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# Variable Semantic Input and Novel First-Language Vocabulary Learning

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WASHINGTON UNIVERSITY IN ST. LOUIS

Department of Psychology

Variable Semantic Input and Novel First-Language Vocabulary Learning  
by  
Nichole Runge

A thesis presented to the  
Graduate School of Arts and Sciences  
of Washington University in  
partial fulfillment of the  
requirements for the degree  
of Master of Arts

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*May 2015*

## ABSTRACT OF THE THESIS

Semantic Input Variability and the Acquisition of Novel First-Language Vocabulary

by

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Master of Arts in Psychology

Washington University in St. Louis, 2015

Professor Mitchell Sommers, Chair

Vocabulary learning involves mapping a word form to a semantic meaning. An individual asked to learn the Spanish word for “apple,” for example, must map a new word form (*manzana*) onto the appropriate semantic representation. Previous studies have found that acoustic variability of word forms can improve second language vocabulary acquisition (Barcroft & Sommers, 2005; Sommers & Barcroft, 2007). The current experiments investigated whether variable semantic input could have a similar beneficial effect on first language vocabulary learning. Participants learned low-frequency English vocabulary words and their definitions. Half of the words were shown with the same verbatim definition at each of the six exposures, while the other half appeared with a differently worded, but synonymous, definition at each of the six exposures. After the learning phase, two cued recall tests were administered. In the first test, each word form was supplied and participants were instructed to write its definition. In the second test, participants were given a novel definition of each word and were asked to provide the correct word form for the definition. Younger adults in Experiment 1 were more accurate for words studied in the variable condition, whereas the accuracy scores of older adults in Experiment 2 did not significantly differ by condition. These results are discussed within the TOPRA model framework (Barcroft, 2002) and the associative deficit hypothesis.

## Introduction

Vocabulary acquisition requires learning a new word form, remembering its semantic meaning, and mapping the two items together in memory. One way to affect memory for the form-meaning mapping in vocabulary learning is through the use of variable input. In the case of auditory input, variability is often introduced by changing one or more indexical properties—properties related to the speaker such as age, gender, and current emotional state. Thus, one of the more common ways of introducing input variability is to have stimuli spoken by multiple speakers rather than a single talker (Mullennix, Pisoni, & Martin, 1989; Martin, Mullennix, Pisoni, and Summers, 1989). Past studies have shown an improvement to second-language (L2) vocabulary acquisition for younger adults when variable word form input was manipulated by having the target Spanish word forms spoken by multiple speakers versus a single talker (Barcroft & Sommers, 2005).

Limitations of previous studies examining input variability and vocabulary learning is that almost all of the studies involve form-based variability in the acquisition of known semantic representations. In the current study, I extend this previous work by examining the effects of semantic variability on acquisition of novel first-language (L1) vocabulary. Refined understanding of the effect of input variability on memory is not only important to the area of cognitive psychology, but given the practical implications, it can also affect pedagogy by making learning more effective and efficient. The following literature review will first look at the effect that variable word form input has had on word identification and memory in previous experiments. Following this, I will review studies of semantically based input variability. Lastly, I will describe the rationale behind the current studies and how they expand on previous work.



## **Variable Word Form Input**

In the domain of speech perception, the processing of variable input has been shown to come at cost to word identification. In a study by Mullennix et al. (1989), participants heard the carrier phrase “Say the word \_\_\_\_\_ for me” in noise with different words presented in the blank. Two sets of lists were presented in a blocked format. On one of the lists, the same talker spoke all of the presentations, while on the other list, the talker producing the carrier phrase and word was rotated through 15 different speakers. After each trial, participants named the target word as quickly and accurately as possible into a microphone that recorded response latencies. Results indicated that participants were faster and more accurate at word naming in lists spoken by a single talker, compared with multiple talkers, suggesting there was a perceptual cost to identifying variable input.

The cognitive costs of processing variable input also affect later memory for those items. In a free recall memory task, participants who heard words at an interword interval of 1.5 s were able to recall more words from the single talker lists compared to multiple talkers lists (Martin et al., 1989). Martin et al. (1989) suggested that the reduced performance for multiple talker lists could be attributed to the additional costs of talker normalization when items were spoken by a number of different talkers compared to when those same items were produced by a single talker.

In a follow up experiment, however, Goldinger, Pisoni, and Logan (1991) suggested that in addition to perceptual cost, input variability could actually have beneficial effects for memory provided listeners had sufficient time to encode both the lexical (word) and indexical (talker) information and bind those two together. Specifically, they proposed that the binding of lexical and indexical information would provide listeners with an additional retrieval cue that might produce better memory if it could compensate for the perceptual costs at encoding that results

from having multiple talkers. To test this hypothesis, Goldinger et al. (1991) measured recall performance for lists in which all of the items were spoken by a single talker and compared that to recall of the same items when presented in a list in which each word was spoken by a different talker. The critical manipulation in this study was the interval between list items, which varied from 250 ms up to 4000 ms. Goldinger et al. (1991) suggested that at the shorter interstimulus intervals, listeners would be unable to bind the lexical and indexical information and therefore, consistent with the results of Martin et al. (1989), single talker lists would produce better recall performance than multiple talker lists. In contrast, for the longest interstimulus interval of 4000 seconds, listeners should have sufficient time to encode and bind both indexical and lexical information. Therefore, Goldinger et al. (1991) hypothesized *better* performance for the multiple talker lists than for the single talker lists in trials with the 4 s interstimulus interval. Consistent with this hypothesis, they found that for the shorter interword intervals of 250 ms and 500 ms, results replicated earlier findings (Martin et al., 1989) in that words from single talker lists were remembered more accurately than those from multiple talker lists. However, they also discovered that at longer interword intervals of 2000 ms and 4000 ms, the findings reversed and the multiple talker lists were remembered more accurately. Although perception of variable input comes at a cognitive cost, these findings suggest that with enough processing time, indexical characteristics from multiple talkers can bind with the lexical information to create a broader, more accessible lexical representation, which can lead to improved memory.

In addition to between-talker variable input, some forms of within-talker variable input have also been shown to affect word identification and memory. In within-talker manipulations, the same speaker says all of the words, but the way in which words are spoken varies. One example is variable speaking rates in which the words are spoken at different speeds (e.g. fast,

medium, and slow). Similar to multiple talker lists, word identification is worse for variable speaking rate lists than for single speaking rate lists (Sommers, Nygaard, & Pisoni, 1994). This suggests that within-speaker variability can also affect spoken word identification. Additionally, in a free recall experiment similar to that of Goldinger et al. (1991) with multiple versus single talker lists, Sommers et al. (1994) found that words from a single speaking rate list were recalled more accurately at shorter interword intervals, but at longer interword intervals, those words from the variable speaking rate lists were recalled more accurately. Considered with the earlier results on between-talker variability, the findings with respect to speaking rate variability indicate that both within- and between-talker sources of variability can influence identification and retention of spoken words.

