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The Effects of Real Words on the Pronunciation of Nonwords

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Abstract

Certain letter strings in the English language can be pronounced in multiple different ways. This study looked at how college students' pronunciations of nonwords with ambiguous letter strings were influenced by real word primes. The nonwords were directly derived from real words with identical letter strings. Subjects saw real words that had either the default pronunciation or alternative pronunciation of that letter string. Results showed there were a higher proportion of alternative responses to nonwords primed by words with alternative pronunciations. These findings support previous research that shows the pronunciation of nonwords can be affected by priming or tasks that bias one pronunciation over another.

Keywords: nonwords, priming, default, alternative

Introduction

The English language is alphabetic, so graphemes, the smallest letter unit, map onto phonemes, the smallest sound unit. Regularities that emerge from this mapping allow readers to establish a set of rules called grapheme-to-phoneme correspondence (GPC) rules (Andrews & Scarratt, 1998). However, certain graphemes can be pronounced as multiple phonemes (ex. pronouncing "c" in city versus coffee), and certain phonemes can be spelled as multiple graphemes (ex. /E/ can be written as "ee" or "ea"). Due to these irregularities, readers cannot establish completely consistent rules when learning words. Exception words, which violate the rules of how a letter string is usually pronounced, and novel words, any word never seen before by a particular reader, may be pronounced using an analogy of an already known word. (Andrews & Scarratt, 1998). Where English is orthographically inconsistent, readers develop both small unit, GPC rules, and large unit, rimes, recoding strategies, according to the psycholinguistic grain size theory (Ziegler & Goswami, 2005). As readers are more exposed to words, they acquire more rime-level units, while less developed readers depend more on GPC rules (Coltheart & Leahy, 1992). Treiman and Kessler (2001) believe readers do not just use one of these recoding strategies at a time, but rather together by using GPC rules that take into account the context.

There has been much debate about the number of mechanisms used to read words. Some think there are separate orthographic, or rule-based, and lexical, word-specific, mechanisms, and some think these work together (Glushko, 1979). In the dual-route (DRC) models, people read aloud by either translating orthography to phonology or retrieving phonology from a storage of information about words (Kay & Marcel, 1981). On the other hand, the parallel-distributed processing (PDP) model argues those two mechanisms are part of one process. Glushko (1979)

has evidence supporting the processes being used concurrently, as inconsistent words (ex. WAVE) took more time to pronounce than consistent words (ex. WADE). These results present support for English readers having conflicts as to what strategy to use for reading words that may not be consistent.

Research has shown that considering context is important when dealing with inconsistency. Considering the syllable that follows the vowel letter string greatly influences the pronunciation of that string when it has multiple phonemes (Kessler & Treiman, 2001). Other studies have found the final consonant model to be the most effective predictor in how vowel digraphs were pronounced (Ryder & Pearson, 1980; Johnson & Venezky, 1976). Consonantal context is taken into account as early as first grade, and increases in strength as reading levels increase (Treiman et. al, 2006). These results show children are sensitive to rime units and not solely GPC rules.

One way to examine how people read ambiguous graphemes is by having them read nonwords, letter strings that look and sound like they could be English words, but are not. By looking at how readers pronounce nonwords, researchers can get a better idea of what types of rules people use. GPC rules tend to be used more often in tasks where subjects only read nonwords (Coltheart & Leahy, 1992; Andrews & Scarratt, 1998). However, when a reader is more developed, there is a slightly greater likelihood they will give an irregular pronunciation. Older elementary school kids, along with adults, give more irregular responses to nonwords than kids who are younger (Coltheart & Leahy, 1992). Treiman et. al (2003) found critical pronunciations, how exception words are pronounced, as opposed to typical, were more likely to be given to exception nonwords than regular ones. Exception and regular nonwords were both derived from the same groups of vowels, but exception words were followed by a consonant that

gives the vowel an ambiguous pronunciation (ex. CHEAD), whereas the regular words, due to consonantal context, had a dominant pronunciation (ex. CHEAL). The proportion of critical pronunciations to total pronunciations was significantly higher for the exception nonwords than the regular nonwords (Treiman et. al, 2006). Although past research shows GPC rules are more likely to be used for nonwords, there are instances of ambiguous letter strings that produce multiple pronunciations. Similarly to reading real words, the consonantal context of nonwords are important when the vowel string itself can be pronounced in different ways.

