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The semantic neighborhood frequency effect : does it exist?

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THE SEMANTIC NEIGHBORHOOD FREQUENCY EFFECT: DOES IT EXIST?

A Thesis

Presented to

the Faculty of the Department of Psychology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Elvin F. S. Chun

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ABSTRACT

THE SEMANTIC NEIGHBORHOOD FREQUENCY EFFECT: DOES IT EXIST?

by Elvin F. S. Chun

Models of visual word recognition have not adequately considered the effects of semantic neighbors and the semantic categories to which they belong. This study proposed a semantic neighborhood frequency effect that may have been a confound in previous studies examining word frequency. The semantic neighborhood frequency effect using a semantic categorization task was tested comparing two models of visual word recognition. The interactive-activation model predicted no effect of semantic neighborhood size, but an effect of semantic frequency within a category; the serial-search model predicted an effect of semantic neighborhood size and a semantic frequency effect for large neighborhoods. The results support the interactive-activation model as well as the existence of a semantic neighborhood frequency effect even when semantic neighborhood size was held constant. A two-stage verification model is presented as an alternative model of semantic categorization.

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The Semantic Neighborhood Frequency Effect: Does It Exist?

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Abstract

Models of visual word recognition have not adequately considered the effects of semantic neighbors and the semantic categories to which they belong. This study proposed a semantic neighborhood frequency effect that may have been a confound in previous studies examining word frequency. The semantic neighborhood frequency effect using a semantic categorization task was tested comparing two models of visual word recognition. The interactive-activation model predicted no effect of semantic neighborhood size, but an effect of semantic frequency within a category; the serial-search model predicted an effect of semantic neighborhood size and a semantic frequency effect for only large neighborhoods. The results support the interactive-activation model as well as the existence of a semantic neighborhood frequency effect even when semantic neighborhood size was held constant. A two-stage verification model is presented as an alternative model of semantic categorization.

The Semantic Neighborhood Frequency Effect: Does It Exist?

It is quite intuitive that words that occur more frequently in language and print should be easier to recognize than words that occur less frequently in usage. Psychologists call this phenomenon the word frequency effect. Word frequency has been shown to influence a number of word recognition and reading tasks. For example, subjects generally respond either more rapidly or more accurately to more frequently occurring words than less frequently occurring words in lexical decision tasks (Chumbley & Balota, 1984; McCann & Besner, 1987) and lexical naming tasks (McCann, Besner, & Davelaar, 1988). The word frequency effect plays a role in many models of visual word recognition.

The major differences among models of word recognition are in their accounts of word frequency effects. Most models assume that lexical entries stored in memory are frequency sensitive in that lexical representations of high-frequency words are more readily available for identification than those for low-frequency words. In this respect, the ease or difficulty of word recognition is a function of the word's frequency. For example, Balota and Chumbley (1984) proposed a two-stage model of word recognition. Balota and Chumbley based their model on the premise that words and nonwords differed on a familiarity/meaningfulness (FM) dimension. In a lexical decision task, an individual makes a global computation of the FM value of a letter string. A quick check is made to determine if a word is producing any meaning or is familiar to the individual. It will take longer to establish an FM value for a low-frequency word than a high-frequency word

since the FM value is a function of an individual's experience with a word. The individual then sets up a criterion that determines lexical decisions. Lower-frequency words will on average have longer recognition latencies than higher-frequency words since they would require more analysis of meaning than higher-frequency words. In this model, word familiarity is directly correlated with word frequency.

Serial-search or verification models assume that lexical access of stored representations operates in a serial manner. Extraction of information from a stimulus is not a sufficient cause for uniquely recognizing it. The extracted features are only adequate to distinguish a set of potential lexical candidates. These candidates have properties that are similar to those extracted from the stimulus. Then, more detailed information is gathered from the lexical candidates until there is a match with the stimulus information. This comparison occurs serially. Examples of this type of model are Becker's (1976, 1979, 1980) verification model, Paap and his colleagues' activation-verification model (Paap, Newsome, MacDonald, & Schvaneveldt, 1982; Paap, MacDonald, Schvaneveldt, & Noel, 1987) and Forster's (1976) serial-search model. These models explain the word frequency effect in terms of a frequency-ordered serial comparison in which lexical candidates are compared with the stimulus. High-frequency lexical candidates are compared before low-frequency candidates until there is a match between the stimulus word and a word stored in the mental lexicon.

Parallel-access models assume that word recognition involves the extraction of features from a stimulus, which are then compared in parallel to all the stored lexical

entries in memory. The lexical entry's activation level will rise above its baseline level depending on the extent to which the stimulus information matches the information stored with that lexical entry. When activation in one of the lexical entries exceeds its critical threshold of activation, word recognition occurs. These models account for word frequency effects by claiming that some aspect of the structure of the lexical entries is sensitive to the frequency of occurrence of the word it represents. The major models of this kind are Morton's (1969, 1970) logogen model and the interactive-activation model of McClelland and Rumelhart (1981; Rumelhart & McClelland, 1982). In the logogen model, lexical entries associated with high-frequency words have lower critical thresholds than those of low-frequency words. High-frequency words are recognized more quickly since their lexical entries require less stimulus information before they exceed their critical threshold. In contrast, the interactive-activation model accounts for the word frequency effect by assuming that the more frequent activation of lexical entries for high-frequency words prompts those entries to produce permanently higher levels of resting activation than those of low-frequency words.

