROOK). We assumed that the most valid index of preexisting strength would emerge as the better predictor of the cued recall. We used an updated version of an extralist cued recall database (Nelson & Zhang, 2000) that includes findings for 3,010 pairs of words tested under similar conditions, with data from an average of 11.29 ($SD = 3.54$) subjects per pair. The results of simple regression analyses indicated that the ratio rule explained 23.9% of the recall variance [$F(1,3008) = 945.19$, $MS_{\text{res}} = 0.051$; $R = .49$], whereas the free association probabilities explained 16.9% of that variance [$F(1,3,008) = 613.16$, $MS_{\text{res}} = 0.056$; $R = .41$]. Given only a single predictor, the ratio rule explains more cued recall variance than does free association probability.

Two points can be made about these findings. First, the ratio rule explains 7% more of the cued recall variance than does free association probability. The size of this difference is nontrivial in research applications that call for manipulating preexisting strength where accurate measures can be crucial for deciding theoretical issues. The conclusions of most experiments are based on a few dozen word pairs at most, so even small gains in measurement accuracy can be critical. The second point is that controlling both backward and cue competitor

strength is crucial in any research purporting to manipulate preexisting forward strength based on free association probabilities.

STUDY 2

Predicting Similarity Ratings

Similarity ratings have also been used to assess preexisting strength (e.g., Barrett & Fossum, 2001; Fischler, 1977; Garskoff & Forrester, 1966; Kammann, 1968). Pairs of words are provided, and subjects judge their associative similarity by reporting a numerical value lying along a defined scale. Free association and similarity rating differ both in the information provided and in the response expected. The important difference is the presence of the word pair, as compared with using the cue word to generate a target. The specific goal of Study 2 was to determine whether links that affect free association would also affect similarity ratings. If the procedures for indexing strength converge, ratings will be affected by forward strength, cue competitor strength, and backward strength. Ratings will be higher when forward and backward strengths are higher, and they will be lower when cue competitor strength is greater. Although other links effectively predict extralist cued recall, they will have negligible success in predicting ratings. Alternatively, the procedures may diverge, because the target does not have to be generated in the ratings task. Both words of the pair are physically present, and cue competitor strength may no longer bias the estimate of preexisting strength. A ratio rule that evaluates the sum of forward and backward free association probabilities relative to competitor strength may provide the best description of forward strength, whereas a mean forward strength rule that sums forward and backward strength may provide the best summary description of ratings.

To evaluate these alternatives, ratings of associative similarity were obtained for 1,016 word pairs, and regression procedures were used to determine whether free association measures of preexisting strength would predict the similarity ratings. The second aim of Study 2 was to determine whether ratings or free association probabilities would predict cued recall better. One of the most significant issues in studying how prior knowledge affects memory performance revolves around the choice of the methods used to index the strength of pairwise relationships. If the measures are differentially effective in predicting recall, the source of the discrepancy should lie in what each task measures about associative strength.

Method

Subjects. Ninety-four students from classes in psychology participated and were given course credit for their service.

Procedure. The experimenter read the following instructions to each subject:

Some word pairs are more related than others. For example, most people would say that CAT DOG is more strongly related than GUARD DOG. The purpose of this study is to collect ratings on a large number of items

from a large number of people in order to determine whether such ratings can predict recall. If DOG were recently studied, would CAT be a better memory cue than GUARD? Such results will be important for understanding how memory works.

What we want you to do today is rate each pair of words that you are given on a scale of 1–7 in terms of their degree of mutual association or relatedness. If the first word readily calls the second word to mind or if you can find an easy way to relate the two words to each other, then give the pair a higher rating. Conversely, give the pair a lower rating when they seem weakly associated or related. Please use the full scale in making your judgments.

Remember, simply rate each pair with the numbers 1 through 7 in a way that reflects how strongly you believe the words are associated or related.

The pairs were presented one at a time on a computer screen at a self-paced rate to each subject. They were asked to make their rating as quickly as possible and then press the space bar for the next pair. Each subject rated all of the pairs, which were randomly divided into four blocks of 254. The pairs were independently randomized for each subject, and a 5-min rest break was provided after each block. The task required a little over an hour.

Materials. The pairs were selected unsystematically from a cued recall database of 2,000 + pairs (Nelson & Zhang, 2000; <http://luna.cas.usf.edu/~nelson/>). Each cue had a forward link to its target, and the strength of such links varied widely. The 1,016 pairs used for this study can be found at the same Web address, along with the descriptive statistics, similarity ratings, and extralist cued recall probabilities for each pair. Table 4 provides a list of the features considered in the process of analyzing the data, along with their associated summary statistics.

