Running Head: PRONOUNCEABILITY EFFECT IN L2 LEARNERS

Phonological form influences memory for form-meaning mappings in adult second-language learners.

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Abstract

This study asks whether phonological form affects adult second language learners' ability to learn the meanings of novel words. Specifically, we ask whether hard-to-pronounce words, defined as having phones/phone combinations not present in the learner's native language, are more difficult to learn meanings for, and further, if learnability differences are due to interference from production problems or more general representational difficulties. We exposed participants to easy- and hard-to pronounce novel word-novel object pairings and tested their memory for the pairings. Participants who had either repeated words aloud, performed subvocal repetition, or heard another learner's attempts to repeat the words during exposure performed worse on hard-to-pronounce words when tested immediately after exposure. When tested the following day, all participants, regardless of exposure condition, showed the effect. In a follow-up experiment, participants who engaged in an articulatory suppression task during learning did not have more difficulty with hard-to-pronounce words, suggesting that differences cannot simply be due to interference. Rather, we suggest that more difficult phonological forms lead to weaker representations which are then more difficult to link up with meanings in memory.

Keywords: Second language acquisition, vocabulary learning, phonological form, memory

Phonological form influences memory for form-meaning mappings in adult second-language learners.

Vocabulary learning is an essential part of learning a second language (L2). But as anyone learning a new language knows, some words are more difficult to learn than others. This is perhaps most salient when thinking about word forms; forms with unfamiliar sounds or sound combinations are harder to recall than those with familiar phonological material (Gathercole, Frankish, Pickering & Peaker, 1999; Vitevich & Luce, 2005). However, it is also the case that some form-meaning mappings prove more difficult for learners than others, with factors such as grammatical and semantic type known to affect learning (Ellis & Beaton, 1993; deGroot, 2006). Here we explore the potential effect of form on learning meaning. In particular, we ask if words with difficult phonological forms (from the perspective of the first language, L1) are initially harder to learn meanings for than words with simpler or more familiar phonological forms. We further ask if learnability differences are due to aspects of production (interfering with memory formation for instance) or more general representational difficulties inherent in forms that violate the L1 phonological system.

Background

Not all words are created equal from a learning perspective, and a variety of factors contribute to the ease or difficulty of learning. A word's grammatical class, for example, can affect how easily it is learned, with nouns being easier than verbs (Roberts 1969). This could be related to concreteness; several studies have found that words with more imageable meanings are easier to learn (Ellis & Beaton, 1993; deGroot 2006). But it is not just about L2 semantics. Lotto and deGroot (1998), for instance, found that it is easier to learn the meanings of L2 words that correspond to words that are frequent in the L1.

Phonological form also plays a role in word learning, particularly form learning. Longer words, for instance, are harder to recall from memory than shorter words (Baddeley, Thomson & Buchanan, 1975; Papagno & Vallar, 1992). Phonological similarity among L2 word forms can also make learning and recall more difficult (Creel, Aslin & Tannenhaus, 2006; Papagno & Vallar, 1992). But this effect is not limited to aspects of the L2 words in isolation, the learner's L1 also influences what is easy or hard to learn. Rodgers (1969), for example, found that Russian vocabulary items rated as difficult-to-pronounce (based on the complexity of the consonant clusters and whether or not those clusters were allowable in English) were not learned as well as those that were easy to pronounce. More recently, Ellis and Beaton (1993) found that recall of German vocabulary items was highly correlated with how well the words fit the phonological patterns of English, the learners' L1. deGroot (2006) found a similar effect for native speakers of Dutch learning an artificial language.

Ellis and Beaton (1993) and deGroot (2006) both propose that novel phonological patterns (such as unfamiliar phonotactic sequences) are more difficult to repeat in working memory, thereby interfering with the ability to form a strong representation of the word form in long-term memory. Building on this, we reason that, because of their weaker representations

relative to easy-to-pronounce words, it might be more difficult to link up hard-to-pronounce words with meanings in memory. Thus, in addition to being harder to recall, we hypothesize that L2 forms that are phonologically quite distinct from L1 forms might also initially be harder to learn the meanings for.

We test this proposal in 4 experiments in which we exposed adult native English speakers to form-meaning pairings where the nature of the word forms, but not meanings, differed in terms of their similarity to English. Some forms were easy to pronounce, whereas others violated English phonology and were hard for native English speakers to pronounce. Learning was assessed using a recognition test rather than the more typical recall test, which allowed us to separate out difficulties recalling forms or pronouncing words (inherent in any test involving production) from difficulties remembering a word's meaning. If a word form that is hard to pronounce leads to a weaker representation and therefore more difficulty in learning the associated meaning as we hypothesize, learners should perform worse on the hard-to-pronounce than the easy-to-pronounce words – a pattern we refer to as the *pronounceability effect*. Participants were tested immediately after the exposure session to assess immediate learning, as well as a day later to assess retention. We varied the learning conditions slightly between the experiments, in an effort to better understand the nature and source of the effect.