The Neighborhood Frequency Effect

In many visual word recognition studies, researchers may have overlooked the neighborhood frequency effect (i.e., the frequency of a word's orthographic neighbors affects the recognition of that word). Grainger (1990) proposed that studies examining the word frequency effect may have obscured the neighborhood frequency effect in the process. For example, low-frequency words tend to have higher-frequency orthographic

neighbors while high-frequency words tend not to have higher-frequency orthographic neighbors. This may have confounded previous findings of the word frequency effect since neighborhood size and neighborhood frequency were not controlled.

The concept of orthographic neighborhood concerns the degree of orthographic similarity between words. Coltheart, Davelaar, Jonasson, and Besner (1977) defined a word's orthographic neighbors as all other words of the same length that can be generated by changing one letter in that word while preserving the other letter positions (e.g., READ and REED). Neighborhood size is represented as the size of all the possible orthographic neighbors a word has. Furthermore, a nonword's neighbors are all other words or nonwords that can be generated by changing one letter in the nonword while preserving the other letter positions (e.g., FOAD and neighbors like TOAD and BOAD). Coltheart et al. (1977) observed a significant effect of neighborhood size on latencies to nonwords (i.e., nonwords with more neighbors taking longer to reject). However, they observed no effect of neighborhood size on lexical decision latencies for words. Grainger, O' Regan, Jacobs, and Segui (1989) noted that Coltheart et al.'s finding was confounded by the fact that bigram frequency, a factor that is strongly correlated with neighborhood size, was not controlled. Subsequently, Grainger et al. found that neighborhood frequency, rather than neighborhood size, was the critical factor in determining word recognition latencies. Words with one or more higher-frequency orthographic neighbors took longer to recognize than words with no higher-frequency neighbor. For example, BLUR is orthographically similar to the more frequently occurring word BLUE. It would be harder

to recognize BLUR when compared to a word with no higher-frequency orthographic neighbor like BLUE. Grainger et al. called this phenomenon the neighborhood frequency effect. Recognition latencies and errors increased significantly when a word was orthographically similar to at least one other higher-frequency word. When both neighborhood size and printed frequency were controlled, the same results occurred.

Grainger and Segui (1990) examined the neighborhood frequency effect even further. They reported results similar to those above using a larger selection of words with varying frequencies and lengths. Their study also demonstrated that when neighborhood frequency was controlled, clear word frequency effects were present. For example, low-frequency words that were used tended to have higher-frequency neighbors and high-frequency words tended to not have higher-frequency neighbors. Low-frequency words were probably compared with several higher-frequency neighbors and high-frequency words were probably compared with no higher-frequency neighbors. As a result, the word frequency effect reported in the literature may have been tainted. Grainger (1990) found that when the frequencies of a word's orthographic neighbors were controlled, there was no difference in the effects of stimulus word frequency in lexical decision and naming tasks. This is contrary to the consistent experimental finding that word frequency effects are larger in lexical decision tasks than in word-naming tasks (e.g., Besner & McCann, 1987; Paap et al., 1987).

The neighborhood frequency effect in the lexical decision data of Grainger (1990) and Grainger and Segui (1990) tend to support the interactive-activation (parallel-access)

model of visual word recognition (McClelland & Rumelhart, 1981) in terms of interference between lexical representations competing for identification in the word recognition process. The interpretation of this competition between similar lexical entries depends on the particular model of visual word recognition. The interactive-activation model explains this competition in terms of mutual inhibition between word-level nodes. Serial models of visual word recognition explain the competition between similar lexical entries in terms of a frequency-ordered search (Forster, 1976) or in terms of a serial-verification process (Becker, 1976, 1985; Paap et al., 1982; Paap et al., 1987).

The interactive-activation model correctly predicted the absence of an additive effect of number of higher-frequency neighbors on lexical decision latencies (Grainger, 1990). In this model, potential word candidates compete for identification through the process of mutual inhibition between activated word-level nodes. The activation level of a given node is determined by that word's frequency (resting-level activation) and the number of letters it shares with the stimulus in the same position. A word with many higher-frequency neighbors does not increase inhibition between activated word-level nodes since these neighbors mutually inhibit each other. Their activation levels are lower at a given instant than the activation level of an isolated higher-frequency neighbor. As a result, the total inhibition directed toward a stimulus word tends to be comparable when a word has one or more higher-frequency neighbors.

The results of Grainger (1990) and Grainger and Segui (1990) did not support the serial-search model of visual word recognition. These models incorrectly predicted an

additive effect of number of higher-frequency neighbors. In these models, if a stimulus word has several higher-frequency neighbors, then more verification cycles need to be computed before the stimulus is correctly identified. In the verification process, higher-frequency neighbors will be checked before lower-frequency neighbors. Each time a check is made, a certain amount of time is consumed. This will necessarily cause a delay in the recognition of words with higher-frequency neighbors as opposed to those without any higher-frequency neighbor. This was contrary to what was found.