One concern with these earlier studies of input variability is whether any source of variability would produce similar patterns of results for identification and memory. To address this, Sommers and Barcroft (2006) proposed the extended phonetic-relevance hypothesis. According to this framework, only sources of variability that affect phonetically relevant properties will have an effect on identification and later memory of a word (Sommers & Barcroft, 2006). The earlier findings on talker characteristics and speaking rate are consistent with this proposal because both affect acoustic properties such as formant frequencies and formant transitions that are the principal cues for phoneme identification. On the other hand, overall amplitude is one characteristic of speech that is hypothesized to be phonemically irrelevant because relevant speech characteristics such as formant frequencies do not vary as a function of overall presentation level (Sommers, & Barcroft, 2007). Consistent with the extended phonetic-relevance hypothesis, Sommers et al. (1994) reported that word identification for lists spoken at the same overall amplitude did not significantly differ from lists spoken with variable

amplitudes. In addition, in an L1 recall task, memory for words in multiple versus single amplitude lists did not differ, regardless of the interstimulus interval (Nygaard, Sommers, & Pisoni, 1995). These findings support the extended phonetic-relevance hypothesis and also suggest that not all forms of variable input will affect one's memory or identification performance.

The experiments discussed so far have all dealt with identification and memory for highly familiar words in an individual's L1. In a series of experiments investigators have also examined whether input variability could have similar beneficial effects for learning new words in an L2 (Barcroft & Sommers, 2005; Sommers & Barcroft, 2007). Just as Goldinger et al. (1991) found a benefit of multiple talkers on later recall of individual items, a positive effect of variable word form input on memory has also been found in some L2 vocabulary learning studies. Barcroft & Sommers (2005), for example, exposed participants to six repetitions each of 24 Spanish nouns. The meaning of each word was always depicted through the same picture, and participants listened to the corresponding word form spoken by native Spanish speakers. Eight of the words were always spoken by the same talker (no variability condition), eight of the words were spoken twice each by three different talkers (moderate variability condition), and eight of the words were spoken one time each by six different talkers (high variability condition). After the learning phase, vocabulary learning was assessed through accuracy and latency scores in two cued recall tests. In the Picture-to-L2 test, participants were shown each of the studied pictures, one at a time, and asked to name the Spanish word for each item as quickly and accurately as possible. In the L2-to-L1 test, participants heard each of the Spanish word forms and were asked to name its English translation. In both tests, words from the high variability condition were remembered significantly better and produced more quickly than those in the medium variability condition,

which in turn were remembered significantly better and produced more quickly than those in the no variability condition. This finding suggests that just as variable word form input can improve free recall of individual English words given sufficient interword intervals (presentation time in the Barcroft and Sommers (2005) study was 5 s), it can also improve later memory for novel L2 vocabulary.

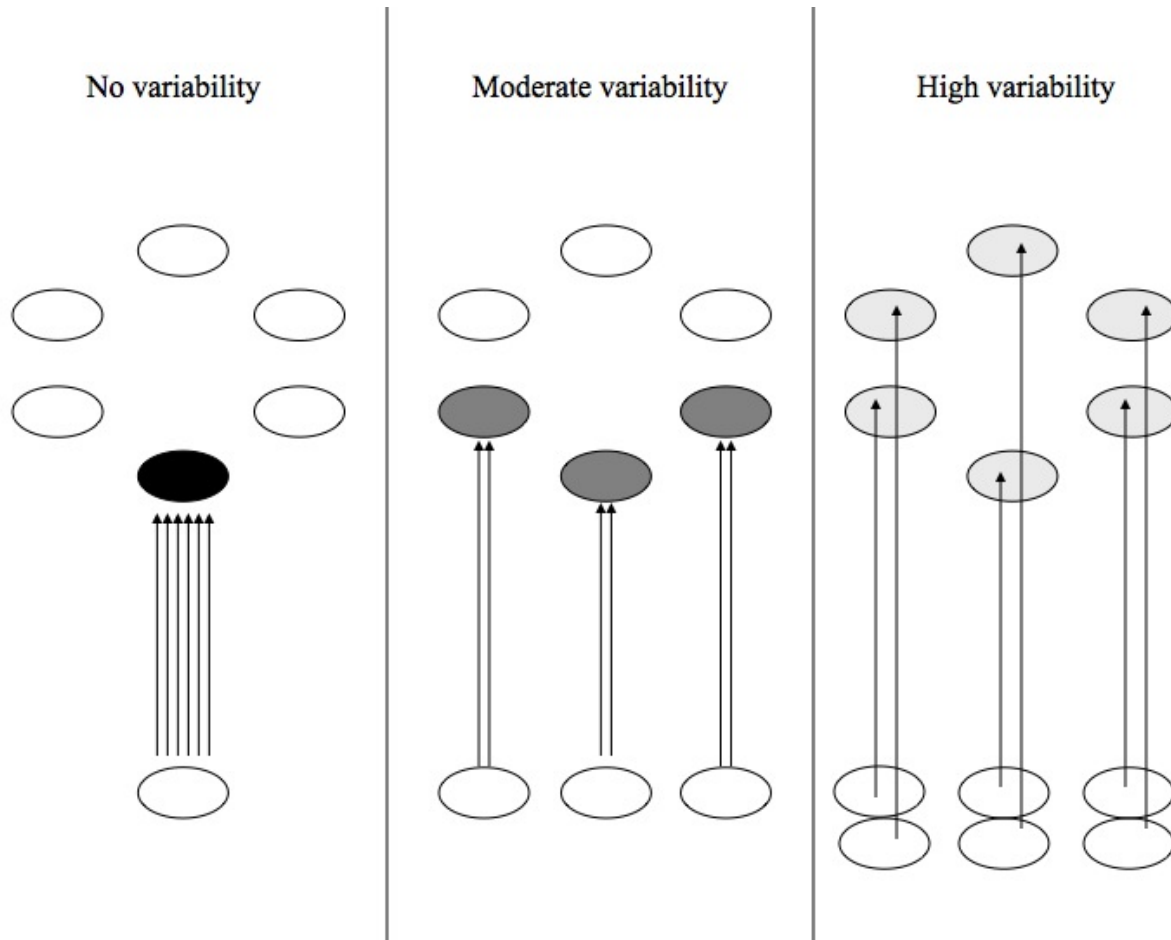


Figure 1: Model of acoustically varied input (bottom circles) and resulting lexical representations (top circles).

The authors suggested that the findings of beneficial effects of variability were a consequence of variability producing a more distributed representation of the new vocabulary items. This proposal is illustrated schematically in Figure 1, which indicates the extent of

variable input on the bottom of the figure and the strength of the resulting lexical representations (darker shading indicates strong representations) at the top. Consider the far right panel of the figure. This represents the case of high variability (six different talkers producing the L2 items). In this case, the resulting representations are broad, but each individual representation is relatively weak. On the other hand, in the constant input condition (far left panel), the representation is much narrower, but it is also stronger as a result of six repetitions of the exact same talker-word combination. Barcroft and Sommers (2005) suggested that the benefits of variability are due in part to the broader representation available in that condition.

To further investigate parallels between memory for L1 words and L2 vocabulary learning with respect to input variability, Sommers and Barcroft (2007) examined whether the extended phonetic-relevance hypothesis also held for learning L2 vocabulary. Specifically, they compared sources of variability that either were (speaking rate) or were not (overall amplitude) phonetically relevant in terms of their effects on L2 vocabulary learning. Consistent with the phonetic-relevance hypothesis, variability in speaking rate affected subsequent memory for the novel word forms, with variable speaking rate input resulting in faster and more accurate recall on both dependent measures (Picture-to-L2 and L2-to-L1). In addition, there was no difference in memory between the variable and constant condition with regard to overall amplitude (Sommers & Barcroft, 2007). These findings suggest that the beneficial effects of some sources of acoustic variability on memory for known L1 words can also be obtained when individuals are learning novel L2 vocabulary words.