All of these previously mentioned studies examined reading just nonwords, but do the rules people use vary if there is any sort of biasing or priming effects? According to the flexible unit hypothesis, the size of the orthographic unit used depends on the demands of the task given (Brown & Deavers, 1999). Other research using different types of priming that will be discussed below supports Brown and Deaver's flexible unit hypothesis, as it does affect people's nonword pronunciation. The different types include short-term priming, where the nonword immediately follows the prime, and long term priming, where there is a gap between the nonword and prime.

One form of priming that does affect nonword pronunciation is semantic priming. Subjects were shown ambiguous nonwords like LOUCH, which could be pronounced to either rhyme with COUCH or TOUCH. Before seeing the nonwords, they were shown a real word (e.g SOFA or FEEL) semantically related to one of those rhymes to try to activate lexical models that would produce one of those phonological representations. This task supported lexical information playing a role in pronunciation of novel words (Rosson, 1983).

Another method of priming is using real words that have similar orthography and phonology to the nonword. It is important to have both those properties, as there was no effect of priming when the real word is only similar sounding and contains a different grapheme (Kay &

Marcel, 1981). In other words, primes that only rhymed with one of the pronunciations of the vowel string, but were a different vowel string did not influence the nonword pronunciation (ex. priming GLEAD with BED). Additionally, when faced with a lexical decision task, participants performed better when form related primes rhymed with the target word than when the form prime did not rhyme (Bowers et. al, 2002). Although this particular study was not concerned with how nonwords were pronounced, it still shows the importance of orthography and phonology when priming.

Priming effects can be seen in children as young as elementary school. Brown and Deavers (1999) found that presenting children with a clue word before the nonword increased the number of analogy, using the rime level unit of a word, responses. This study used short-term priming, as the target nonword was presented right after showing the clue word. The types of words children are exposed to will influence what responses they give. In a study done by Khanna et. al (2010), kids were taught different neighborhoods that were always pronounced according to GPC rules (regular), were equally likely to be pronounced typically or exceptionally (ambiguous), were usually pronounced exceptionally (irregular), or exclusively pronounced irregularly (no regular analogy), and then read a series of nonwords. Their task used long-term priming, as the children had multiple sessions receiving instruction on the real words and then were tested on the nonwords. Overall, there were a larger proportion of GPC pronunciations for nonwords from regular-consistent neighborhoods, and a decrease in proportion when the frequency of regular pronunciations in the neighborhood decreased. There were also age differences, as older children were more sensitive to rime units and had similar results to the adult readers (Khanna et. al, 2010). Children are able to take rime unit into consideration when primed with real words similar to the target nonwords.

Adults also show biasing to nonword pronunciation when primed with certain real words beforehand. When subjects are primed with regular real words, they produce mostly regular pronunciations for the nonwords, but when primed with exception words, they are slightly more likely to give an exception response than a regular response to the nonwords. There was a delay between when subjects saw the prime and the target nonword making this a long-term priming study. (Burt & Humphreys, 1993). Kay and Marcel (1981) also found similar results in their study, which used short term priming, as there was a significant difference between the group who was primed with irregularly pronounced words (ex. seeing the word HEAD before YEAD) and the group who saw words with regular pronunciations beforehand. Although there tends to be more regular pronunciations than irregular even with the priming, being shown irregular words does have an impact on the proportion of irregular nonword pronunciations.