Experiment 1

In this first experiment, two groups of participants were exposed to easy- and hard-to-pronounce words, and learning assessed at two time points. According to our hypothesis, the pronounceability effect should be apparent whether or not participants actually say the words, however, it is possible that the effect is modulated by attempts at production. Therefore, we had one group of participants repeat the novel word forms aloud during learning, in contrast to participants in the Control condition who were given no strategy other than a prohibition on out-loud repetition.

Method

Participants

Thirty UC Berkeley students, 8 male, 22 female, participated for course credit, (15 in each of two conditions). In this and all other experiments, all were native English speakers with no hearing problems and no previous experience with a Slavic language.

Materials

Although this study takes the form of an artificial language learning study, we chose to use real word forms from Polish. Polish has many sounds and sound combinations not allowable in English, something we required of our stimuli. We also had access to a native speaker, enabling greater naturalness of the auditory stimuli than a synthesizer would have allowed. However, the word forms were paired with novel objects, not their actual meaning, which allowed us to discount the effects of native English words, like frequency or cognate-status, and

to choose stimulus items regardless of their true meaning or grammatical class.

Stimuli consisted of 60 Polish words chosen from the *English-Polish and Polish-English dictionary* (Stanislawski, 1955). There were 24 one-syllable words, and 36 two-syllable words, in an attempt to control for the effects of word length on learning. Half the words at each length were easy-to-pronounce and the other half were hard.[1] Words in the *easy-to-pronounc*e group contained consonant clusters allowable in English. Words in the *hard-to-pronounc*e group contained consonant clusters not present in English, as well as the phone /χ/, which is not part of the English inventory. Three other non-English sounds were present in words in both easy- and hard-to-pronounce categories: the alveolar trill /r/, which is perceptually similar to English /ɹ/, and the two sibilants, alveolopalatal /ɕ/ and retroflex /ʂ/, which previous work has shown are both treated by English speakers as /ʃ/ (Lisker, 2001; McGuire, 2007).

All words were recorded by a female native Polish speaker, and edited for presentation using Wavesurfer 1.8.5. See Appendix A for the stimulus items.

The novel objects that served as the meanings to be learned were planets, gadgets, weapons, or unusual creatures taken from the clip art collection *Art Explosion* (2004). Importantly, none of the stimuli objects had an obvious term in English. Figure 1 shows some examples with their associated word forms. The first two examples are 1-syllable easy- and hard-words respectively, and the second two are 2-syllable easy- and hard-words.

Figure 1. Example stimulus items.

Procedure

The experiment took place in a quiet room on campus. Participants were told that they would be learning new vocabulary words, and to pretend that they were learning an alien language so that they could study abroad on Mars. This direction was intended to explain the unusual nature of the novel objects to be learned.

Novel word-novel object pairings were presented on a computer using Powerpoint. Each

[1] The different numbers reflect the difficulty in finding one syllable easy-to-pronounce words that are not also English words.

slide, consisting of a picture of an object, was presented for 4500 milliseconds, during which the corresponding word form was presented once, starting 10 ms after the slide appeared. Word durations varied from 571 ms for the shortest 1-syllable word (mig) to 1458 ms for the longest 2-syllable word (spulchnić).

Stimuli were presented in 4 blocks. Each block contained all 60 words but in different orders. Thus, participants were exposed to each word-object pairing 4 times. Participants were given a 10-second break between blocks and were warned with a beep when the next block was about to begin. The experimental participants (Out-loud Repetition) were instructed to repeat each word out-loud after hearing it. They were informed that their productions would be recorded for analysis. Those in the Control condition were given no additional instructions other than to not repeat the words aloud.

Testing

Immediately following the exposure phase, participants were given a recognition test assessing their knowledge of the words' meanings. The test consisted of a 3-alternative forced-choice recognition test, conducted on a computer using E-Prime (Schneider, Eschman, & Zuccolotto, 2002). For each test item, a word form played over speakers and three pictures appeared on the screen: the actual meaning, a picture of an object associated with a different word in the learning phase, and a completely novel object (not seen in the learning phase). The familiar foil was included to ensure that participants could not find the right answer simply by responding to familiar objects. The objects that did not appear during exposure were chosen from the same set of clip-art illustrations so as to not stand out from the other objects. Each picture was numbered (1, 2, or 3), and participants responded by pressing the number corresponding to their choice on a computer keypad. Their responses and reaction times were recorded.