Taken together, the findings from both L1 and L2 input variability studies suggest that there is an initial cognitive cost to encoding acoustically relevant variable input. However, provided individuals are given sufficient time to encode and bind the lexical and indexical

information, this initial cost at encoding is more than compensated when individuals are required to remember the items, producing improved recall for variable compared with constant input conditions. These benefits of acoustic variability are thought to arise from a broader representation for the varied input. In the following section, I consider studies that have examined the effects of semantic variability, rather than word form variability.

### **Variable Semantic Input**

Although Barcroft and Sommers (2005) proposed that input variability promotes L2 vocabulary learning because it generates a broader representation, there is an alternative explanation based on levels of processing (LOP; Craik & Tulving, 1972). Specifically, the LOP framework suggests that deeper processing at encoding will result in better memory retrieval. If the increased word form variability in Barcroft and Sommers (2005) promoted deeper processing, then the benefits for this condition may not necessarily be a direct consequence of the input variability producing a more distributed representation. Instead, it may reflect another instance in which deeper processing promotes memory for the items.

To adjudicate between the benefits of variability per se and variability promoting deeper processing, Sommers & Barcroft (2013) conducted a study similar to the earlier L2 vocabulary learning experiments (Barcroft & Sommers, 2005; Sommers & Barcroft, 2007) but changed the nature of the input variability. Rather than varying the word form, they varied the referent picture used to depict each of the target items. Thus, participants in this study always heard the same word form (the exact same file) but these were paired with either six repetitions of the exact same stimulus (i.e. the same picture of a cat), three different pictures of a cat each presented twice, or six different pictures of a cat each presented once. From the LOP perspective, this type

of referent variability should promote deeper processing and produce better recall than a condition in which the same referent is presented on each of six presentations. In contrast, Sommers and Barcroft (2013) applied a different model—the Type of Processing Resource Allocation (TOPRA) model—to suggest that referent variability would not improve memory for L2 items and, in fact, might impair it.

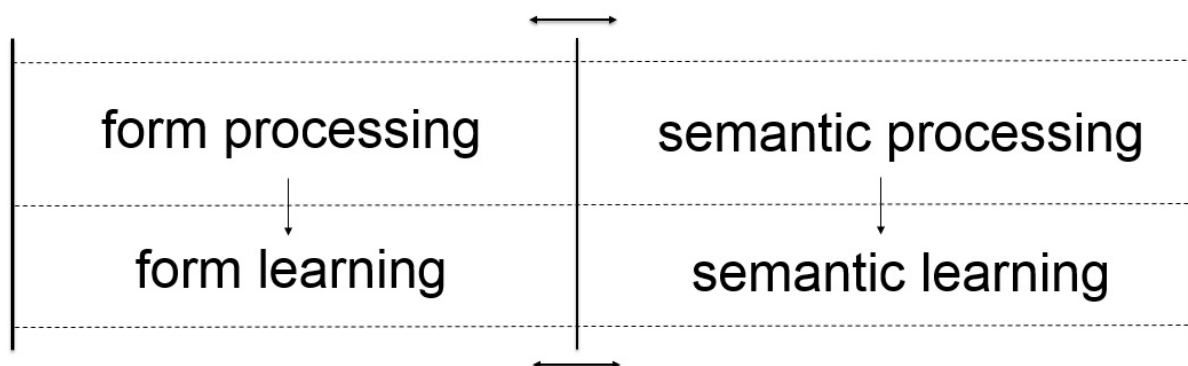


Figure 2: The TOPRA model.

The TOPRA model (Barcroft, 2002) was developed to specify the relationship between the nature of input variability and the nature of the learning task, and it posits that word form processing directly relates to word form learning, whereas semantic processing directly relates to semantic learning (Figure 2). The model suggests that individuals can allocate attention to either form-based or semantic-based aspects of the stimuli and can do so flexibly depending upon the nature of the input. When variability is introduced, the nature of that variability will direct the allocation of processing resources. Thus, when form-based variability is introduced as in the case of multiple talkers, resource allocation will primarily be to form-based aspects of the input. Crucially, the model proposes that learning will be best when the nature of the input matches the demands of the learning task. The model therefore provides an excellent account of the talker variability and L2 vocabulary learning results (Barcroft & Sommers, 2005) because there is form-based variability at input (in the form of talker variability) and the listeners' task is to learn



form-based information (e.g., to learn that the new word form *gato* maps onto the existing semantic representation of cat).

Applying the TOPRA model to this study on referent variability, Sommers and Barcroft (2013) suggested that varying the referents of to-be-acquired L2 vocabulary items would promote non-form-based processing (e.g., additional visual processing and additional semantic processing). Consequently, in contrast to the LOP predictions of improved vocabulary learning for the condition with referent variability, the TOPRA model predicts either no benefit or poorer performance in the variable condition. Consistent with this hypothesis, Barcroft and Sommers (2013) reported that vocabulary learning was least accurate and slowest in the condition with high variability (six referents for each Spanish word) and best in the no variability condition (same picture at each of six exposures). This study supports the TOPRA model because the nature of the input variability differed from the nature of the to-be-acquired material and resulted in worse recall. Whereas the nature of the task was to acquire novel Spanish word forms, the variability was non-form-based. By requiring participants to visually and semantically process variable input in the semantic meaning domain (i.e. cat), fewer resources were available to process and encode the novel Spanish word form (i.e. *gato*).

Although not designed specifically to test the TOPRA model, an earlier study by Dempster (1987) examined the effects of context variability on learning new L1 vocabulary. Dempster (1987) had participants learn 38 novel L1 vocabulary words in 3 different conditions. In one condition, only the word and its definition were given (LOGGIA—balcony). In the second, participants saw not only the definition as in the first condition, but also saw a sentence using the word (LOGGIA—balcony; (1) Juliet stood at the *loggia* while Romeo declared his love.). The third condition was identical to the second except that in addition to the simple

definition, they saw 3 different sentences with the word (LOGGIA—balcony; (1) Juliet stood at the *loggia* while Romeo declared his love. (2) The upper *loggia* at the opera house was filled to capacity. (3) Each apartment had its *loggia* overlooking the courtyard.). After the learning phase, participants were given a booklet and asked to write the appropriate definition next to the list of supplied words. Across five experiments, definition recall did not significantly differ between any of the conditions. On the surface, these findings seem inconsistent with the TOPRA model. Context variability focuses attention on semantic information and the nature of the to-be-acquired information was also semantic (definitions). According to the TOPRA model, therefore, context variability should have improved definition learning relative to the simple definition condition.

### **The Present Studies**

One explanation for the failure to find benefits of context variability on learning novel definitions (Dempster, 1987) is that the manipulation was not sufficiently strong in terms of semantic processing to demonstrate improved learning of semantic information. In the present experiments, I used a more direct semantic variability manipulation while having participants learn 24 novel English vocabulary words and their meanings. Each word appeared with its definition six times, and the experimental manipulation was whether the definition itself was variable or constant. In the ‘constant’ condition participants saw twelve of the words with the same verbatim definition at each of the six exposures (e.g., Cavil – to pointlessly criticize, Cavil – to pointlessly criticize, ... ). In the ‘variable’ condition, the other twelve words were shown with a differently worded, but synonymous, definition at each of the six exposures (e.g., Cavil – to pointlessly criticize; Cavil – to raise trivial objections, Cavil – to complain about things that

are not important, Cavil – to be unnecessarily critical, Cavil – to nitpick unnecessarily, Cavil – to detect petty flaws). After the learning phase, participants took two tests. In the first, each studied word was shown one at a time, and participants were instructed to type its definition. This test was similar to the one given by Dempster (1987), and it aimed to assess semantic learning. In the second test, a newly worded definition for each of the words appeared one at a time, and participants were asked to type the word that corresponded to that definition. This test assessed memory for the novel word forms.