People also show a bias even when the words and nonwords are presented all as one list. Subjects either saw only nonwords, low-frequency exception words (ex. GAUGE) and nonwords, or words derived from the critical nonwords and nonwords. The groups who had real words mixed in to the list produced more analogy responses than the group who just saw nonwords. The exception word and prime word groups did not show a significant difference in how many analogy responses were given, but the results still showed having real words in this type of task does cause people to use larger units rather than GPC rules (Brown & Deavers, 1999). Even when people are taught how to pronounce a set of nonwords, they will use analogy rules when exposed to a new set of similar nonwords. People who were taught the subordinate pronunciation, also known as the critical pronunciation, for a set of nonwords were more likely to generalize that pronunciation onto a test set of nonwords compared to those who learned a pronunciation not previously existent in the English language for the particular grapheme. These

results were due to the subordinate pronunciations having undergone warping, accommodating an exception pronunciation of a letter string into one's representational space (Armstrong et. al, n.d.). What is important to take away from Armstrong et. al (n.d.) pertaining to the present study is despite the dominant and subordinate pronunciations both being in one's O-P information, the subordinate pronunciation was generalized to the test nonwords when subjects were taught that pronunciation in training (Armstrong et. al, n.d.). Previous research, as mentioned earlier, found people are more likely to read ambiguous nonwords as the dominant pronunciation when there is no priming (Coltheart & Leahy, 1992; Andrews & Scarratt, 1998). However, biasing subjects with the exception pronunciation has been shown to affect how they pronounce nonwords (Burt & Humphreys, 1993; Kay & Marcel, 1981; Khanna et. al, 2010; Brown & Deavers, 1999).

The current study is looking at similar concepts of previous studies by testing the effects of priming on nonword pronunciation. We want to observe if priming people with one pronunciation of an ambiguous vowel or consonant grapheme will influence how they pronounce a nonword with the same grapheme. There has been little research on consonants with ambiguous pronunciations, so we also want to see if there is the same type of effect using those graphemes as well. We expect people to use analogy rules and read the nonwords the same way as the real words they were shown. There will most likely be more regular pronunciations in general due to ceiling effects, but being primed with the alternative pronunciation will cause a greater likelihood of pronouncing the nonwords derived from that particular letter string with the alternative pronunciation than those primed with the regular one.

Methods

Participants

41 students from introductory psychology courses at the University of Connecticut participated in return for credits that went towards their grades. All were native speakers of English and typically developed readers.

Stimuli

We used ten different ambiguous grapheme groups, five vowels and five consonants that had a variety of real words with each pronunciation. Ten nonwords were directly derived from each of the groups and all were monosyllabic (see Appendix). They could not sound like any real English word regardless of how the grapheme was pronounced. A pilot experiment was conducted to help narrow down the real word list, as well as determine the conditions for the actual experiment. Real words that were frequently mispronounced or deemed as not a real English word were eliminated from the list. Based on the subjects' pronunciations of nonwords, we determined the real word conditions for the actual experiment; the pronunciation used more often became the default condition, and the pronunciation used less often became the alternative condition.

We used a within subject design with two real word conditions, so participants saw a mix of the preferred and alternative word sets. Due to the elimination of two groups, one condition had six preferred sets and four alternative sets, and the other had six alternative and four preferred. We created two word orders for each condition and two orders for the nonwords. Each real word was shown to subjects three times, so each word list was comprised of three randomized sub-lists. To randomize the words and nonwords, we used the random function in Excel. The word list had one hundred twenty trials and the nonword list had one hundred. There were a total of eight different versions created in E-Prime to account for all of the combinations of word and nonword lists.

Procedure

Participants read the list of real words and then the list of nonwords immediately after, with the entire session taking approximately fifteen minutes. We obtained informed consent right when the subject entered the room, and then they were instructed to put on a headset that was connected to a voicebox in order to trigger each word. Participants were then told they would see a list of real words one at a time. They needed to read each one out loud as quickly as possible, but without making mistakes. There were six practice trials, followed by a chance for them to ask questions before the actual task began. Each word was preceded by a plus sign in the center of the screen to focus the subject's attention, and then the word was presented in a black font with a white background in all caps. There were one thousand milliseconds between when the subject said the word and the next plus sign. A break was given half way through the list.

