ON THE PROCESSING OF NOVEL ROOT+SUFFIX COMBINATIONS*

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1. Introduction

New words are constantly entering language. When a new word is formed by the combination of existing morphemes, it is expected to follow language-specific structural patterns called *selectional restrictions*. If a new word follows these restrictions, then it can be considered to be morphologically legal, and if it violates these restrictions, then it can be said to be morphologically illegal. For example, in English, the derivational suffix *-ify* combines with nouns to form verbs, as in *classify* (*class+ify*). While not attested in English, a word like *bird+ify* should be morphologically possible, because it does not violate the selectional restrictions governing the use of the suffix *–ify*. However, the form *bird+ment* violates the selectional restrictions of the suffix *–ment*, which combines with verbs to form nouns with a general meaning of 'state' or 'action,' and does not typically combine with nouns. If selectional restrictions play a role in word formation, one would expect novel words following selectional restrictions to be more acceptable to native speakers than morphological illegal pseudowords.

There is evidence that derivational suffixes have mental representations beyond their occurrences in derived words. Reid and Marslen-Wilson (2003) reported a suffix-suffix *interference effect* when participants were presented with different suffixes attached to the same stem in a prime-target pair. This is taken as evidence that suffixes have independent representations in the mental lexicon. Hay (2001) demonstrated that the relative frequencies of the base, affix, and derived form of a word can influence whether the complex derived form will be decomposed. This requires that the base and suffix that make up a derived form interact, which in turn suggests that suffixes themselves have their own representations in the mental lexicon and accompanying statistical properties that are worthy of consideration. The interactions of roots and affixes have not been fully explored.

In the following series of experiments, selectional restrictions and family size were both considered as possible influences on the processing of novel root+suffix combinations in English.

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1.1 Selectional Restrictions

Selectional restrictions specify the ways in which we expect morphemes to combine, and although the shape of possible words in English may be largely governed by the selectional restrictions of affixes (Plag, 2003: 44-68), there has been relatively little psycholinguistic research into the processing of morphological legal and illegal complex words. Libben (1993) used nonsense roots combined with real English affixes (prefix+nonsense root+suffix) in a study of morphological processing examining the role of selectional restrictions. The lexical category of the nonsense root was supplied by the suffixes that combined with it, and when there was a mismatch between the lexical category supplied by the prefix and that supplied by the suffix, the target could be said to be violating selectional restrictions. For example, in the nonword *rebirmity* (*re+birm+ity*), the prefix *re-* tells the reader that *birm* is a verb, because verbs combine with this prefix. The suffix *–ity* typically combines with adjectives. Since one suffix must be applied before the other, either *re-* is combining with the noun *birmity*, violating restrictions governing *re-*, or *–ity* is combing with the verb *rebirm*, violating restrictions governing *-ity*. When presented with target items that violated selectional restrictions of English (e.g., *re+birm+ity*), participants responded more slowly than to legal nonwords of an equivalent length. Libben (1994) reported similar findings in a case study of an aphasic patient. The patient made more errors on a naming task when target items were morphologically illegal than in morphologically legal targets of the same length. Results from these studies suggest that individuals are sensitive to the internal morphological structure of words. Both of these studies used nonword roots to overcome concerns surrounding the effects of lexical properties of the root (e.g., frequency) and to bypass difficulties related to potential differences in semantic interpretability of base and affix combinations. Real words, because they are real, are more natural to speakers, and if combinations of real morphemes can be successfully used in testing, the results can be generalized to a greater extent that results from nonword data.

In a study by Burani et al. (1999), real Italian roots and suffixes were used, with combinations both abiding by and violating selectional restrictions of Italian. This study revealed no differences in reaction times or accuracy based on the violation of selectional restrictions, although reaction time and accuracy were influenced by the semantic interpretability of the presented targets. When participants found the novel combinations of words and suffixes to be easier to interpret, they had greater difficulty rejecting these targets as nonwords in lexical decision. It follows that if selectional restrictions affect interpretability, then they should also affect lexical processing.

1.2 Morphological Family Size and Frequency

Research suggests that complex words that occur frequently are processed as single units (e.g., see Meunier & Segui, 1999). Some models hold that the mental lexicon contains each word a speaker knows listed individually, while others hold that each morpheme has an individual listing and that complex words are obligatorily parsed into their components. Between the two extremes are such models as the dual-route race models, where the way a word is

processed is dependent on the properties of the word as a whole and its constituent morphemes (Baayen & Screuder, 1999; Frauenfelder & Schreuder, 1992). Models allowing for the decomposition of complex words can better describe the processing of novel forms. Novel root+suffix pairs cannot be interpreted without decomposition of the whole into its constituents. In the present study, pseudowords composed of real English roots and real suffixes in novel combinations are presented to speakers. This assumes that speakers must decompose novel words in order to process them.