The TOPRA model would predict that semantic-based variability during study would result in improved performance in a semantic-based task (Barcroft, 2002). Thus, the hypothesis for the first test (provide the definition given the word) is that definition recall accuracy will be higher for words studied in the variable condition compared to the constant condition. On the other hand, the TOPRA model would predict that increased processing of variable semantic input will take away resources from the processing of the word form, leading to impaired word form memory at test (Barcroft, 2002). Thus, the prediction for the second test in which participants need to provide the new word form is that there will either be no benefit of variability or possibly poorer performance in the variable condition.

## **Experiment 1**

### **Methods**

**Participants.** Twenty-six healthy, native English speaking young adults (14 females) aged 18-22 years old ( $M = 19.8$ ,  $SD = 1.3$ ) participated in Experiment 1. All were recruited from an undergraduate psychology research pool at Washington University in St. Louis and received either course credit or \$10 for their participation.

**Experimental Words.** The words used were 24 low-frequency English words. All were between 3 and 12 letters in length and were either nouns, verbs, or adjectives. Seven synonymous, but differently worded, definitions were created for each word using dictionaries and thesauruses. One of the definitions was set aside to be used during the test phase, and the other six definitions were randomly ordered and counterbalanced for use in the training phase. All definitions were between 1 and 11 words in length. The stimuli were divided into two equal groups that were matched for both word and definition length. Group A had an average of 7 (SD = 2.4) letters in each word and 3.25 (SD = 1.1) words in each definition, and Group B had an average of 6.83 (SD = 1.9) letters in each word and 3.11 (SD = 1.4) words in each definition. The words and their definitions can be found in the Appendix.

**Procedure.** Participants were tested individually in a quiet room. There were four phases to the study: a learning phase, a Word-to-Definition test, a Definition-to-Word test, and a posttest questionnaire.

At the beginning of the learning phase, participants were told that they would see obscure English words and their definitions on the computer screen in front of them. They were warned that word-definition pairs would appear multiple times and even though some definitions may be worded differently, the meaning of the word would stay the same. They were instructed to learn the words and their meaning to the best of their abilities, as they would be tested on them later. Each trial lasted a total of 6.5 s. Participants saw each target word on the screen for 500 ms, after which its definition appeared underneath and both were shown together for 6 s. An intertrial interval of 1 s occurred between trials. In this within subject design, each participant saw half of the words in the constant condition and half of the words in the variable condition. In the constant condition the word was presented with the same definition at each of the six exposures.

In the variable condition, the word was shown with a differently worded, but synonymous, definition at each of the six exposures. The particular definition that was used in the constant condition was counterbalanced so that each definition was used as the sole definition of that word for an equal number of the participants. In the variable condition, the participant viewed all six variants of the word. The presentation of the stimuli was blocked by condition. The order of the presentation of words in Group A was randomized once and this same randomization was used for all participants. The same was done for the Group B word list. The condition and word list that appeared first was counterbalanced across participants. Participants first saw all twelve words and their definitions in one of the two conditions, which was then repeated five more times, before moving on to the other condition.

After the learning phase, participants were immediately administered the Word-to-Definition test. Participants were shown each of the 24 words, one-at-a-time in a randomized order, and were told to type the word's definition using the keyboard. Those participants unable to recall a particular definition were allowed to leave the answer blank and move on to the next word. There was no time limit and no penalty for wrong answers. Participants were given the Word-to-Definition recall test first to avoid additional exposure to the definitions (recall cues in the second test were definitions of the words).

The third phase of the experiment was Definition-to-Word recall test in which participants were given the novel 7<sup>th</sup> definition variant to each of the 24 words and were asked to type the studied word it defines. A novel definition was used to ensure that the recall cue (in this case the definition) was equally novel in both the constant and variable presentation conditions. Similar to the Word-to-Definition test, the order of the presentation of the definitions was

randomized for each participant, and participants were told that they could skip any definitions for which they could not remember the word.

The final phase was a posttest questionnaire. This was done with pen and paper. There were two demographic questions: age and gender. Participants were also asked to list from memory all of the words, if any, of which they knew the definition before entering the study.

**Scoring.** Any words that participants reported knowing before entering the experiment were removed from analysis. Total proportion correct was then calculated by dividing their score by the total possible raw score of remaining items. If a participant knew four words or more in either condition, their data were excluded from analysis. None of the participants in Experiment 1 indicated knowing more than 2 words in either condition.

In the Word-to-Definition test, a score of 1 was given to completely correct productions, and a score of .5 was given to partially correct definitions. For the Definition-to-Word test, a score of 1 was given for correct answers, and a score of .5 was given if there was a single error. Single errors were defined as the deletion of a single letter, the addition of a single letter, or the location swapping of two letters. All other responses in both tests received a score of 0.

In addition to accuracy scores, the total percent of incorrect pairing responses was also recorded. Incorrect pairings were considered all those responses that would have been given a score of 1 or .5 if they had been recalled with the correct cue, but in these cases they were intrusions or incorrect associations. An example would be writing the correct definition of *palter* ('to tell lies'), but writing it in response to an incorrect cue, such as *skirr*.

A subset of 50% of the data files were independently scored by two raters who were blind to the condition in which words appeared. Interrater reliability exceeded .95 in all test types and conditions. One of the raters was then chosen to independently score the remaining data files.

**Analysis.** Accuracy scores for participants performing at floor were excluded from analysis. Floor performance was defined as receiving a score of 0 out of 24 in either or both of the test phases. Data from two participants were excluded, leaving the data from 24 participants to be discussed in the following section.