Right after the real word list was finished, subjects were instructed that they were going to see a list of nonwords one at a time. The instructions explained what a nonword is and gave the example of "tave." They were told to read each one as if it were a real English word as quickly as possible. We stressed to each subject there was no right or wrong answer and to pronounce it how they thought it should be pronounced. Six practice trials were given, with four of the words coming directly from Treiman et. al (2003) to get subjects used to reading nonwords that could be pronounced multiple ways. After the practice, subjects were given a chance to ask questions before beginning. Similar to the real word task, each nonword was preceded by a plus sign in the center and one thousand milliseconds between the pronunciation of the nonword and the next plus sign. The same font, color, and background were used as the real words. There was no break in the nonword list.

After the conclusion of the nonword list, subjects were debriefed on the purpose of this experiment. We explained that we were looking at the effect of real words on the pronunciation of nonwords. We pointed out the nonwords were directly derived from the real words and all had ambiguous pronunciations. We wanted to see if the real words with which the subject was primed influenced how they pronounced the nonwords.

Results

Real words and nonwords were both scored according to whether subjects gave an acceptable answer or not. The words and nonwords were coded as incorrect, correct, or a mistrigger, which is when the microphone did not pick up the subjects voice the first time, so they had to repeat themselves. Any mistriggers were discarded from further analysis. Another person also scored all of the data. One subject was thrown out from all further real word and nonword analysis because too many of their nonword responses were incorrect. There was no analysis on reaction time, as it was not necessary for the purpose of this experiment.

Table 1 shows the accuracy rate of each real word priming condition by repetition block. A two way repeated measures ANOVA was conducted to look at the effects of priming condition and repetition block on accuracy. The ANOVA revealed that the words with alternative pronunciations were read more accurately than the words with default pronunciations ($F(2,78)=3.37$, $p<.05$). There was also a significant difference in accuracy by repetition block, with subjects reading words more accurately in later blocks ($F(1,39)=4.86$, $p<.05$). Additionally the interaction between priming condition and repetition block yielded a significant difference ($F(2,78)=4.66$, $p<.05$).

Table 2 shows nonword acceptability rate by condition. A paired sample t-test shows no significant difference in acceptability rate based on the real word priming condition (t=.415, df=39, p=.680)

The proportion of alternative responses was calculated for each priming condition. The number of alternative pronunciations was divided by the total number of acceptable responses for each subject and each nonword item. Table 2 shows the average proportions by subject for each condition. Paired sample t-tests showed a significant difference between the proportion of alternative pronunciation to the nonwords primed by real words with alternative pronunciations and nonwords primed by real words with default pronunciations ($t_{subjects}$=-12.06, df=39, p<.05, t_{items}=-12.05, df=99, p<.05). Nonwords were more likely to be given an alternative pronunciation when the real word primes contained that same pronunciation.

Figure 1 and Figure 2 are scatterplots showing the proportion of alternative responses of each condition by individual subjects and nonword items respectively. Most subjects and nonword items are on the vertical axis, meaning the default primes reinforced only using the default pronunciation. The variation of where points fall on the vertical axis implies some subjects and nonword items were more susceptible to the priming effects. There is one subject who is an outlier, as they gave a larger proportion of alternative responses to nonwords that were primed by real words with the default pronunciation. After going back and looking at the subject's data, it was observed that they used the alternative pronunciation for almost an entire word group in the preferred condition and did not seem to show strong priming effects in the alternative condition. In regards to Figure 2, the two furthest outliers had high proportions of alternative pronunciations in both conditions. Both nonwords came from the group of words beginning with "c", in which the alternative pronunciation could be more likely to be used in

certain situations instead of the default (see Figure 3 for examples of each pronunciation) due to there being certain rules for this particular phoneme based on what vowel follows it.