The Semantic Neighborhood Frequency Effect

The neighborhood frequency effect was found in lexical decision tasks. What about the effect of neighborhood frequency on tasks that involve a more pronounced use of the semantic system? Most of the lexical decision tasks that examined word frequency involved the use of primes that were either related or unrelated to a target word. It may be that this kind of task assesses the semantic content of a word in addition to its orthography and phonology. The concept of neighborhood used by Grainger (1990) and Grainger and Segui (1990) refers to the orthographic similarity between words (i.e., more specifically, the number of letters shared by different words). Another type of neighborhood that exists in terms of the physical similarity of words is phonology. For example, McCann and Besner (1987) found that pseudohomophones (e.g., TRAX) were named faster and more accurately than controls (e.g., PRAX). Since TRAX has a high-frequency phonological neighbor (TRACKS, a real word) it was named faster than PRAX which has no phonological neighbor.

It is quite reasonable to assume that a third kind of neighborhood exists, namely the semantic neighborhood. Based on Coltheart et al.'s (1977) original definition of orthographic neighborhood, a semantic neighborhood is defined as the group of all other words of the same semantic category that can be generated. This is not to say that orthography and or phonology do not matter. For example, for the semantic category of fruit, the semantic neighborhood would include words such as PEAR, LIME, and so on that exhausts every possible variety of fruit. PAIR and LAME are very similar to the fruits, one phonologically and the other orthographically. However, only the semantic properties of the words are of concern here. The phenomenon of the neighborhood frequency effect can be applied to the semantic neighborhood. The semantic neighborhood frequency effect can be defined as follows. If a word is semantically similar to a more frequent word in a particular category (semantic neighborhood), then it would be harder to recognize this word as compared to a word with no higher-frequency semantic neighbors. For example, using the Battig and Montague type categories, MILE has no higher-frequency neighbor in terms of a unit of distance (Battig & Montague, 1969). However, FURLONG has many higher frequency semantic neighbors (e.g., FOOT and INCH had a higher-frequency of response than FURLONG). Therefore, FURLONG would be harder to recognize than MILE as a unit of distance.

Following the work of Neely (1976, 1977), Becker (1980) used a lexical decision task with category typicality as a variable since facilitation and inhibition effects due to semantic context were observed in the past. Becker found that high-typicality words in a

category were recognized faster than low-typicality words. Based on his findings, Becker made the important distinction between facilitation-dominant and interference-dominant effects of semantic context in lexical decision tasks using primes. He proposed that a specific prediction strategy is used for facilitation-dominant semantic processing. This meant that when an individual is given a prime whose category membership is small (small semantic neighborhood), the individual generates a small semantic set. For instance, a prime such as CHAIR has only a limited set of members. With only a small semantic set to choose from, it would be easier to identify an exemplar of that category. According to Becker, a category with not too many semantic alternatives should produce very little, if any, delay in the recognition of a related or unrelated member of that category. On the other hand, if a prime with a large semantic set is presented (e.g., FURNITURE), Becker proposed that interference-dominant semantic processing is used. Observers will tend to use an expectancy strategy since the size of category membership is presumably large enough that it cannot be exhausted prior to the onset of a target stimulus in the lexical decision task. Also, when the target is an unrelated word, the search of the large semantic set delays consideration of the members related to the target. This, in turn, produces a delay in responding to that target. When compared to the prediction strategy, the expectancy strategy is more time consuming since identification is dependent on the size of the semantic set of a given prime.

Becker's (1976, 1980) argument is relevant to the notion of semantic neighborhood frequency. The exact frequency of a word is not the crucial factor in recognition using a

semantic categorization task. The crucial factor is the size of the semantic neighborhood (semantic set) generated from the given category (cf., Grainger, et al., 1989). It is within the semantic neighborhood that semantic word frequency will affect word recognition. Interference between semantically-similar lexical representations competing for identification in the visual word recognition process can be described in terms of a frequency-ordered serial-search or verification process (serial-search models) or in terms of mutual inhibition (parallel-access models). These two models make different predictions concerning the effects of semantic frequency on a semantic categorization task such as that used by Van Orden (1987) and his colleagues (Van Orden, Johnston, & Hale, 1988). The task of semantic categorization was used instead of a priming task since it was assumed that categorizing a word necessarily involves knowing the semantic relationship between a word and a category (cf., Schvaneveldt & McDonald, 1981). Primes, on the other hand, may be too broad to elicit the proper semantic neighborhood.

The serial-search model (Becker, 1976, 1980; Forster, 1976; Paap et al., 1982; Paap et al., 1987) predicts an additive effect of number of higher-frequency semantic neighbors in a semantic categorization task. The greater the size of the category's semantic set, the more verification time is needed before correctly identifying the stimulus. Therefore, category decision latencies are a direct function of the semantic set size. It is not the semantic neighborhood frequency of a word per se that influence recognition, but rather the size of the semantic set that determines the onset of recognition. With a large semantic set (a general category), the verification process proceeds from higher-frequency

semantic neighbors to lower-frequency semantic neighbors. High-frequency neighbors will be identified faster than low-frequency neighbors. The same process occurs for a category with a small semantic set (a specific category). However, the recognition latencies of the two kinds of semantic sets are different, with the small semantic sets having shorter recognition latencies than the large semantic sets. Thus, a semantic neighborhood frequency effect is predicted, with the size of the effect dependent on the semantic neighborhood size. A large effect is expected given a large neighborhood size; a null effect is expected given a small neighborhood size.