## Results & Discussion

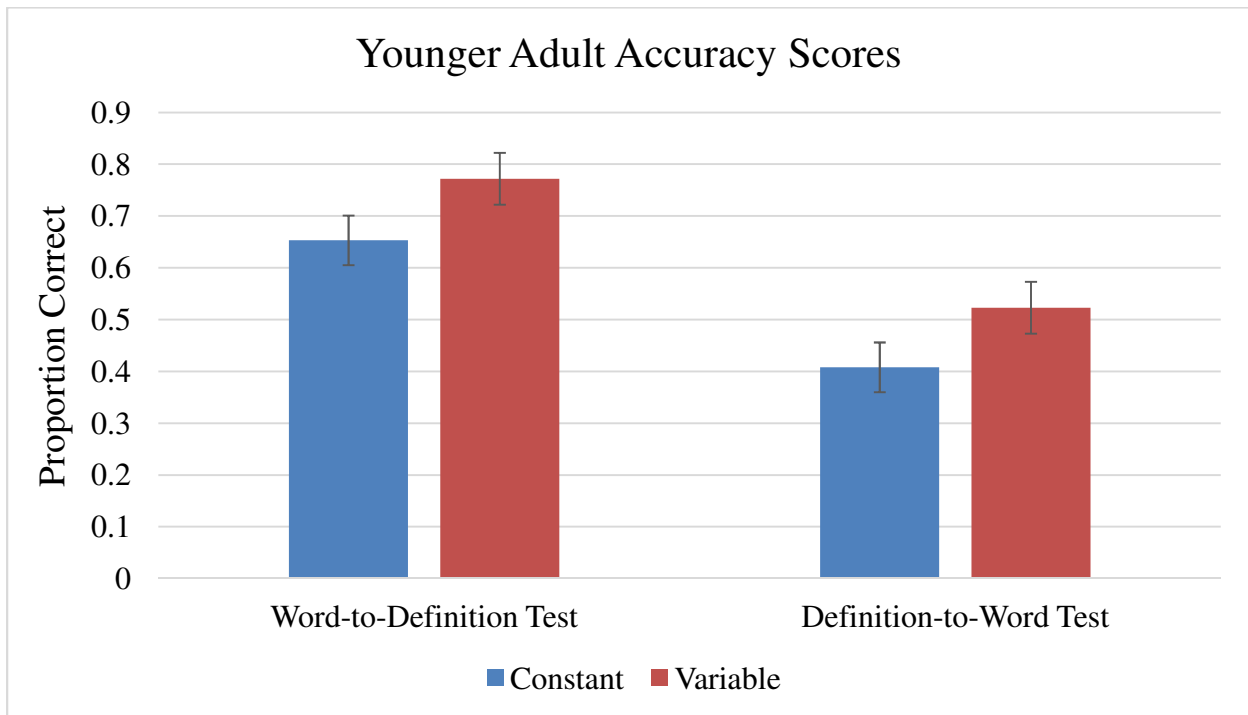


Figure 3: Effect of semantic input condition on younger adult accuracy scores for two test types.

Figure 3 shows the mean accuracy scores based on condition and test type. Accuracy scores were analyzed by a 2 (Condition: constant, variable) X 2 (Test Type: Word-to-Definition, Definition-to-Word) repeated measures ANOVA. Overall accuracy scores were higher for those vocabulary items studied in the variable condition than the constant condition,  $F(1, 23) = 26.10$ ,  $p < .001$ ,  $\eta^2 = .53$ . Overall higher accuracy scores were also found in the Word-to-Definition test than the Definition-to-Word test,  $F(1, 23) = 60.18$ ,  $p < .001$ ,  $\eta^2 = .72$ . There was no significant

interaction between test type and condition ( $F(1, 23) = .006, p = .937$ ), suggesting that the benefit of variability was similar across the two test types.

The main effect of condition on vocabulary acquisition suggests that variable semantic input can improve L1 vocabulary learning relative to conditions with constant input. In addition, the absence of an interaction between condition and test type suggests that variable input improves later cued recall memory for both measures—word-to-meaning, as well as meaning-to-word.

The finding of higher accuracy for words from the variable condition in the Word-to-Definition test supports the hypotheses derived from the TOPRA model that relevant semantic-based variability during learning can result in improved memory for semantic items at test. For the Definition-to-Word test in which participants saw a newly worded definition and had to supply the studied word it defines, higher accuracy scores for words from the variable condition also suggest that variable semantic input can improve vocabulary acquisition, even when what is being recalled is the word form. This finding is inconsistent with the TOPRA model which hypothesized that the variable definitions would have engaged semantically-based processing, leaving fewer resources for remembering word form information compared to the no variability condition. Two possible mechanisms that may account for the positive effect of variable semantic input on later recall of the word form will be considered in the General Discussion.

The other main effect found—that accuracy was higher for the Word-to-Definition test than the Definition-to-Word test—replicates a pattern seen in previous studies in which participants are less accurate in recalling a novel word form than other aspects of the stimuli (e.g., translation and definition; Barcroft & Sommers, 2005; Sommers & Barcroft, 2013).



Lastly, on average 6.7% of the responses that younger adults gave were considered incorrect pairings in which a correct or partially correct response was recalled to an incorrect cue. This will be compared to the percentage of such responses that older adults gave in the results section of Experiment 2.

### Exact Replication

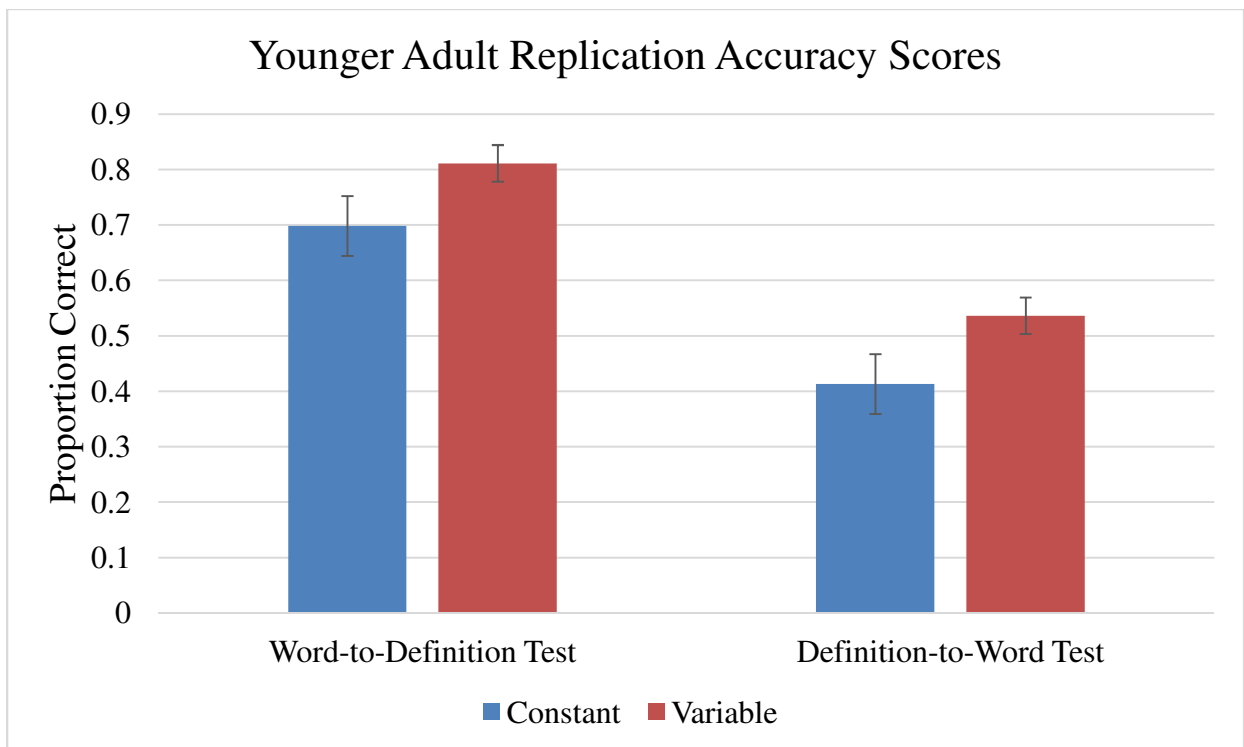


Figure 4: Effect of semantic input condition on younger adult replication accuracy scores for two test types.

Experiment 1 was the first study to find a benefit of semantic variability in vocabulary acquisition. An exact replication of Experiment 1 was performed to investigate the reliability of the findings. The same pattern of results was found, and Figure 4 shows the mean accuracy scores based on condition and test type. Words studied in the variable condition produced higher test accuracy than those studied in the constant condition,  $F(1, 23) = 11.41, p = .003, \eta^2 = .33$ .