Participants were tested on 20 1-syllable and 30 2-syllable words, with each group equally divided between easy- and hard-to-pronounce words. We did not test participants on all words to avoid having test items appear as correct answers before they appeared as decoys, thereby ensuring that no test item could be ruled out because it had already been correctly paired with another word. (During pilot testing participants sometimes reported that they could infer an answer using this information.) Test item types (e.g. 2-syllable hard, 1-syllable easy) were randomized, but the order was the same for all participants, again to ensure that no pictures appeared as correct responses before they appeared as a decoy.

Participants returned to the lab one day later to take another recognition test of the same design to assess retention.

Results

Recognition Test

Percent correct scores. Mean percent correct scores on the first recognition test are shown in Figure 2a for each syllable and difficulty type by condition[2]. For ease of presentation,

[2]An analysis of the productions of participants in the Out-loud repetition condition confirmed that the words chosen as hard-to-pronounce indeed were more difficult ($F(1,28) = 174.10$, $p<0.001$); participants mispronounced hard-to-

in this and all figures, striped bars indicate easy-to-pronounce words, while solid bars indicate hard-to-pronounce words. (Note that all bars are significantly above chance – 33%). Results showed that participants were significantly worse at recognizing the correct meaning for hard-to-pronounce words (difficulty: $F(1,28) = 9.60$, $p < 0.001$). While condition was not significant ($F(1,28) = 1.13$, $p = 0.297$), the interaction between condition and difficulty approached significance ($F(1,28) = 3.50$, $p = 0.072$): difficulty was significant for the Out-loud Repetition condition ($F(1,14) = 6.59$, $p = .022$), but not the Control condition ($F(1,14) = 1.18$, $p = 0.308$). Thus, in the short term the pronounceability effect seems to be restricted to participants who actually produced the words.

Word length was a not significant factor overall ($F(1,28) = 2.06$, $p = 0.162$), but a significant interaction between the number of syllables and condition ($F(1,28) = 4.52$, $p = 0.042$) revealed that word length was significant for the Control condition ($F(1,28) = 5.94$, $p = 0.029$) but not the Out-loud Repetition condition ($F(1,28) = 0.26$, $p = 0.621$), demonstrating that the Control participants showed better recognition for 1-syllable words than 2-syllable words.

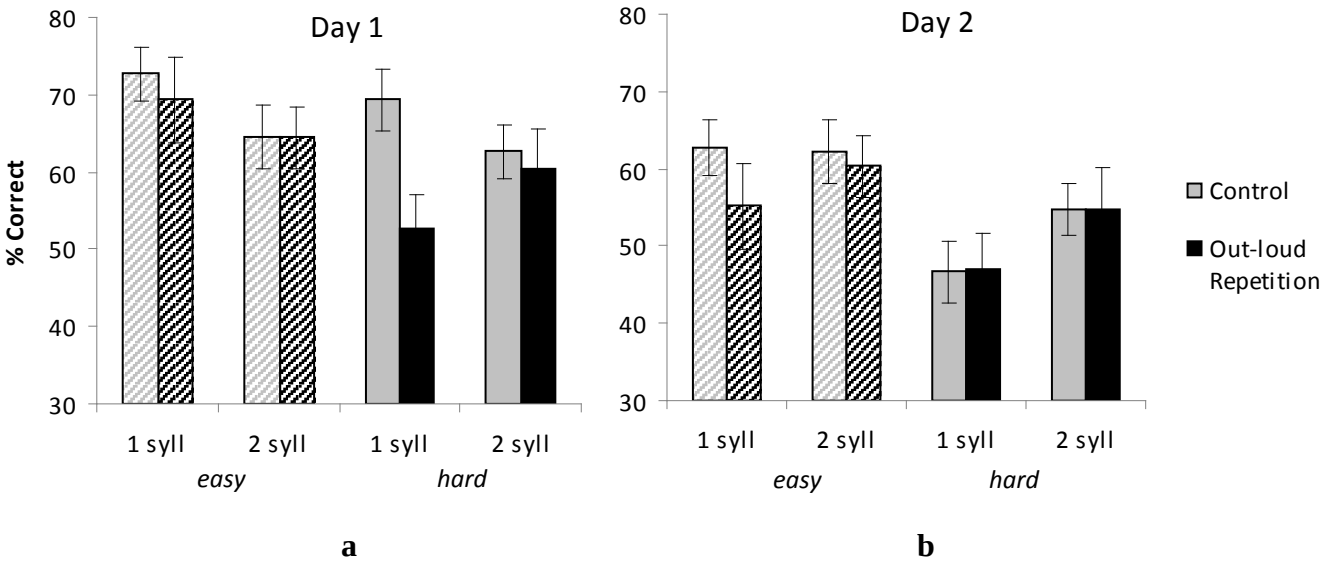

Figure 2. Percent correct for easy- and hard-to-pronounce 1- and 2-syllable words by condition on test 1(a) and test 2(b).