Further analysis breaking down the data by word group shows significant differences in responses for each group except for one. There was no difference between the proportions of alternative responses for nonwords beginning with "g." ($t=-1.65$, $df=9$, $p=.134$). Table 3 shows an example of each real word priming condition and a nonword for this group, as well as all the word groups. In the other nine word groups, nonwords primed by real words with alternative pronunciations were more likely to be pronounced with the alternative pronunciation.

Discussion

The results of this experiment do support the hypothesis that subjects will be more likely to give an alternative pronunciation to a nonword when they were primed with a real word containing that same pronunciation. Furthermore, all ten of the word groups, except for one, were also more likely to be given the alternative pronunciation when primed with that pronunciation. The nonsignificant results for that one group could be due to the similar proportions of alternative pronunciations between the two conditions. Some of the nonwords primed by real words with the default pronunciation received an alternative pronunciation, which makes the proportion in this condition higher. Additionally, the proportion of alternative responses for this word group in the condition primed by alternative pronunciations was one of the lower values relative to other word groups in the same condition. The combination of these two factors are what probably resulted in no significant differences. However, there were overall significant differences in nonword pronunciation depending on the real word condition.

These findings align with previous studies that show priming people with an exception real word will bias their nonword pronunciation (Burt & Humphreys, 1993; Kay & Marcel,

1981; Khanna et. al, 2010; Brown & Deavers, 1999). Similar to Burt and Humphreys (1993), our results support the concept of long term priming, referred to as delayed priming in their study, as subjects were shown a list of real words followed by a list of nonwords. A future study could look at the effects of a longer delay, like Khanna et. al (2010) who conducted separate sessions for real word instruction and the nonword pronunciation task. That particular study had more intensive real word tasks and was done with children, so it would be worthwhile to examine if our real word priming would still bias college students' nonword pronunciations with a longer delay time.

The flexible unit hypothesis put forward by Brown and Deavers (1999) is also supported by this experiment since the nonword responses differed depending on what real word prime was shown. A larger orthographic unit, in this case the rime-level, was more likely to be used when the prime was a real word with an alternative pronunciation. In past research, when there was no prime, subjects would use predominantly GPC rules, smaller units, to pronounced nonwords (Coltheart & Leahy, 1992; Andrews & Scarratt, 1998, Brown & Deavers, 1999). Treiman et. al (2006) did show that as readers develop, they use more exception pronunciations on nonwords, but only for exception nonwords. The present study only had one set of nonwords that were intentionally ambiguous, and the larger unit was more often used for the groups of nonwords that were primed by real words with alternative pronunciations.

Participants were using already known orthographic information to pronounce the nonwords, which supports PDP models (Glushko, 1979; Khanna et. al, 2010). If GPC rules were only used to pronounce the nonwords, then the default pronunciation would have been given for each one, as this pronunciation tended to be the regular pronunciation. Similarly, if only rime-level units were used, the alternative pronunciation would have been given for every nonword.

This study supports the claim that people use words that resemble the nonwords and specific spelling-to-sound rules, rather than one or the other (Glushko, 1979).

Although college students were the subjects of the experiment, the results are still important for how schools should teach children to read. As mentioned in the previous paragraph, people used both GPC and rime-level units, consistent with Ziegler and Goswami's psycholinguistic grain size theory. Since English is an inconsistent language, people develop small-unit and large-unit recoding strategies (Ziegler & Goswami, 2005). This development calls into question how teachers in English speaking countries should teach children to read. Ziegler and Goswami (2006) discuss three different approaches: letter-phoneme, rime patterns, and whole word. They seem to conclude that all three approaches should be used since certain words have no orthographic neighbors (ex. yacht), whereas others have consistent GPC rules (ex. cat). Our results show support for the importance of teaching with all approaches because readers do take into consideration multiple grain sizes.