Accuracy scores were higher for the Word-to-Definition test than the Definition-to-Word test,  $F(1, 23) = 68.13, p < .001, \eta^2 = .75$ , and no significant interaction between test type and condition was found,  $F(1, 23) = .06, p = .810, \eta^2 = .003$ .

## Experiment 2

Experiment 2 was identical to the first experiment, except that all participants were individuals older than age 65. Older adults have been shown to experience an associative binding deficit in which they have a particularly difficult time remembering associations between or within items (Naveh-Benjamin, 2000). In one experiment, for example, Naveh-Benjamin (2000) presented younger and older adults with word-nonword pairs. After the learning phase, participants were given a word recognition test in which 20 words were shown, half of which were targets and half of which were previously unseen distractors, and participants were to circle those items they had seen during the study phase. They were also given an associative recognition test in which all items had been seen during the study phase, but half of the pairs were intact pairs (i.e. were pairs presented in the study phase) and half were rearranged pairs containing pairs of items that were both presented during study but were paired with other stimuli. At test, younger adults performed significantly better than older adults on the associative recognition tasks, but no age differences were found in the word recognition task. Naveh-Benjamin (2000) posited that this pattern of findings—intact single-item memory but impaired memory for pairs—suggests an age-related deficit in the ability to bind two or more aspects of stimuli.

Within the TOPRA model, variable semantic input is hypothesized to create a broader representation of each word's meaning with multiple memory traces to distinct definition

variants. If older adults experience an associative binding deficit, one might expect that by having multiple definitions that are only weakly associated with a single word, any benefits of input variability would be attenuated (or even lost entirely). Thus, older adults were expected to demonstrate either less or no benefit of semantic variability on L1 vocabulary learning relative to younger adults.

In addition, older adults' hypothesized associative deficit would also be expected to influence the word and definition pairs themselves, resulting in more overall incorrect pairings for older adults, regardless of condition or test type. Thus a greater percentage of older adult responses are expected to be incorrect pairings in which a correct item is recalled with an incorrect cue. If this is the case, then a main effect of age is also predicted, with incorrect pairings as one contributing factor to worse accuracy scores for older adults compared to younger adults.

## **Method**

Twenty-five healthy, native English speaking older adults (23 females) aged 66-84 years old ( $M = 73.8$ ,  $SD = 4.9$ ) participated in Experiment 2. All were recruited from the Aging and Development Subject Pool at Washington University and were compensated \$10 for participation in the study. Procedure, scoring, and analysis were identical to that of Experiment 1, with the addition of a Mini-Mental States Examination (score range = 28-30). One participant was excluded from analysis for knowing four of the words in one of the two experimental conditions before entering the experiment.

## Results & Discussion

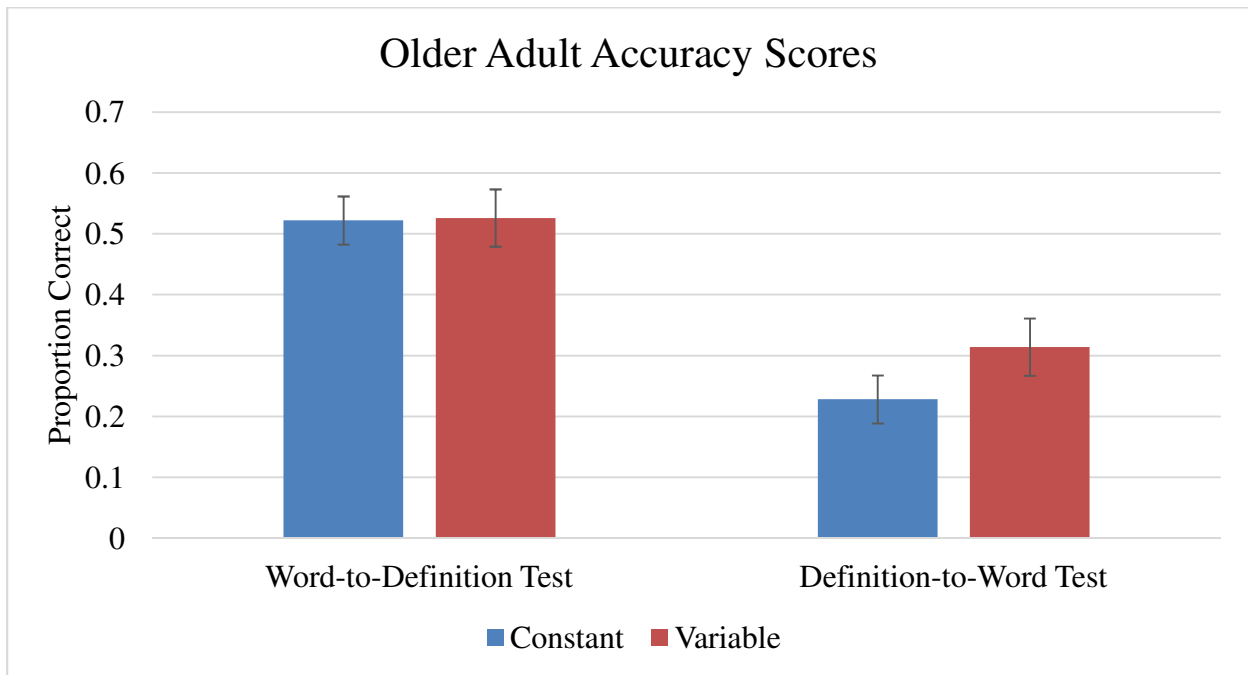


Figure 5: Effect of semantic input condition on older adult accuracy scores for two test types.

Figure 5 shows the mean accuracy scores of the older adults based on condition and test type. An omnibus ANOVA was conducted with condition (constant, variable) and test type (Word-to-Definition, Definition-to-Word) as repeated measures. The overall accuracy scores did not significantly differ between the constant and variable conditions,  $F(1, 23) = 2.91, p = .102, \eta^2 = .11$ ). Similar to younger adults, older adults accuracy was higher in the Word-to-Definition test than the Definition-to-Word test  $F(1, 23) = 66.54, p < .001, \eta^2 = .74$ . In addition, there was no significant interaction of condition by test type  $F(1, 23) = 2.94, p = .100, \eta^2 = .11$ ).

Next, in order to understand how the older adult sample from Experiment 2 may differ from the younger adults sample from Experiment 1, a cross-experiment ANOVA was conducted with age (younger, older) as an independent measures factor and condition (constant, variable) and test type (Word-to-Definition, Definition-to-Word) as repeated measures. There was a main

effect of age,  $F(1, 46) = 11.47$ ,  $p = .001$ ,  $\eta^2 = .20$ ), with younger adults scoring higher at test than older adults. In addition, there was a significant interaction of age and condition,  $F(1, 46) = 4.36$ ,  $p = .042$ ,  $\eta^2 = .09$ , with younger adults receiving more of a benefit from the variable condition compared to the older adults.

The absence of a difference between the variable and constant conditions for the older adults suggests that they are not able to construct or use the broader semantic representation afforded by variable input to increase access to memory as seen in younger adults. Within the TOPRA model, constant semantic input will produce a strong, but relatively narrow representation in memory, resulting from repeated exposures to the same word-definition pairs. It is possible that these repeated opportunities for binding words with their definitions might minimize any age-related deficits in associative binding for the constant input condition. On the other hand, variable semantic input in the model produces a broad representation in memory made up of multiple weaker representations. If older adults have a binding deficit, the weaker representations may be at a greater disadvantage, which could mitigate the memory benefits that a broader semantic representation was shown to have on younger adults.