The interactive-activation model (McClelland & Rumelhart, 1981) predicts the absence of an additive effect of number of higher-frequency semantic neighbors on category decision latencies. The inhibition acting on a given category node is a function of the activation levels of all the other nodes at the same category level (all members of the category). The higher the activation of the semantic neighbor nodes, the stronger the inhibition on the category node. In this model, the activation level of a given category node is determined by the frequency of the category members (resting-level activation). Thus, the nodes of high-frequency semantic neighbors will have relatively high activation levels; this would result in high-frequency neighbors being identified faster than low-frequency neighbors. The relatively high activation level of the high-frequency semantic neighbor nodes will generate more inhibition on the category node when compared to the inhibition generated by the less activated nodes of low semantic frequency neighbors. However, due to the mutual inhibition of the high-frequency semantic neighbors, inhibition

on the category is comparable with either high-or low-frequency neighbors. Because of this, identification latencies should be similar in a semantic categorization where categories with either a large or small semantic set is used. A semantic neighborhood frequency effect should be observed regardless of semantic neighborhood size, with high-frequency semantic neighbors being recognized faster than low semantic frequency neighbors.

The present study tested between the serial-search and interactive-activation models of visual word recognition when applied to a semantic categorization task. Since identification of a word precedes recognition of a word (e.g., Van Orden, et al., 1988), this study compared semantic frequency with printed word frequency. In a lexical decision task, the word frequency effect is a robust phenomenon. The same logic can be applied to a semantic categorization task. Van Orden et al. (1988) proposed that word identification in reading proceeded from spelling to sound to meaning. Therefore, a word of higher printed, or lexical frequency, should be recognized faster than a word of lower printed frequency. If this is so, then it can be deduced that categorizing a word should also depend on lexical word frequency. However, this study proposed that a word's semantic frequency with respect to a particular category may also influence word recognition.

The participants in this study made semantic categorization decisions with targets from large or small categories, and of either high- or low-frequency with respect to printed word frequency or semantic frequency. The serial search model predicts an effect of neighborhood size (semantic and lexical) and an effect of frequency only within a large neighborhood. The interactive-activation model predicts no effect of neighborhood size

(semantic and lexical), but an effect of frequency (semantic and lexical) within a neighborhood.

Method

Observers

Twenty students from the San Jose State University subject pool participated in this study. All were native English speakers and had normal or corrected-to-normal vision.

Stimuli and Apparatus

The observers were asked to make decisions as to whether or not a word was an exemplar, or member of a particular semantic category. The experiment was generated on an IBM-AT-compatible computer with an 80386 processor using the Micro Experimental Laboratory software package (Schneider, 1990). Each category was presented one at a time followed by a target word that had a .50 probability of being a category exemplar. The stimuli were presented on the screen of a Sony CPD-1303 monitor that was 20 cm high and 28 cm wide. The stimuli were 160 categories with their respective target words. The independent variables were the target type (semantic or lexical), category size (large or small), and the frequency of occurrence of the exemplar targets (high or low). There were eight experimental conditions presented based on the 2 (type of target stimulus) X 2 (semantic category size) X 2 (frequency of the target stimulus) design. There were 10 replications for each of the eight conditions for a total of 80 trials. The other 80 trials were fillers. These items contained various categories and targets that were not used as the test stimuli. To prevent a positive response bias to the categories, the fillers did not

contain any category exemplars. As a result, each of the critical trials were matched with a filler trial. The dependent variables were the response times (RTs) in determining whether a target word belongs to a particular category and the errors associated with each decision. All categories and targets were presented in uppercase format.

Large categories. The large categories and exemplars were chosen from the category norms of Battig and Montague (1969). This measure consisted of category norms for verbal items in 56 categories. The category norms were ranked in terms of the total amount of occurrences with respect to each category for all the participants who responded in Maryland and Illinois. The large categories were those that had an excess of 40 exemplars. The target words were either semantic or a lexical control. A high-frequency semantic exemplar of the large categories was the first item listed in the category norms, while a low semantic frequency exemplar was chosen from those that occurred only once in the category norms. A high-frequency lexical exemplar was the highest frequency item in the category with respect to printed frequency of occurrence; a low-frequency exemplar was the lowest frequency item in the category with respect to printed frequency of occurrence. These words were cross-referenced with the printed frequency norms computed by Kucera and Francis (1967). The mean frequencies of printed occurrence for the semantic targets were 30.4 per million (high semantic frequency) and 4.6 per million (low semantic frequency). The mean frequencies of printed occurrence for the lexical targets were 128.4 per million (high-frequency) and .4 per million (low-frequency).

Small categories. The small categories and exemplars were a subset of the large categories. For example, TYPE OF LEAFY VEGETABLE was used as a small category. It was subset of the large category of TYPE OF VEGETABLE. The range of possible leafy vegetables is rather constrained when compared to a type of any vegetable. As a result, the size of the category of TYPE OF LEAFY VEGETABLE was smaller than the category of TYPE OF VEGETABLE. A high-frequency semantic exemplar was the most frequently occurring item that fit the category; a low-frequency exemplar was an item that occurred only once in the category norms. Likewise, a high-frequency lexical exemplar was the highest frequency word in terms of printed occurrence in the category, and a low-frequency lexical exemplar was the lowest-frequency word in terms of printed occurrence. The mean frequencies of printed occurrence for the semantic targets were 67 per million (high semantic frequency) and 3.4 per million (low semantic frequency). The mean frequencies of printed occurrence for the lexical targets were 53.1 per million (high-frequency) and 1.4 per million (low-frequency).