The biggest limitation to this experiment was the real world stimuli lists. While there were significant results, there were not that many real words in each group. It could be a possible explanation for why the one word group did not show significant differences. These short lists were due to the restricted number of words that have the pronunciation for each group and condition, as well as the words could not overlap with another word group (ex. cheerlead containing both "ch" and "ea"). Due to these factors, there were only four words in each condition for each group. Showing subjects each word three times did have an effect, but there might have been a stronger effect if there was a larger variety of words shown rather than repeating the same words. Additionally having a longer list of nonwords may have produced a

stronger effect, but creating these was difficult because they could not sound like real words when pronounced with either the default or alternative pronunciation.

Furthermore, if we were to do this experiment again, individual differences would be considered. There may be a pattern of what types of readers are more influenced by the priming, or which readers gave more acceptable nonword responses. Although subjects overall gave mostly acceptable responses, there was some variation. I would hypothesize better readers gave more alternative responses to nonwords primed by alternative real words because more developed readers have good phonological awareness, or ability to identify and recognize phonological units of any size (Ziegler & Goswami, 2005). Skilled readers would be more aware of the rime-level units, which could possibly influence these readers to use the larger unit when reading the nonwords.

This particular experiment tested people who were native English speakers, so a future direction would be to explore people who speak other languages. A similar experiment could be done that compares the results of people who speak English, a purely alphabetic language (ex. Spanish), and a language that uses whole word units (ex. Chinese). One would hypothesize that speakers of the purely alphabetic language would be the least influenced by the alternative primes, and the speakers of whole word languages would be most influenced. Another experiment could look at speakers of another specific language (ex. only using subjects whose native language is Spanish). These future studies would provide further information on how people read words based on what language they know.

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Table 1
Real Word Accuracy by Repetition Block

Word Condition:	Preferred	Alternative
Repetition:		
1	.96	.98
2	.98	.99
3	.98	.99

Table 2
Nonword Acceptability Rate and Proportion of Alternative Responses by Real Word Condition

Real Word Condition:	Preferred	Alternative
Acceptability	.92	.92
Proportion of alternative responses to total responses	.07	.39

Table 3
Examples of Real Words with a Default and an Alternative Pronunciation, and a Nonword for Each Word Group

Word Group:	Default	Alternative	Nonword Example	Proportion of Alternative Responses by Condition: P	A	Pilot Data
-ood	mood	hood	zood	.00	.43	.00
th-	theory	there	therf	.01	.30	.00
ch-	chart	chord	cheb	.01	.11	.00
-ead	plead	head	vead	.09	.38	.07
-ey	prey	key	quey	.00	.08	.10
-ow	how	blow	smow	.08	.30	.14
g-	gift	giant	gern	.11	.21	.20
-ose	dose	rose	plose	.12	.91	.29
-our	hour	pour	jour	.02	.48	.30
c-	city	code	cerg	.38	.68	.33