In addition to an associative deficit affecting the link between variable semantic input and the semantic representations of the items in memory, if older adults experience an associative deficit, they would also be expected to have difficulty binding the word to its correct definition. Thus, general evidence for an age-related associative binding deficit was also investigated by looking at the percentage of incorrect word-definition pairings of older adults compared to younger adults. Consistent with the associative deficit hypothesis, on average 13.8% of all older adults responses across the two tests were considered incorrect pairings, which was significantly

greater than the 6.7% of such responses produced by younger adults in Experiment 1 ( $t(46) = 3.23, p = .002, d = .93$ ).

## **General Discussion**

In summary, variable semantic input improved younger adults' accuracy on later definition recall. In addition, younger adults correctly recalled more word forms when given a novel definition variant for words that had been studied in the variable condition. On the other hand, older adults' overall accuracy did not significantly differ between variable and constant semantic input conditions. In the following sections, I first consider implications for the expected benefit of semantic variability on the Word-to-Definition test before discussing the surprising finding of a benefit of semantic variability for younger adults in the Definition-to-Word test. I next consider the absence of such benefits for older adults before discussing the limitations of the studies and directions for future research. Finally, I discuss possible pedagogical implications of the findings and make concluding remarks.

### **Younger Adult Data**

The findings from the present experiments improve our understanding of the effect of variable input on vocabulary learning in several ways. Experiment 1 with younger adults was the first experiment to show an improvement in recall of semantic information as a consequence of semantically based input variability. This finding differs from that of Dempster (1987) who did not find a semantic recall benefit for words studied in multiple, compared with constant, contexts. One possible account for these differences is the types of variability used. Whereas the Dempster study (1987) included variable semantic contexts in which a word would appear, the current study varied the wording of the definitions themselves. Thus, the different definition

recall findings between the two studies may be due to methodological differences, with the definition variability manipulation being a more powerful one.

The younger adult definition recall results are a critical complement to those of Barcroft and Sommers (2005) in evaluating the TOPRA model. Recall that Barcroft and Sommers (2005) reported that form-based input variability significantly improved acquisition of new word forms. The current studies utilized a similar method, only it was semantic input that was varied during learning and that produced benefits in a semantically based task (recall of definitions). The TOPRA model posits that it is the extent of match between the nature of the variable input (form versus meaning) and the task that serves to establish both the direction and magnitude of effects for input variability (Barcroft, 2002). Thus, within the context of the TOPRA model, the benefits of definition variability in the word-to-definition test for young adults is a result of a broader representation in which multiple definitions, rather than a single definition, are linked to the new word form.

In addition to testing cued recall of definitions (where the new word form is the cue), the current studies also gave participants a previously unseen variant of each word's definition and asked them to give the studied word it defines. The rationale behind using both the Word-to-Definition and Definition-to-Word tests is that the latter provides an additional test of the TOPRA. Within the TOPRA model, semantically based variability should not benefit a form-based test and therefore young adults were not expected to benefit from the variable condition. In contrast to these predictions, younger adults performed more accurately for those words studied in the variable than in the constant input condition.

One possible reason for the beneficial effects of semantic variability in the Definition-to-Word test comes from work on perceived fluency. Callender and McDaniel (2009) had

participants read an article either once or twice and found similar performance on measures of comprehension for the two groups. They hypothesized that a higher perceived fluency of the material during the second reading did not result in increased processing over than of the initial reading. Similarly, it is possible that those word-definition pairs that were presented in the constant condition are perceived more fluently with each additional exposure, resulting in less processing of the pair (e.g., Cavil - to raise trivial objections, Cavil - to raise trivial objections, Cavil - to raise trivial objections, ...). On the other hand, every word and definition seen in the variable condition is a novel pairing. At later exposures, although the word has been previously seen, this is the first time the participant has seen this definition variant. It is possible that this causes processing of the word form above and beyond that of the constant condition as the participants maps this word form to its novel definition variant (e.g., Cavil - to raise trivial objections, Cavil - to detect petty flaws, Cavil - to nitpick unnecessarily, ...).

A second possible reason for the unexpected benefit of variable presentations in the Definition-to-Word test is directly related to the size of the semantic representation discussed previously. In the Definition-to-Word test, participants see a novel definition, which then activates the presented definition(s) seen during the learning phase, which then activates the word form. Given that those words studied in the variable condition are hypothesized to have a broader semantic representation, it may be easier to correctly recognize the novel definition as meaning something similar or the same to the definition(s) seen during the learning phase. For example, the variable definitions for *cavil* were as follows: to raise trivial objections, to pointlessly criticize, to complain about things that are not important, to be unnecessarily critical, to nitpick unnecessarily, and to detect petty flaws. One can imagine that the broader semantic representation created by those definitions may facilitate correct identification of the novel



definition (to find fault unnecessarily) as meaning something similar to the previously seen definitions of *cavil*. In addition, in the variable condition, the novel definition will activate all six of the presented definitions, providing six alternatives to access the word form. In contrast, if someone saw the same variant at each exposure during study, it may be harder to correctly identify the new variant as being an appropriate definition for *cavil*. Additionally, even if the test definition is correctly linked to the single studied definition, if the link between this studied definition and the word form fails, there is no alternative with which to access the word form.

### **Older Adult Data**

Experiment 2 was conducted with older adults in order to further elucidate mechanisms underlying the beneficial effects of semantic variability on learning novel L1 vocabulary. In contrast to the findings with younger adults, the findings from Experiment 2 revealed that variable versus constant semantic input did not significantly change older adults' recall accuracy for either test. Few studies have examined age differences in the effects of input variability. Sommers (1997) found that older adults exhibited greater reductions than younger listeners in moving from single- to multiple-talker word lists. However, no studies, to my knowledge, have examined the effect of multiple talkers on older adults' later memory for single items or novel vocabulary.

Within the associative deficit framework, older adults have difficulty making associations among different components of presented stimuli. Within the TOPRA model, such associative deficits could reduce or eliminate any beneficial effects of variability because it is the binding of different components that is proposed to produce the benefits of variable input. In the case of talker variability (Barcroft & Sommers, 2005) the binding is between voice information and

word form information. In the current study, the binding is between individual definitions and word forms. In either case, if older adults are less able than young participants to bind those pieces of information, then they may not achieve as broader representation or the link between definitions and word forms may be too weak to produce benefits. A critical test of this account would examine whether older adults exhibit benefits of talker variability in learning L2 vocabulary studies. Within the TOPRA model, they would be expected to show less benefit from such variability than did young adults (Barcroft & Sommers, 2005).

### **Limitations & Future Directions**

From the perspective of the TOPRA model, perhaps the most significant limitation and clearest need for future research is to derive an objective and independent measure of the semantic- and form-based demands in any task. Without an index of the extent to which a given task engages semantic- versus form-based processing, the TOPRA model can quickly become tautological. It is easy, for example to suggest that the reason young adults benefited from semantic variability in the Word-to-Definition test is because the learning task involved semantic variability. However, without an index of the semantic- versus form-based demands on a given task, it is not possible to manipulate these various demands systematically to provide stronger test of the TOPRA model.

A second direction for further research is to consider conditions in which constant input might produce beneficial effects. For example, in the Definition-to-Word test, if participants were presented with the definition they saw during studying, the TOPRA model would predict better performance in the constant than in the variable condition because this condition results in a single, but less distributed representation. Thus, if participants received the same definition as a

cue in the Definition-to-Word test, then the strength of this definition might produce better performance for the constant condition.