Procedure

The observers were run individually in a small experimental room under normal lighting. They were told to look at the computer monitor and determine whether a word was an exemplar of a particular category for each trial. They were told to signal a response of “category exemplar” by pressing the “1” key and a response of “not a category exemplar” was to be signaled by pressing the “3” key. The observers were able to initiate each trial by pressing the SPACE BAR. They were also told to respond as

rapidly and accurately as possible. The instructions were also presented on the computer monitor.

The observers proceeded with 10 practice trials to familiarize themselves with the experimental task. None of the category names or target words used in the practice trials were in the experimental trials. A trial consisted of a category name appearing for 2000 ms, followed by a fixation point ("+") to indicate where the target stimulus would be presented. After 500 ms, the target stimulus replaced the fixation point. The target stimulus remained until the observer made a response. Both the category and target appeared in the middle of the screen. No feedback on speed or accuracy was given to the observers. Following the ten practice trials, the observers proceeded through the 160 experimental trials. The entire procedure required approximately 30 minutes.

Results

Omnibus Analyses

Response times in excess of 2500 ms or less than 350 ms (1.9%) were eliminated from the analyses. Reaction times under 350 ms were assumed to reflect an anticipatory response; RTs over 2500 ms were assumed to reflect a lapse of concentration by the observer or not understanding either the category or target word. The number of errors were rather high ($M = 8.0$, $SD = 2.6$), which showed the difficulty of the experimental task.

The response times for correct responses were analyzed in a 2 (target type) X 2 (category size) X 2 (target frequency) analysis of variance (ANOVA), with all factors

being within-subjects. The analyses yielded a significant main effect for target frequency, $F(1,19) = 159.17, p < .001$. Response times were faster with high-frequency words ($M = 844$ ms) than low-frequency words ($M = 1020$ ms). The three-way interaction of target type, category size, and target frequency was also significant, $F(1,19) = 29.75, p < .001$. The sources of this interaction will be discussed in the next three sections.

A three-way ANOVA of the error rates indicated significant main effects for target type, $F(1,19) = 9.15, p < .01$, for target frequency, $F(1,19) = 45.37, p < .001$, and for category size, $F(1,19) = 4.53, p < .05$. More errors were made for semantic targets, low-frequency targets, and small categories. The three-way interaction was not significant, $F(1,19) = 1.25, p > .10$.

To test the serial-search and parallel-access models in semantic categorization, two separate two-way within-subjects ANOVAs were conducted for both semantic and lexical target types.

Semantic Target Data. The mean correct response times and error rates are summarized in Table 1. The correct response times were analyzed in a 2 (category size) X 2 (target frequency) within-subjects ANOVA. The analysis yielded a significant main effect for target frequency, $F(1,19) = 79.09, p < .001$. High-frequency targets ($M = 875$ ms) were categorized faster than low-frequency targets ($M = 1066$ ms). However, the main effect for category size was not significant, $F(1,19) = 2.11, p > .1$. The Category Size X Target Frequency interaction was significant, $F(1,19) = 27.49, p < .01$. Analysis of the simple effect of target frequency for the large category size ($F(1,19) = 91.92, p < .001$)

Table 1

Mean Reaction Times (ms) and Error Rates for Semantic Target Words as a
Function of Category Size and Target Frequency

Target Frequency	Category Size			
	<u>Large</u>		<u>Small</u>	
	RT	% Error	RT	% Error
High				
<u>M</u>	764	1.5	886	8.8
<u>SE</u>	44	0.1	46	2.1
Low				
<u>M</u>	1096	19.5	1037	20.7
<u>SE</u>	43	2.3	47	2.8

revealed that high-frequency words were categorized an average of 332 ms faster than low-frequency words. There was also a similar difference for recognition in a small category, $F(1,19) = 21.24$, $p < .01$, with high-frequency words being categorized an average of 151 ms faster than low-frequency words. Analysis of the simple effect of category size for the high-frequency words ($F(1,19) = 19.23$, $p < .001$) showed that targets from a small category took 122 ms longer to categorize than targets from a large category. However, for low-frequency words, the opposite result occurred. Low-frequency words were categorized 59 ms faster for small categories than from large categories, $F(1,19) = 4.47$, $p < .05$. Also, a one-way within-subjects ANOVA based on the difference between the categorization times for the high- and low-frequency targets ($F(1,19) = 27.49$, $p < .001$) revealed that there was a greater semantic neighborhood frequency effect for large categories ($M = 332$ ms) than for small categories ($M = 151$ ms).

A two-way ANOVA on the error rates yielded only a significant main effect for target frequency, $F(1,19) = 108.96$, $p < .001$. Error rates were higher for low-frequency words ($M = 20.1\%$) than for high-frequency words ($M = 5.2\%$).