Frequency effects are well attested in studies of linguistics, but it is only relatively recently that family size has been revealed as a statistical factor. Family size is a count of the number of words that are morphologically related to a target. For example, *colourful* is morphologically related to *colour,* and part of its morphological family. In a lexical decision experiment examining the processing of monomorphemic words in Dutch, Schreuder and Baayen (1997) found that nouns with more morphological relatives were processed more quickly than nouns with fewer lexical relatives. This effect was not observed for the cumulative frequency of related forms. Borrowing terminology from Schreuder and Baayen (1997), Morphological Family refers to all the words that are formed with the base word via derivation or compounding, but not inflection, and the Morphological Family Size is a count of all these words. They propose that the family size effect is a semantic effect related to the activation of the morphological relatives of a target by exposure to the target, which in turn leads to the activation of the semantic representations of their morphological family members. Family size effects have also been found for verbs (De Jong, Schreuder & Baayen, 2000) and for complex words, where it the family size of a base of a complex word was found to affect reaction times (Bertram, Baayen, & Schreuder, 2000). Supporting the hypothesis that family size effects are semantically based, it has recently been shown to be sensitive to context (de Jong, Schreuder, & Baayen, 2003).

Previous studies of suffix processing have focused on suffix frequency. Burani and Thornton (2003) examined the roles of relative frequencies of base and suffix in the processing of derived Italian words. One experiment found that the relative frequency of suffixes affected reaction times and error rates, with participants responding with longer reaction time latencies and more errors in lexical decision to highly frequent suffixes attached to nonword bases. Two further experiments used real roots and real suffixes, where the roots were of high and low frequency. In both these experiments, the frequency of the root appeared to determine processing speed, while the variations in suffix frequency did not appear to influence results.

In summary, evidence suggests that affixes can have independent representations in the mental lexicon and that lexical properties specific to each affix (e.g., frequency) can affect morphological processing. Evidence also suggests that speakers of a language may be sensitive to the morphological structure of words, with the most reliable results emerging from studies using nonwords combined with real affixes. Results using both real roots and real affixes have been more problematic. The lexical properties of the root appear to be more strongly predictive of processing speed and accuracy, while semantic interpretability appears to be more predictive of difficulty in lexical decision than violation of selectional restrictions.

The goal of the present study is to investigate how native speakers of English process novel legal and illegal combinations of real roots and real suffixes, while examining possible effects of suffix family size on the processing of these novel combinations.

2. The Present Study

In the present study, real roots and real suffixes of English were combined to form novel pseudowords which were then used a target stimuli in lexical decision experiments. Conceptually, these experiments aimed for a greater understanding of the factors determining the acceptability of novel words and how such novel words might be processed. The research questions asked were whether native speakers of English are sensitive to the selectional restrictions of affixes and whether suffix family size influences processing in speed or accuracy. If speakers are sensitive to selectional restrictions, then it should be easier for them to reject root+suffix combinations where selectional restrictions have been violated. Similarly, if participants are strongly influenced by suffix family size, it should be more difficult for them to reject items including suffixes of high suffix family size.

2.1 Experiment 1: Lexical Decision (Root+Suffix)

The first experiment used in this investigation was a simple lexical decision task. For this task, morphological legality was manipulated in a series of real morpheme root+suffix pairs. A root+suffix pair was considered to be morphologically legal if the lexical category of the base matched the preferred lexical category of the suffix. The combinatorial properties of the selected English suffixes were extracted from Quirk & Greenbaum (1973: 436 – 441), Carstairs-McCarthy (2002: 45-57) and by independent analysis of existing words in the CELEX database (Baayen, Piepenbrock & Gulikers, 1995). The root+suffix pairs were divided into two conditions, "Match" (followed selectional restrictions) and "NonMatch" (violated selectional restrictions). This experiment focused on four suffixes, two of high suffix family size, and two of low suffix family size. They were divided such that there was one high and one low family size suffix in both conditions. CELEX was used to determine the morphological family sizes of English suffixes. If suffix family size plays a role in the processing of derived words, then novel root+suffix combinations containing a suffix with a high family size might be expected to generate longer lexical decision latencies and more errors, as they are more likely to be incorrectly analyzed as real words. If participants are sensitive to morphological structure as defined through selectional restrictions, then more errors and longer lexical decision latencies would be expected to follow morphological legal items.