### **Pedagogical Implications**

The current findings have a high potential to be practically applied to L1 vocabulary learning. At the moment, many young adults may be studying for the GRE or for classroom vocabulary tests by making flashcards of the word and a single variant of its definition.

Experiment 1 shows that variable semantic input aids younger adults in both word-to-definition recall, as well as novel definition-to-word recall. Thus, GRE study books and instructors can improve L1 vocabulary acquisition by creating materials that incorporate a variety of differently worded definitions to each word form.

### **Conclusion**

Experiment 1 expanded the literature on the effect of variable input in vocabulary acquisition by finding that variable semantic input can improve both definition and word form recall in younger adults. On the other hand, not only was older adults' accuracy lower than younger adults, but also they did not receive a benefit from variable input.

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## Appendix

### GROUP A WORDS

#### Cadger

- Variant 1.) one who asks for items through charity
- Variant 2.) moocher
- Variant 3.) bum
- Variant 4.) panhandler
- Variant 5.) one who gets items through begging
- Variant 6.) freeloader
- Test Variant) beggar

#### Pelf

- Variant 1.) unlawfully attained loot
- Variant 2.) money, especially of a questionable source.
- Variant 3.) monetary gains made dishonorably.
- Variant 4.) ill-gotten riches
- Variant 5.) wealth, especially when dishonestly acquired.
- Variant 6.) riches attained in a disreputable manner
- Test Variant) fraudulently acquired wealth

#### Larrup

- Variant 1.) to physically attack
- Variant 2.) to beat
- Variant 3.) to lash
- Variant 4.) to flog
- Variant 5.) to strike
- Variant 6.) to assault
- Test Variant) to hit

#### Quisling

- Variant 1.) one who collaborates with the enemy
- Variant 2.) two timer
- Variant 3.) betrayer
- Variant 4.) back stabber
- Variant 5.) double crosser
- Variant 6.) turncoat
- Test Variant) traitor

#### Exiguous

- Variant 1.) sparse
- Variant 2.) very small in quantity
- Variant 3.) deficient in amount
- Variant 4.) meager
- Variant 5.) scarce

Variant 6.) scrumpy  
Test Variant) extremely scanty

### Pother

Variant 1.) a fuss  
Variant 2.) a stir  
Variant 3.) a confusion  
Variant 4.) a disordered occurrence  
Variant 5.) a state of nervous activity  
Variant 6.) a disturbance  
Test Variant) a commotion

### Adumbrate

Variant 1.) to omit details and state strictly the main facts  
Variant 2.) to give a sparse description  
Variant 3.) to tell only main points  
Variant 4.) to give a brief description  
Variant 5.) to put forth only core information  
Variant 6.) to describe roughly  
Test Variant) to give a sketchy outline

### Meretricious

Variant 1.) decorated to the point of tackiness  
Variant 2.) gaudy  
Variant 3.) done in an overly showy manner  
Variant 4.) loud and flashy in appearance  
Variant 5.) overdone ornateness  
Variant 6.) excessively ornamental  
Test Variant) tastelessly showy

### Fustian

Variant 1.) bombastic dialogue  
Variant 2.) irritatingly self-important communication  
Variant 3.) embellished discourse in an attempt to sound important  
Variant 4.) pompous language  
Variant 5.) inflated speaking  
Variant 6.) high-flown speech  
Test Variant) pretentious speech

### Votary

Variant 1.) a zealous worshipper  
Variant 2.) a devoted believer  
Variant 3.) A person who is fervently devoted  
Variant 4.) an enthusiastic disciple  
Variant 5.) a staunch supporter

Variant 6.) a dedicated devotee  
Test Variant) a faithful follower

### Ort

Variant 1.) a tidbit of discarded food  
Variant 2.) a crumb  
Variant 3.) a morsel left after a meal  
Variant 4.) a leaving of food  
Variant 5.) a bit of food  
Variant 6.) a leftover fragment of food  
Test Variant) a food scrap

### Suppliant

Variant 1.) to ask earnestly  
Variant 2.) to beseech  
Variant 3.) to humbly beg  
Variant 4.) to implore  
Variant 5.) to respectfully request  
Variant 6.) to petition  
Test Variant) to sincerely solicit

## **GROUP B WORDS**

### Palter

Variant 1.) to talk in a deceptive manner  
Variant 2.) to use trickery in speech  
Variant 3.) to speak insincerely  
Variant 4.) to give false information  
Variant 5.) to speak with the intent to deceive  
Variant 6.) to tell lies  
Test Variant) to talk misleadingly

### Raiment

Variant 1.) attire  
Variant 2.) garb  
Variant 3.) outfit  
Variant 4.) material that clothes the body  
Variant 5.) garments  
Variant 6.) apparel  
Test Variant) clothing

### Skirr

Variant 1.) to go speedily  
Variant 2.) to travel with great speed  
Variant 3.) to go rapidly  
Variant 4.) to move in a fast way



Variant 5.) to travel in a hurried manner  
Variant 6.) to proceed swiftly  
Test Variant) to move quickly

### Cavil

Variant 1.) to raise trivial objections  
Variant 2.) to pointlessly criticize  
Variant 3.) to complain about things that are not important  
Variant 4.) to be unnecessarily critical  
Variant 5.) to nitpick unnecessarily  
Variant 6.) to detect petty flaws  
Test Variant) to find fault unnecessarily

### Otiose

Variant 1.) idle  
Variant 2.) slothful  
Variant 3.) listless  
Variant 4.) inactive  
Variant 5.) disinclined to work  
Variant 6.) indolent  
Test Variant) lazy

### Minatory

Variant 1.) expressing a threat  
Variant 2.) menacing  
Variant 3.) dangerous  
Variant 4.) frightening  
Variant 5.) sinister  
Variant 6.) intimidating  
Test Variant) of a threatening nature

### Aplomb

Variant 1.) composure  
Variant 2.) self-assurance  
Variant 3.) assurance of manner  
Variant 4.) self-possession  
Variant 5.) a firm belief in one's own powers  
Variant 6.) self-confidence  
Test Variant) poise

### Cunctation

Variant 1.) the act of putting off an action to a later time  
Variant 2.) postponement  
Variant 3.) delay  
Variant 4.) stalling  
Variant 5.) inactivity resulting in things getting put off until later

Variant 6.) tardiness  
Test Variant) procrastination

### Orison

Variant 1.) an appeal to a deity  
Variant 2.) a petition to a deity  
Variant 3.) a communication with God  
Variant 4.) a plea to a deity  
Variant 5.) the act of praying to God  
Variant 6.) an entreaty to God  
Test Variant) a prayer

### Perspicuous

Variant 1.) presented in a manner that is easily grasped  
Variant 2.) intelligible  
Variant 3.) straightforward  
Variant 4.) readily apparent  
Variant 5.) comprehensible  
Variant 6.) understandable  
Test Variant) easy to understand

### Welter

Variant 1.) a jumble  
Variant 2.) a hodgepodge  
Variant 3.) a messy collection of different things  
Variant 4.) a large number of unorganized items  
Variant 5.) a disorderly mixture of objects  
Variant 6.) a confused mass of items  
Variant Test) a heap of objects

### Jejune

Variant 1.) lacking excitement  
Variant 2.) unexciting  
Variant 3.) devoid of interest  
Variant 4.) not interesting  
Variant 5.) uninteresting  
Variant 6.) dull  
Test Variant) boring