Lexical Target Data. The mean correct response times and error rates are shown in Table 2. The correct response times were analyzed in a 2 (category size) X 2 (target frequency) within-subjects ANOVA. Only the main effect for target frequency was significant, $F(1,19) = 27.07$, $p < .001$. Response times were faster for high-frequency words ($M = 863$ ms) than for low-frequency words ($M = 973$ ms).

Table 2

Mean Reaction Times (ms) and Error Rates for the Lexical Target Words as a
Function of Category Size and Target Frequency

Target Frequency	Category Size			
	<u>Large</u>		<u>Small</u>	
	RT	% Error	RT	% Error
High				
<u>M</u>	868	3.1	857	11.2
<u>SE</u>	53	1.3	49	2.3
Low				
<u>M</u>	959	11.2	988	7.3
<u>SE</u>	46	2.0	49	2.2

A two-way ANOVA on the error rates revealed only a significant Target Frequency X Category Size interaction, $F(1,19) = 14.41$, $p < .01$. The simple effect of target frequency for the large category size, $F(1,19) = 16.60$, $p < .01$, indicated that the interaction was due to the fact that more errors were made on the low-frequency words ($M = 11.2\%$) than high-frequency words ($M = 3.1\%$). There was no difference in error rates for target frequency in the small category sizes, $F(1,19) = 1.15$, $p > .10$.

Semantic vs. Lexical Targets. To determine the validity of the semantic neighborhood frequency effect, the correct responses were analyzed in a Target Type X Target Frequency within-subjects ANOVA. The mean correct response times and error rates are shown in Table 3. The analysis revealed a significant main effect for target frequency, $F(1,19) = 159.17$, $p < .001$, with high-frequency words ($M = 844$ ms) being categorized faster than low-frequency words ($M = 1020$ ms). The Target Type X Target Frequency interaction was also significant, $F(1,19) = 10.74$, $p < .01$. Examination of the simple effect of target type on low-frequency targets indicated that lexical targets were categorized an average of 93 ms faster than semantic targets, $F(1,19) = 11.46$, $p < .01$. However, high-frequency semantic targets ($M = 825$ ms) were also categorized faster than high-frequency lexical targets ($M = 863$ ms), although this effect was not significant, $F(1,19) = 2.14$, $p > .10$. A one-way within-subjects ANOVA on the difference in categorization times for high- and low-frequency targets ($F(1,19) = 10.74$, $p < .01$) revealed that the frequency effect was larger for semantic targets ($M = 241$ ms) than for lexical targets ($M = 110$ ms).

Table 3

Mean Reaction Times (ms) and Error Rates for Target Frequency as a Function of Target Type

Target Frequency	Target Type			
	<u>Semantic</u>		<u>Lexical</u>	
	RT	% Error	RT	% Error
High				
<u>M</u>	825	5.1	863	7.1
<u>SE</u>	43	1.2	49	1.4
Low				
<u>M</u>	1066	20.1	973	9.2
<u>SE</u>	43	1.7	46	1.2

A two-way ANOVA on the error rates indicated a main effect for target type, $F(1,19) = 9.15$, $p < .01$, and for target frequency, $F(1,19) = 45.37$, $p < .001$. More errors were made for semantic targets ($M = 12.6\%$) and for low-frequency words ($M = 14.7\%$). The Target Type X Target Frequency interaction was also significant, $F(1,19) = 16.62$, $p < .01$. The analyses of the simple effects of target type on target frequency yielded a significant effect of target type on low-frequency targets, $F(1,19) = 18.13$, $p < .01$, with more errors with semantic targets than lexical targets.

Discussion

Evidence for a Semantic Neighborhood Frequency Effect

This study tested between the serial-search and interactive-activation models of visual word recognition with respect to category size and semantic neighborhood frequency using a semantic categorization task. The two models made different predictions with regard to semantic frequency and lexical frequency. The serial-search model predicted an effect of neighborhood size for both semantic and lexical targets; it also predicted a semantic frequency effect for large categories. Thus, categorization times should be faster for smaller categories, with no difference due to semantic or lexical frequency. Also, categorization times should be faster for high-frequency words relative to low-frequency words, with a greater difference in large categories. The interactive-activation model predicted no effect of neighborhood size for both semantic and lexical targets, but a general effect of frequency within a neighborhood. Thus, categorization

times should be faster for higher-frequency targets than lower-frequency targets regardless of category size.

The results of this study for the lexical and semantic targets show support for the interactive-activation model of visual word recognition. For the lexical targets, the model accurately predicted no effect of category size, but an effect of frequency, with high-frequency words being categorized faster than low-frequency words. However, for the semantic targets, the expected pattern of results did not occur. Upon closer inspection of Table 1, it is evident that the main effect of semantic target frequency is eliminated due to the significant interaction of target frequency and category size. For high-frequency target words, categorization times were significantly faster for large categories relative to small categories. For low-frequency target words, however, categorization times were faster for small categories relative to large categories. This slight inconsistency with the interactive-activation model may be attributed to the fact that during the experiment's debriefing, observers indicated that they did not understand some of the categories and exemplars. This may have inflated the RTs for the high-frequency semantic targets in the small categories.