Participants A total of 48 native speakers of English were recruited from the University of Alberta undergraduate population. They were paid for their time. Three participants were removed because of very slow reaction times (more than 2 standard deviations above the mean) and high error rates (>30%).

Apparatus The experiment was carried out on an Apple Macintosh computer using a program scripted in PsyScope 1.2.5.

Materials Two-hundred and fifty-six novel pseudowords were created by combining existing words and suffixes. Sixty-four bases were selected from the CELEX lexical database (Baayen et al., 1995) based upon length, family size, and frequency. The four suffixes were selected for their combinatorial properties and family size.

All bases selected were single syllable monomorphemic roots (nouns, verbs, and adjectives) with a CVCC structure. Each base combined with each of the four selected suffixes and served as its own control. The selected nouns had an average CELEX lemma lexical frequency of 281.67 (range: 3 – 1841). Verbs had an average lemma lexical frequency of 274.75 (range: 36 – 883) and adjectives had an average lemma lexical frequency of 269.75 (range: 11 – 1205). Choosing words that occur relatively frequently in English ensured that the bases would be recognized as existing English words, and would not be treated as nonwords.

Suffixes were selected based on family size and on their selectional restrictions. Table 1 summarizes the relevant suffix properties.

Suffix	Family Size	Family Size Category	Derivation (Base→derived class)	Example
-ation	543	High	V→N	colourize+ation→ colourization
-ic	726	High	N→A	cube+ic→cubic
-ling	24	Low	N→N	duck+ling→ducklin g
-th	169	Low	A→N	warm+th→warmth

Table 1: Summary of suffix properties in Experiment 1.

Target stimuli were created by combining bases with suffixes. For example, the noun *kelp* was suffixed to become ***kelpic,*kelpling *kelpation,*** and ****kelpth.***

Procedure Participants were comfortably seated in front of an LCD iMac computer monitor. They were asked to decide whether a string of text presented on the screen (target, word, nonword) was a word in English, and to indicate their choice by pressing the appropriately labelled keys on the keyboard. Stimuli were presented on the computer screen one word at a time. Participants were asked to decide as quickly as possible while remaining accurate. When the subject responded, the screen cleared and the next trial began.

Results & Discussion Before beginning data analysis for Experiment 1, all individual items with a response time (RT) faster than 350 ms or slower than 3000 ms were removed. These items were considered to be errors. Error rates were then calculated by subject and by item. Forty-five of the target pseudowords had error rates greater than 25%. These made up a significant portion of the target items (approximately 21%). They were left in for analysis because these errors spoke directly to the questions under study. In lexical decision, participants are asked to quickly decide if a target is a word or not.

More errors should be expected when targets are more word-like. While we expect there to be genuine errors in the data, the number of errors generated suggests that there might be another reason for participant error. We can hypothesize that more errors will be generated when the target is more word-like.

For the subject analysis, a Repeated Measures ANOVA was run across the morphological fit and family size conditions. Morphological fit (violation or non-violation of selectional restrictions) was collapsed across base type, so that "good morphological fit" was an average for both the high and low suffix family size conditions. Table 2 summarizes the breakdown of stimulus categories.

		Suffix Family Size	
		High	Low
Morphological Fit	Good	N+*ic* V+*ation*	N+*ling* A+*th*
	Bad	N+*ation*	N+*th*

Table 2: Suffix Family Size and Morphological Fit

This repeated measures ANOVA (Figure 1) revealed a significant effect of Family Size $F_1(1, 44) = 10.86$, $p = .0019$ and a significant interaction effect between Family Size and Morphological Fit, $F_1(1, 44) = 36.71$, $p<.0001$. Morphological Fit alone was not found to be significant. An ANOVA run on the items supported these results.