Results and Discussion

Predicting similarity ratings. Table 5 presents the results of the simultaneous multiple regression analysis, and Table 6 presents the zero-order and partial correlations. The regression was significant [$R = .44$; $F(7,1008) = 33.92$, $MS_{\text{res}} = 0.33$], explaining 18.5% of the variance. As is shown in Table 5, forward and backward strength emerged as the only significant predictors of the ratings. A stepwise regression indicated that backward and forward strength explained 11.7% and 5.7% of the ratings variance, respectively. The partial correlations show that both backward ($r = .30$) and forward ($r = .20$) strength were correlated with the ratings, after adjustments for correlations with other variables. The remaining partial correlations with the ratings were low, including the correlation between ratings and cue competitor strength ($r = -.05$). Not surprisingly, when forward + backward strength and the ratio rule from Study 1 were entered as predictors of similarity ratings, the simple summation rule explained more variance (17.5%) than did the ratio rule (1.9%).

The results of Studies 1 and 2 indicate that free association probabilities and associative similarity ratings are not appreciably influenced by several predictors that influence cued recall, including mediated strength, target activation strength, target competitor strength, and target frequency. Although both indices are affected by backward strength, this variable explains more variance in the ratings data than in the free association data. Importantly, the results also indicate that free association probabilities, but not ratings, are affected by cue competitor strength. Cue competitor strength explains a significant 19% of the variance in free association probabilities and a nonsignificant 0.7% in associative similarity ratings. Competitor strength has a different influence in the two tasks because the target response is provided in the rating task, whereas it must be recalled from memory in free association, and as in all recall tasks, the ratio rule prevails (Nelson et al., 1998; Raaijmakers & Shiffrin, 1981).

Predicting cued recall. Because the pairs used in the ratings study were taken from the cued recall database, probability of recall was available for each pair. This commonality allowed us to directly compare free association probabilities and similarity ratings as predictors of cued recall probability, in order to determine the best predictor. The results of the multiple regression analysis showed that the regression was significant [$F(2,993) = 163.51$, $MS_{\text{res}} = 0.047$], with an adjusted $R^2 = 24.6\%$. The beta coefficients (and standard errors) for free association probabilities and ratings were .32 (.06) and .30 (.01), respectively. The difference in beta is small but significant ($t = 7.74$), and the stepwise regression showed that free association probabilities explained 15.8% of the variance in cued recall, whereas ratings explained 8.8%. When the ratio rule was substituted for free association probabilities, explained variance rose to 29.4%, with the ratio rule explaining 25.2% and similarity ratings explaining 4.2%.

These results indicate that free association probabilities and the ratio rule provide better preexisting strength indices than do similarity ratings when it comes to predicting cued recall. The predictive advantage of free association presumably stems from its differential sensitivity to cue competitor strength. Success in both free association and cued recall are affected by this variable, because these tasks depend on recovering words from memory, using associatively related cues. In contrast, the cue and the target are seen together during ratings, and search and response recovery processes are not involved.

GENERAL DISCUSSION

In free association, the probability that the cue produces a target word has been treated as an unbiased estimate of forward strength (e.g., Nelson et al., 2000). The mean forward strength interpretation of free association probabilities assumes that the same word pair is represented many times in memory and that free association probabilities for a given cue word estimate the mean of

Table 4
Summary Statistics for the 1,016 Word Pairs Used in Study 2

Feature	<i>M</i>	<i>SEM</i>	Minimum	Maximum
Forward strength	.15	.004	.00	.82
Backward strength	.11	.006	.00	.92
Mediated strength	.03	.002	.00	.41
Cue competitor strength	.40	.01	.00	.90
Target competitor strength	.48	.01	.00	.95
Target activation strength	4.93	0.06	1.89	11.03
Target frequency	91	4.86	0	1,772
Similarity rating	4.87	0.02	2.64	6.35
Probability of cued recall	.52	.008	0.00	1.00

Table 5
Predicting Associative Similarity Ratings From
Six Associative Indices and Target Frequency

Feature	Standardized Beta	Standard Error	<i>t</i> Value	% Explained Variance
Backward strength	.34	.12	9.92*	11.7
Forward strength	.20	.17	6.35*	5.7
Cue competitor strength	-.06	.10	-1.66	0.7
Log (.5 + target frequency)	.06	.03	2.05	0.3
Target competitor strength	-.06	.09	-1.55	0
Target activation strength	.04	.01	1.21	0
Mediated strength	.03	.41	0.83	0

* $p < .05$.

these strengths. This interpretation assumes that other closely related links have no effect on this estimate, but the findings of Study 1 were inconsistent with this interpretation. Free association probabilities provide a biased index of preexisting forward strength. Forward strength no doubt plays a role in response production, but response probabilities are also influenced by cue competitors and, to a minor extent, by backward links. Associates are less likely to be produced in free association when competing associates are activated by the cue, and they are somewhat more likely to be produced when they have stronger backward links to the cue. Taking these biases together, free association probabilities tend to underestimate the preexisting strengths of word pairs. As in cued recall, free association follows a ratio rule, with response production determined, in part, by the preexisting strength of the target, relative to the strengths of competing alternatives (Raaijmakers & Shiffrin, 1981). As compared with free association probabilities, a simple ratio rule that computes the sum of forward and backward strength, relative to competitor strength, explains 7% more of the cued recall variance for 3,010 pairs taken from dozens of extralist cuing experiments.