For the lexical targets, the serial-search model incorrectly predicted an effect of category size and a neighborhood frequency effect for only the large semantic categories. However, the data for the semantic targets showed partial support for the serial-search model. For instance, high-frequency words were identified faster than low-frequency word for both large and small categories, with a greater difference in the large categories.

However, the pattern of results was different from what was predicted. There was no significant difference in categorization times for both large and small categories.

This study also explored the existence of a semantic neighborhood frequency effect. Considering the data, it seems that the semantic neighborhood frequency effect cannot be discounted. Even though this study used lexical and semantic frequency, the results mirror the orthographic neighborhood frequency effect in visual word recognition (Grainger, 1990; Grainger & Segui, 1990). For example, it is not the size of the category that necessarily determines categorization, but the number of neighbors a word has that determines categorization latencies. This occurred for both the lexical and semantic targets (see Tables 1 and 2). The results from the semantic targets also provide evidence that it is not the semantic category size, but the number of semantic neighbors a word has that determines categorization latencies. A semantic frequency effect occurred even when neighborhood frequency was held constant. In this study, the high-frequency targets had no higher-frequency semantic neighbor. Also, the low-frequency targets had no lower-frequency neighbor. Targets with one or more higher-frequency semantic neighbors took longer to categorize than targets with no higher-frequency semantic neighbors (see Table 1). This is the semantic neighborhood frequency effect. The same holds true for the lexical targets, but using lexicality as the neighborhood (see Table 2).

A Two-Stage Verification Model in Semantic Categorization

Even though the results of this study show more support for the interactive-activation model, the serial-search model can still be salvaged. The serial-search model is

a model of visual word recognition. The testing of this model would require examining the lexicality of words. The semantic categorization task requires a different processor than a lexical decision task since another stage of processing has to occur to induce correct categorization. For example, in Becker's (1980) model, verification is based on printed word frequency. In this study, verification should have been based on semantic frequency. If the serial-search model holds true for semantic categorization, the size of the semantic set that is generated should affect the verification process, with larger semantic sets requiring more verification time than smaller semantic sets. Based on the data, it seems that an additional verification process occurred in order to correctly categorize a word. This could possibly explain the failure to support the serial-search model. Instead of one verification process, it is proposed that another verification process is needed in order to correctly classify a word as a member of a semantic category.

The proposed verification process occurs after the initial identification of the target word independent of the category. For instance, after processing the category, the observer generated a semantic set of all possible category members (cf., Becker, 1980). When the target word appeared, a preliminary verification process occurs with high semantic frequency neighbors checked before low-semantic frequency neighbors. Once the word is identified, a secondary verification process occurs which results in semantic categorization. In this verification process, the word is semantically checked to determine whether category membership is upheld. This is similar to the network and feature models of semantic memory (e.g., Collins & Quillian, 1969, Smith, Shoben, & Rips, 1973, 1974).

A semantic concept is stored in the mental lexicon as a set of features in the feature model. The features include a set of defining features, which are crucial to the meaning of the concept, and characteristic features, which are less important. Defining features are processed before characteristic features. As a result, saying that a LETTUCE is a type of vegetable should be faster than saying a LETTUCE is a type of leafy vegetable.

The same reasoning holds for the proposed secondary verification process. However, categorization is proposed to be the reverse process of the feature model of semantic memory. For a large category like type of vegetable, a person generates a large semantic set whose features would include defining feature of a type of vegetable (e.g., CORN and CARROT). For a small category like type of leafy vegetable, a person generates a small set of features that would include a characteristic feature of a type of leafy vegetable (e.g., LETTUCE and KALE) as well a set of defining features. The generation of the semantic sets occurs prior to the presentation of the target stimulus. After presentation of the target word, all of the semantic features of that word are generated, both defining and characteristic features. These features are then checked in a process similar to that of the serial-search model. Features that are more relevant to the observer (i.e., features of high-frequency) are checked before features that are not as relevant (i.e., features of low-frequency).

If a large category like type of vegetable is presented, any defining or characteristic feature of the target word would produce category recognition based on the semantic frequency of the target. This can be viewed as a simple self-terminating process.

Verification of any feature would initiate category recognition. However, if a small category like type of leafy vegetable is presented, the target needs to be verified that it is leafy and that it is a vegetable. This can be viewed as a complex self-terminating process. Therefore, semantic categorization involving a small, restricted category should take longer than semantic categorization involving a large category. A target must satisfy both conditions (i.e., the target must have a defining and characteristic feature of the category) in order for it to be correctly categorized. If one feature is not true, then a word is not a category member. This will necessarily take more time than matching only one feature of a category. On the other hand, semantic categorization involving a large, general category would involve a check for either a defining or characteristic feature of the category. If this type of verification process occurs, then it is logical that semantic categorization involving a small category should, on average, be similar to semantic categorization involving a large category. Also, higher-frequency neighbors will be verified before lower-frequency neighbors. The results for both the semantic and lexical targets show some partial support for semantic categorization based on a two-stage verification process. For instance, categorization times were generally similar regardless of category size. The major difference in categorization times was due to target frequency; high-frequency words were categorized faster than low-frequency words by an average of 177 ms as can be seen in Tables 1 and 2.