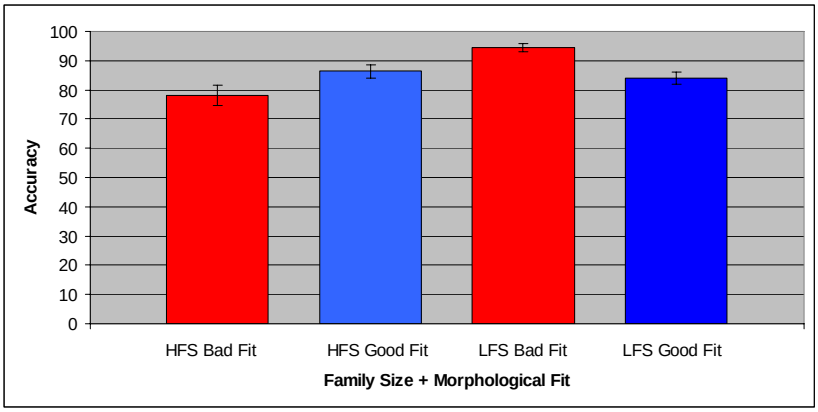

Figure 1: Repeated Measures ANOVA of Family Size and Morphological Fit: There was a significant difference between the number of errors generated in the high and low family size conditions. No statistical difference based on selectional restrictions was found.

It does not appear that participants were sensitive to selectional restrictions during this task. While there was an interaction between family size and morphological fit, these data should be considered preliminary because there was just one suffix per family size category in the 'bad morphological fit' condition, and so suffix-specific properties could not have been averaged out. These data do suggest that targets containing suffixes with a higher family size

might be more difficult for participants to reject as nonwords. More experimentation is necessary to clarify these results.

Reaction times were also recorded and analyzed as a secondary measure of processing. If participants took longer to correctly decide that a target pseudoword was not a real word in English based on either the suffix family size or the morphological legality of the target item, then this might reflect roles for each in processing. In a Repeated Measures ANOVA, suffix family size was found to significantly influence RT, $F_1(1, 43) = 67.56$, $p < .0001$, and there was an interaction effect found between suffix family size and morphological fit $F_1(1, 43) = 69.516$, $p < .0001$. Similar results were revealed in the items analysis. However, there is a serious concern about the effect of letter length on these data.

Overall, participants appeared to be sensitive to suffix family size, on average making more errors when presented with targets that included suffixes having a high family size. This does not, however, explain an abundance of errors made for one low family size suffix, *-ling*. Selectional restrictions, represented by morphological fit, did not appear to influence participant responses. The next step in this investigation was to examine participant opinions of the target items more closely.

2.2 Offline Ratings

An offline questionnaire was administered to determine the acceptability of the critical stimuli used in Experiment 1. The purpose of this questionnaire was to determine whether or not selectional restriction violations influenced native speaker responses to the target items. If speakers are sensitive to the internal morphological structure of words, then items that include a morphological violation are expected to be rated less acceptable than critical items that follow the morphological patterns of English. This task was not timed, so letter length was not expected to influence results. As in the online lexical decision experiment, suffix family size was also investigated.

Participants A total of 172 native speakers of English were recruited from the University of Alberta population. Questionnaires were administered in the Centre for Comparative Psycholinguistics and in an Introductory Linguistics lecture.

Apparatus The experiment required pencils and the questionnaire paper.

Materials The critical stimuli created for Experiment 1 were used in this questionnaire. Each questionnaire consisted of 80 items, 20 of which were critical. Fillers consisted of real words (simple and complex).

Procedure Participants were given a list of items and asked to rate each item on how acceptable they thought it was as a word in English. The ratings were done on a scale of 1 to 5, 1 being 'not at all acceptable as an English word' and 5 being 'completely acceptable as an English word.'

Results Of the four suffixes tested in this questionnaire, the suffix *–ling* (good morphological fit, low suffix family size), had the highest average acceptability rating. Figure 2 gives the complete breakdown of ratings by family size and violation of selectional restrictions.

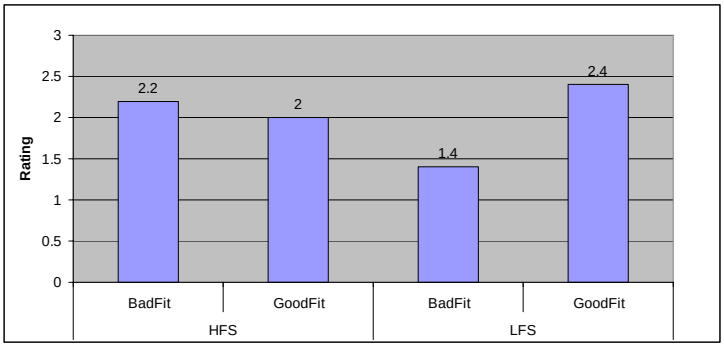

Figure 2: Acceptability ratings by family size and morphological fit. Participants found N+*ling* combinations to be most acceptable, and N+*th* combinations to be the least acceptable.