Free association probabilities, however, are not as complex as they might have been. They are negligibly affected by mediated links and by unique features of the target, such as its competitors, its frequency, and links involving its associates. Although these features are im-

portant in predicting cued recall (Nelson & Zhang, 2000), they explain little variance in free association. Unlike cued recall, the production of a response in free association does not appear to be determined by computing the intersection of a cue and its associates with a response and its associates (Nelson et al., 1998). Unless a target word is studied in the experimental context, its unique features do not play an important role in its free production. The findings of Study 1 deny the intersection and the mean forward strength explanations, and they are most consistent with the cue competition explanation.

In the associative similarity ratings task, both a cue word and a sample target word are presented. Because of the target's physical presence, its features might be expected to have a stronger effect on the estimation of strength, but this expectation was disconfirmed. Ratings increased as a function of forward and backward strength, but importantly, cue competitor strength had a nonsignificant effect on the ratings. Both ratings and free association are affected by some, but not all, of the closely related links. The findings suggest that forward and backward probabilities can be combined additively to form a net strength index, but the two methods are differentially affected by competing links activated by the cue. Cue competitor strength is more important to free association, where a response must be recalled, than to ratings with the target present. The competition explanation provides the best summary description of the free associa-

Table 6
Zero Order Correlations (Below Diagonal) and Partial Correlations (Above Diagonal)
Between Eight Associative Features, Rated Similarity, and Frequency

Index	Rating	Fsg	Bsg	QCsg	TFreq	TCsg	TAsg	Msg
Similarity rating	—	.20	.30	-.05	.07	-.05	.04	.03
Forward strength	.26	—	.10	-.34	.13	.13	.04	-.02
Backward strength	.31	.06	—	.17	-.14	-.42	-.10	-.18
Cue competitor strength	-.15	-.37	.06	—	.05	.36	-.20	-.30
Log (.5 + frequency)	.00	.15	-.27	-.04	—	.14	.13	.13
Target competitor strength	-.21	-.02	-.45	.31	.25	—	.21	-.13
Target activation strength	-.01	.14	-.26	-.17	.23	.26	—	-.03
Mediated strength	.03	.12	-.18	-.40	.15	-.14	.08	—

Note—Rating, similarity rating; Fsg, forward strength; Bsg, backward strength; QCsg, cue competitor strength; TFreq, log (.5 + target frequency); TCsg, target competitor strength; TAsg, target activation strength; Msg, mediated strength.

tion index, whereas a modified mean forward strength explanation provides the best summary description of similarity ratings. The differences between the two methods for measuring strength comes closer to a difference in kind than to one of amount, suggesting that preexisting strength is not a unitary construct.

The cued recall findings suggest that free association probabilities predict recall better than do ratings because these probabilities are sensitive to the presence of cue competitors. Both free association and cued recall require the retrieval of a word related to the cue. In free association, any related word meets the criterion for stopping retrieval, but in cued recall, only the studied target meets the criterion. There are task differences, but the subject's problem is similar in both tasks, and that is to produce a related word from memory. Under a task compatibility rationale, free association probabilities are better predictors than are ratings because there is more overlap in the psychological processes underlying free association and cued recall. The present findings provide some support for this idea, because forward, backward, and cue competitor links predict free association probabilities and extralist cuing probabilities. Both task probabilities are effectively described by a ratio rule, whereas similarity ratings are not.

The nonunitary, method-dependent nature of prior lexical knowledge is theoretically significant. Indices of preexisting strength between word pairs are more likely to be effective predictors of memory performance when the psychological processes in the measurement task more closely match those in the criterion task. Maps of associative networks constructed on the basis of free association probabilities are likely to be useful for predicting recall probabilities, because the two tasks share the cuing function. By this rationale, co-occurrence norms (e.g., Landauer & Dumais, 1997) will be less effective than free association and ratings in predicting cued recall, because such norms are collected from textual material—basically, from what writers write. Writing requires word production, but the constraints are substantially different, as compared with those in free association and cued recall. Maki, McKinley, and Thompson (2004) have shown that cosine values and free association probabilities are correlated ($r = .27$, $n = 49,362$), but cosine statistics do not effectively predict cued recall. When cosine statistics and the ratio rule were compared as predictors of the cued recall data used in Study 1, the regression was significant [$F(2,2198) = 337.20$, $MS_{\text{res}} = .05$, adjusted $R^2 = .23$], but a subsequent stepwise regression indicated that 15.6% of the variance in recall was predicted by the ratio rule, whereas 7.8% was predicted by the co-occurrence norms (cf. Steyvers, Shiffrin, & Nelson, 2005). When similar analyses compared cosine statistics and sim-

ilarity ratings, the ratings explained 12.4% of the variance, and the cosine statistics explained 0%.