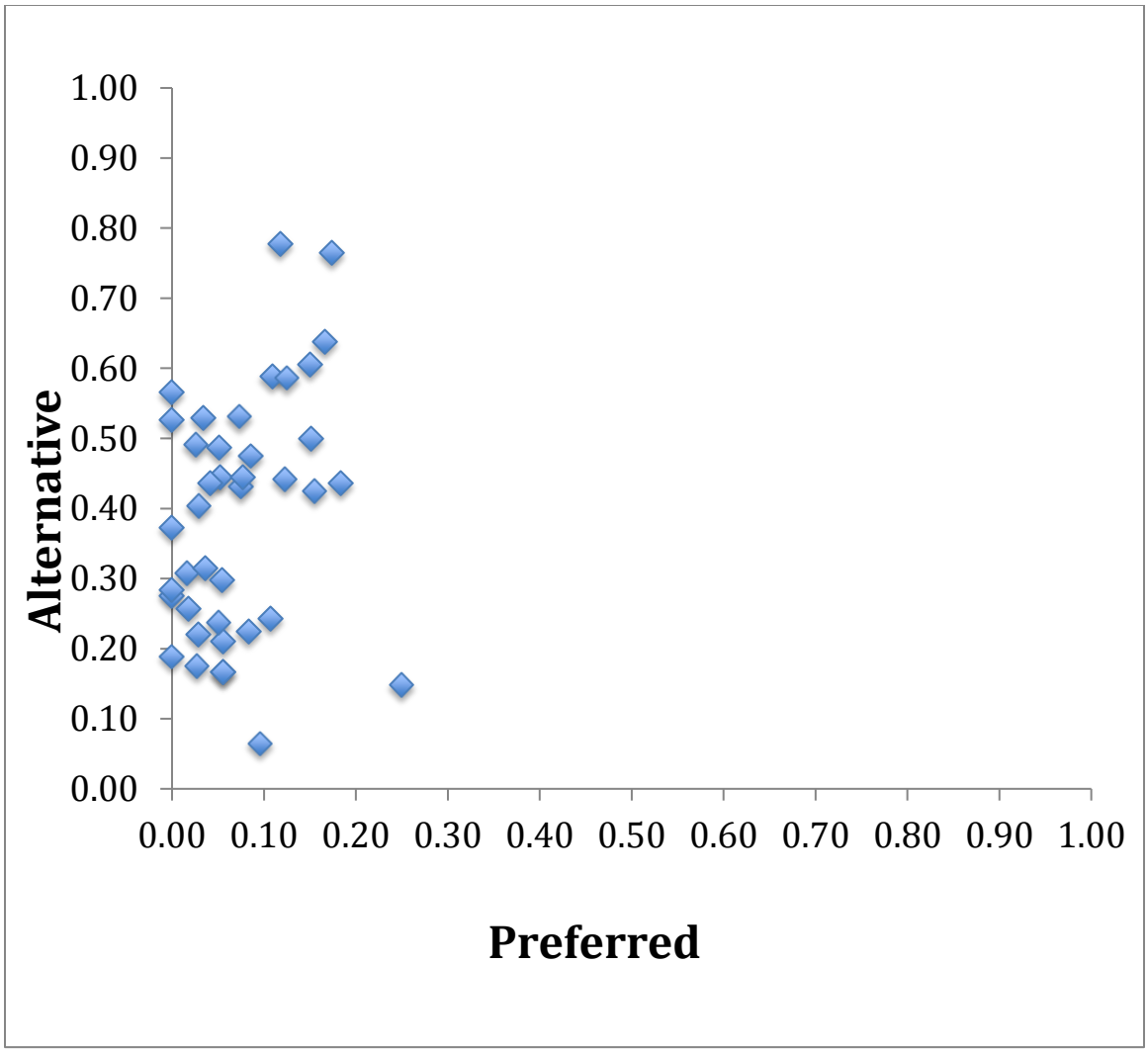

Figure 1. The proportion of alternative responses for each real word priming condition by subject.