The results of the error rates provide further support for the two-stage-verification process in semantic categorization. Error rates were similar for both large and small

categories, with a slightly higher rate for small categories, but error rates were significantly higher for low-frequency semantic targets. A high-frequency semantic neighbor will get checked before a low-frequency semantic neighbor. A low-frequency semantic neighbor is presumed to induce more errors in categorization since it occurs at the very end of the verification process if at all. For instance, a low-frequency semantic member may or may not be in the self-generated semantic set of an observer. If this is the case, and all possible semantic neighbors are checked, the typical response would be a non-member categorization. This is highly plausible because, as stated previously, the observers indicated during the experiment's debriefing that they did not know some of the words or understand the category. They indicated that they typically made a response of non-member when they did not understand the word or the category that was presented. This resulted in longer categorization times and more categorization errors.

As for the slight advantage in correctly categorizing high-frequency targets of large categories, this can be explained by the category confirmation process. For a large category, correct categorization would require either recognizing a defining or characteristic feature of a given semantic category. However, if the categorization is based on a small semantic category, correct categorization would require the confirmation of both defining and characteristic features of a category. Thus, more errors of generality (i.e., making a decision based on only defining characteristics for the general semantic group to which the target word belonged) may have occurred with the presentation of small categories. The errors that occurred were not artifacts of a speed/accuracy trade-

off. More errors were committed with longer categorization times. The majority of errors occurred with low-frequency words regardless of category size.

Semantic Frequency vs. Lexical Frequency

The categorization times for both semantic and lexical targets were quite similar with respect to category size and target frequency. However, there was a slight advantage of high-frequency semantic targets for a large category relative to a high-frequency lexical target. Also, the frequency effect was greater for semantic targets than for lexical targets. This finding indicates that semantic frequency plays a role in semantic categorization since the semantic targets had a lower frequency of printed occurrence as compared to the lexical targets. It is true that the type of frequency is determined by the type of task. However, word identification is usually processed orthographically (e.g., McClelland & Rumelhart, 1981). Higher-frequency words, in terms of printed frequency, should be identified before lower-frequency words. In the two-stage verification model, the first stage requires identification of the target word. The second stage involves the verification of category membership by examining conditionals set up by the category size. It seems that identifying a target word prior to categorization is based on lexical frequency. However, semantic categorization is based more on semantic content than orthographic content. The data indicate that there was only a difference for low-frequency words, with lexical targets being categorized faster than semantic targets. There was no difference in categorizing high-frequency words for either semantic or lexical targets. Taken together, the results of this study imply that semantic categorization may involve more than one

component.. A word of high lexical frequency tends to be well-learned, as is a word of high semantic frequency. Thus, high-frequency words can be accessed rather quickly. On the other hand, a word of low semantic frequency is recognized slower than a word of low lexical frequency simply due to the fact that a person may have seen the word more often than thinking of or using the word in context. Therefore, it is plausible that the word frequency effect may be a product of a semantic frequency effect.

Future Considerations

This study found a semantic neighborhood frequency effect even when semantic neighborhood size was controlled. The results are in line with previous research that used semantic context in lexical decision tasks. In this study, neighborhood frequency was controlled and a semantic categorization task was used. This study used large and small semantic categories, with the smaller categories being a subset of their respective large categories. These categories were chosen from the Battig and Montague (1969) category norms. The limitation of this study was that the small categories and their members that were generated may not reflect the true relationship between them. For instance, for the small category of TYPE OF LEAFY VEGETABLE, the high-frequency semantic member was the highest-frequency member chosen from the large category of TYPE OF VEGETABLE. This member may not be the highest-frequency semantic member of the category TYPE OF LEAFY VEGETABLE. Therefore, this study needs to be replicated by using words that are unique to a particular category. This would mean undertaking the

enormous task of producing category norms for both large and small semantic categories. This would give a more accurate index of the semantic neighborhood frequency effect.

The semantic neighborhood frequency effect should also be examined with respect to the category norms of the individual. In the experiment that was used in this study, category members were based only on normative data (i.e., the category norms of Battig & Montague, 1979). This study did not take into account the individual's unique knowledge for a particular category. There was no index as to the size of the semantic set nor the validity of the category members generated by an individual. A type of generation effect may occur (cf., Gardiner, Gregg, & Hampton, 1988). It is possible that such variables as geographic location and ethnic background influence the size and quality of the semantic set. A low semantic frequency member of a category for one person may be a high-frequency semantic member of a category for another person. Future research on the semantic neighbor frequency effect should focus on this possible confound.

Another possible avenue of research is to examine the amount of false positive errors with respect to categorizing words from small categories. These errors would result from making categorization decisions without looking at the defining features of a particular category. This study found some evidence for this, but there was no control group. It is possible to generate three types of category sizes that parallels Rosch's (1978) three semantic categories. Then it would be possible to compare error rates between the different category sizes.

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Appendix A

Signed Approval Forms

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One Washington Square • San Jose, California 95192-0025 • 408/924-2480

TO: Elvin Chun
3272 Adamswood Dr.
San Jose, CA 95148

FROM: Serena W. Stanford *Serena W. Stanford*
AAVP, Graduate Studies & Research

DATE: April 13, 1995

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"The Semantic Neighborhood Frequency Effect: Does it Exist?"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Serena Stanford immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that each subject needs to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal, will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.