The results of the acceptability questionnaire indicate that speakers do not appear to be strongly influenced by the morphological fit (violation of selectional restrictions) when presented with novel root+suffix pairs in an offline setting, and that family size cannot alone predict participant behaviour.

These results raised questions as to how the target words were responded to in the online task. To gain a better understanding what effect acceptability might have had on responses in the lexical decision experiment, item acceptability ratings were plotted against accuracy in the lexical decision task (Figure 3). Although there is a ceiling effect at 100% accuracy for a number of items, there otherwise appears to be a relationship between higher ratings of offline acceptability and a higher number of errors during the online task. The Spearman Rho correlation between the offline ratings and the online accuracy was found to be significant, $\rho=-.447$, $p<.0001$, with lower acceptability ratings correlating with greater accuracy. That is, when words were not judged to be as acceptable in the offline task, they were also easier to reject as nonwords in the online task.

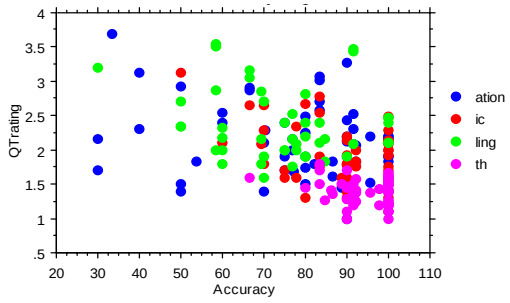

Figure 3: Questionnaire acceptability rating vs. accuracy (% correct)

When reaction times for correct responses were plotted against the offline ratings, similar results were found, with items rated more acceptable also requiring more time to reject as nonwords (ρ=.514, p<.001) (Figure 4). This suggests that items rated in the offline task as more acceptable were treated as being more "word-like" by participants in the online experiment. These results may indicate that there were some unintended semantic factors related to the interpretability of the root+suffix forms that made this task more difficult for certain items.

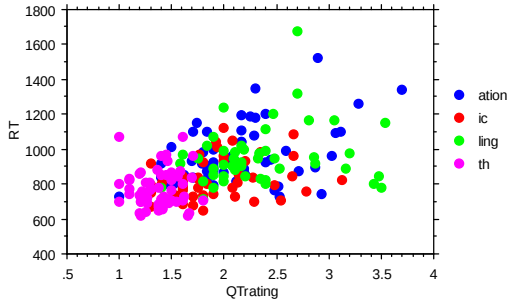

Figure 4: Reaction time and Acceptability ratings

If we hypothesize that semantic interactions between the base and suffix in Experiment 1 influenced results, then it should be possible to overcome this effect by using nonword roots. This takes away the semantic information of the root. This was the goal of Experiment 2.

2.3 Experiment 2: Nonword Lexical Decision

The second experiment looked to nonwords to examine the effects of suffix family size alone. Critical stimuli were composed of nonword bases and the suffixes used in Experiment 1. If suffix family size can affect the processing of novel words, then one might expect suffixes with higher family size to generate more errors and longer response latencies than critical stimuli composed of a nonword root and low family size suffix.

Participants Forty-three participants were recruited from the University of Alberta community. Four participants were removed for excessive error rates across all conditions (>30%) and slow reaction times.

Apparatus Experiment 2 was run on the same equipment as Experiment 1.

Materials Roots from the first experiment were altered in one phonetic feature (voicing of one segment or place of articulation of one segment) to create nonword bases that are phonotactically legal in English (e.g., *birdling* → *pirdling*). Suffixes were not altered.

Procedure The experiment proceeded as in Experiment 1.

Results There were fewer errors in Experiment 2 than in Experiment 1, with all suffixes responded to with greater than 90% accuracy. In the subject analysis, there was no significant difference in error rates found between items classified as high suffix family size and low suffix family size, $F_1(1, 38) = .854$, p=.3611.

In the items analysis of error rate, suffix family size approached significance (p=.07), with more errors made in response to high suffix family size items.

There was a significant effect of family size in an ANOVA run on reaction time, $F_2(1, 214) = 10.11$, p=.0017. Again, however, word length is a serious concern, as it correlates with reaction time.