Free association and ratings predict recall better than do co-occurrence norms. Nevertheless, given that text composed of remotely related words can be comprehended with ease, free association probabilities and ratings are likely to be ineffective, as compared with co-occurrence norms, for describing the lexical knowledge needed to predict text comprehension. Although co-occurrence statistics do not predict cued recall, they provide an alternative index of preexisting strength that predicts reading comprehension and essay quality (Landauer & Dumais, 1997). Co-occurrence norms, free association probabilities, and associative similarity ratings measure different aspects of preexisting strength because they are sensitive to different kinds of lexical connections. Co-occurrence statistics capture constructed meaning, whereas free association norms and, to a more ambiguous degree, similarity ratings may be capturing lexical accessibility. Efforts to map both domains are just beginning, and as in mapping the earth and the universe, different types of maps are likely to be needed for different predictive purposes.

REFERENCES

- BAHRICK, H. P. (1970). Two-phase model for prompted recall. *Psychological Review*, *77*, 215-222.
- BARRETT, L. F., & FOSSUM, T. (2001). Mental representations of affect knowledge. *Cognition & Emotion*, *15*, 333-363.
- CRAMER, P. (1968). *Word association*. New York: Academic Press.
- FISCHLER, I. (1977). Semantic facilitation without association in a lexical decision task. *Memory & Cognition*, *5*, 335-339.
- GARSKOFF, B. E., & FORRESTER, W. (1966). The relationships between judged similarity, judged association, and normative association. *Psychonomic Science*, *6*, 503-504.
- GLAZE, J. A. (1928). The association value of nonsense syllables. *Journal of Genetic Psychology*, *35*, 255-269.
- KAMMANN, R. (1968). Associability: A study of the properties of associative ratings and the role of association in word-word learning. *Journal of Experimental Psychology Monographs*, *78* (Pt. 2), 1-16.
- LANDAUER, T. K., & DUMAIS, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and the representation of knowledge. *Psychological Review*, *104*, 211-240.
- MAKI, W. S., MCKINLEY, L. N., & THOMPSON, A. G. (2004). Semantic distance norms computed from an electronic dictionary (WordNet). *Behavior Research Methods, Instruments, & Computers*, *36*, 421-431.
- NELSON, D. L., MCEVOY, C. L., & DENNIS, S. (2000). What is free association and what does it measure? *Memory & Cognition*, *28*, 887-899.
- NELSON, D. L., MCEVOY, C. L., & SCHREIBER, T. A. (1999). *The University of South Florida word association, rhyme and fragment norms*. Available at <http://luna.cas.usf.edu/~nelson/>.
- NELSON, D. L., MCKINNEY, V. M., GEE, N. R., & JANCZURA, G. A. (1998). Interpreting the influence of implicitly activated memories on recall and recognition. *Psychological Review*, *105*, 299-324.
- NELSON, D. L., SCHREIBER, T. A., & MCEVOY, C. L. (1992). Processing implicit and explicit representations. *Psychological Review*, *99*, 322-348.
- NELSON, D. L., & ZHANG, N. (2000). The ties that bind what is known

to the recall of what is new. *Psychonomic Bulletin & Review*, **7**, 604-617.

RAAIJMAKERS, J. G. W., & SHIFFRIN, A. M. (1981). Search of associative memory. *Psychological Review*, **88**, 93-134.

STEYVERS, M., SHIFFRIN, R. M., & NELSON, D. L. (2005). Semantic spaces based on free association that predict memory performance. In A. Healy (Ed.), *Experimental cognitive psychology and its applications* (pp. 237-249). Washington, DC: American Psychological Association.

STEYVERS, M., & TENENBAUM, J. (2005). The large scale structure of semantic networks: Statistical analyses and a model of semantic growth. *Cognitive Science*, **29**, 41-78.

NOTES

1. Using cue set size or the number of cue competitors as the index of competition does not alter conclusions about the role of competition in free association. With $n = 48,375$, the correlations between free association probability and cue set size and number of cue competitors are $r = -.24$ and $-.32$, respectively.

(Manuscript received February 9, 2004;
revision accepted for publication August 31, 2004.)