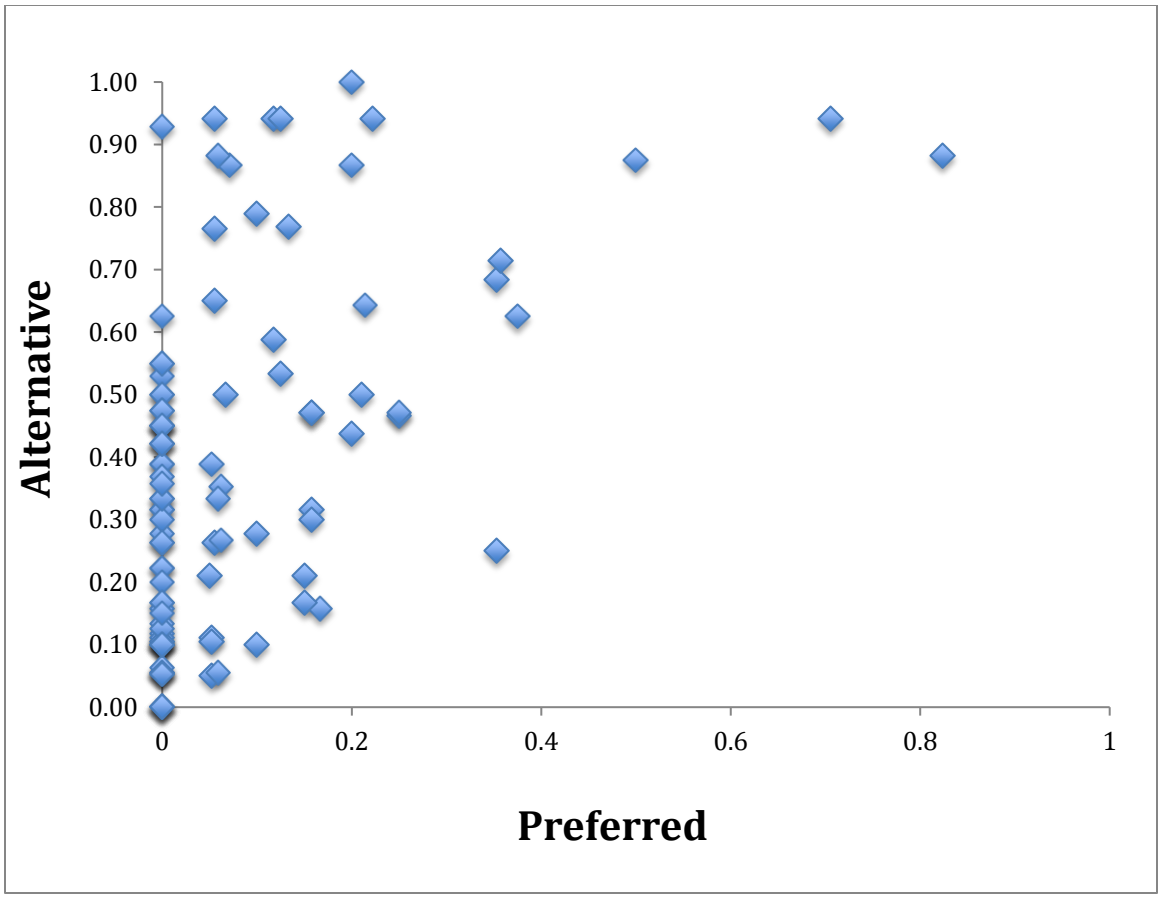

Figure 2. The proportion of alternative responses based on real word priming condition by nonword item.

Appendix A
Full List of Nonword Stimuli

Word Group:	Default	Alternative	Nonword Example	Proportion of Alternative Responses by Condition: P	A	Pilot Data
-ood	mood	hood	zood frood swood trood yood vood drood spood twood grood	.00	.43	.00
th-	theory	there	therf thep thelk theb thech thed theg therb thet thern	.01	.30	.00
ch-	chart	chord	cheb charf cheld chont chig chirt chalp chowd chep chand	.01	.11	.00
-ead	plead	head	vead scead pread	.09	.38	.07

			yead quead yead swead gead clead gwead			
-ey	prey	key	quey bley pwey shrey srey vley drey zey twey scey	.00	.08	.10
-ow	how	blow	smow clow zow scow drow vlow squow swow vrow jow	.08	.30	.14
g-	gift	giant	gern gint gerp geb gith gilp gep girt gid gesp	.11	.21	.20
-ose	dose	rose	plose trose yose quose vose	.12	.91	.29

			kose wose scose brose swose			
-our	hour	pour	jour vour trour blour crour zour grour brour strour frour	.02	.48	.30
c-	city	code	cerg ceft cep cimp cilb cem cif cirm ceng colp	.38	.68	.33