The results from these two studies are suggestive of a role, if a small one, of suffix family size in the processing of novel words. Unfortunately, it is not completely clear from these results. What is striking, however, is the remarkable drop in errors compared to Experiment 1. The difference must lie in the identity of the roots used. The only change in Experiment 2 was the use of modified roots from the first experiment, where one feature was changed to turn the real English root into a phonotactically legal nonword. This means that the great difference in error rates is not based on impossible phonetic combinations. Based on results from the questionnaire and on previous research (e.g., Burani et al., 1999), it is proposed that this difference results from the semantics of the root+suffix combination, or the differing semantic interpretability of the target items.

2.4 Experiment 3: Category Decision Task

In the lexical decision task used in Experiment 1, selectional restrictions did not appear to be a primary factor influencing morphological processing. There were two main goals to Experiment 3. This first was to test whether suffix level effects would be apparent when using a task that has been shown to be sensitive to internal morphological structure. The second goal was to bypass the standard word judgment required in lexical decision. Experiment 3 made use of a category decision task, where participants are asked to determine the lexical category a given target item. Category decision tasks have been found to be sensitive to the internal morphological structure of words (Järvikivi & Niemi , 1999). If selectional restrictions play a role in processing, this type of task might be better able than standard lexical decision to uncover it. Similarly, the decision participants are asked to make does not require a judgment of word identity, so errors caused by the misidentification of nonword items as words are less likely.

Participants Thirty-eight people were recruited from the University of Alberta population. One participant was removed for excessive RTs.

Apparatus The same equipment was used as in Experiment 1.

Methods As in a lexical decision task, stimuli were presented one at a time on a computer screen. Participants were asked to decide for each item whether it was a noun, a verb, or an adjective. Additional roots (46) and suffixes (33) were added for this experiment. No participant saw the same base more than once.

Results Participants tended towards making fewer errors on pseudoword targets containing suffixes with low family size, although this trend did not reach significance. There was no effect of selectional restrictions on the results (Figure 5). Reaction times were also analyzed. No significant differences were found.

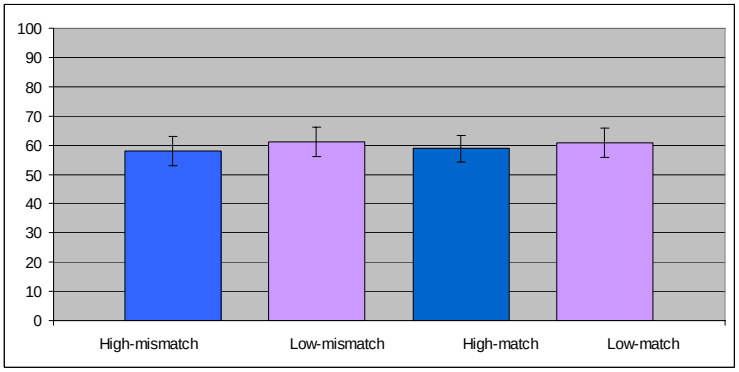

Figure 5: Accuracy by Family size (high and low) and Selectional Restriction match-mismatch. There is a slight preference for more errors in the high family size condition, but this was not significant. Selectional restrictions do not appear to be affecting results

Results from Experiment 4 suggest that native speakers of English are not sensitive to violations of selectional restrictions when presented with novel pseudowords composed of real roots and real suffixes.

3. General Discussion

Participants did not appear to be sensitive to violations of selectional restrictions when presented with structurally illegal English pseudowords. Although suffix family size was found to be significant in the first experiment, this result was not consistent. More data needs to be collected before any firm conclusions can be made. Results from the acceptability ratings suggest that suffix family size and selectional restrictions may not be a primary factor in determining the viability of a novel word. Perception of novel suffixed words in English may be influenced by semantic interpretability, and when dealing with real words, semantic interpretability might be a deciding factor in assessing novel forms. If family size is held to be a viable factor, then it suggests that the number of items in which a suffix occurs (and presumably the number of items containing it within the minds of speakers) are available & accessed during processing.

Results from these experiments did not show any effect of selectional restrictions, with no significant differences between morphologically legal and illegal novel pseudowords found for RT or error rates. On the surface, these results would appear to conflict with Libben (1993), who found that English speakers are sensitive to selectional restrictions governing morphological structure in complex pseudowords. However, because Libben (1993) used nonword roots, there was no pre-existing semantic content available to participants that might have influenced their ability to interpret the target items. It could be that case that speakers *are* sensitive to selectional restrictions, but that these effects are very small, and overridden by strong semantic content.

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