The pattern of results was slightly different when participants were tested one day later, shown in Figure 2b. In this second test, the main effect of difficulty was again significant ($F(1,28) = 9.35$, $p = 0.005$); however, the interaction between difficulty and condition was not

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pronounce words 76.78% of the time, opposed to only 19.72% for easy-to-pronounce words. Participants also exhibited more apparent difficulty producing hard- than easy- words ($F(1,28) = 128.76$, $p < 0.001$),with participants showing pauses, slow articulation, or other signs of difficulty on 0.92% of easy- words and 25.29% of hard- words.

($F(1,28) = 0.68$, $p = 0.418$). (In fact, none of the interactions were significant.) Thus, when retention was tested, participants' memories for word meanings were worse for the hard-to-pronounce words whether or not they actually produced the words aloud. Interestingly, performance was significantly worse for 1- than 2-syllable words ($F(1,28) = 4.41$, $p = 0.045$).

We also analyzed the results of the two tests together to look for significant interactions between the day of testing and other factors. There was a significant main effect of day ($F(1,28) = 27.04$, $p < 0.001$), reflecting participants' tendency to forget words between the two days of testing. There was also a significant interaction between syllable and day ($F(1,28) = 11.49$, $p = 0.002$); performance on 1-syllable words was significantly worse than 2-syllable words on the second day of testing ($F(1,28) = 4.41$, $p = 0.045$), but not the first ($F(1,28) = 2.06$, $p = 0.162$).[3]

Table 1
Mean Reaction Times (in ms) for Correct Responses by Condition and Word-form Type

		Easy-to-pronounce				*Hard-to-pronounce*			
		1 syllable		*2 syllable*		*1 syllable*		*2 syllable*	
Condition		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control	*Day 1*	2726	545	2733	723	3178	927	3182	977
	Day 2	2842	793	2563	758	2765	1120	3088	766
Out-loud Repetition	*Day 1*	2874	833	2922	747	3150	879	3288	665
	Day 2	2901	1096	3111	996	3072	754	3053	958

Reaction times. We also analyzed reaction times (RTs) for correct responses (see Table 1). (Note that RTs two standard deviations above or below an individual participant's mean RT were excluded.) On Day 1 participants responded significantly more quickly to easy-to-pronounce than hard-to-pronounce words ($F(1,28) = 15.90$, $p < 0.001$). The same was true on the second day ($F(1,28) = 7.79$, $p = 0.009$). No other factors or interactions were significant. When both days' results were analyzed together, day was not significant ($F(1,28) = 0.53$, $p = 0.472$), and no interactions involving day were significant. These data therefore suggest that it was indeed more difficult for participants to access the representations of the hard-to-pronounce words, even when they knew the meanings.

[3]We also analyzed whether participants' mispronunciations were correlated with performance, and found a negative but not significant correlation between participants' scores on the recognition test and their average mispronunciation score (r^2=-0.28 Day 1, r^2=-0.24 on Day 2).

Discussion

The results of Experiment 1 show that overall, hard-to-pronounce words were not as accurately recognized as easy-to-pronounce words, confirming the prediction that meanings of hard-to-pronounce words are harder to learn. However, for the Control group, performance on the recognition test was not affected by pronunciation difficulty on the first day of testing, suggesting that direct experience with producing words out-loud does indeed make it more difficult to form a representation of hard-to-pronounce words. However, the fact that pronunciation difficulty was significant for the Control condition on the second day of testing indicates that production experience is not necessary for the pronounceability effect to emerge. (The representations for hard-to-pronounce words were apparently weaker than those for words that were easy-to-pronounce and thus more subject to forgetting). The RT analysis also lends support to the interpretation that hard-to-pronounce words are more difficult to learn; even when answered correctly, recognizing hard-to-pronounce words took more time and perhaps involved more guessing. The fact that syllable number was not significant for response times showed that the pronounceability of words was a stronger factor than even the length of the word, which we might expect to be a particularly important factor in response times (see e.g., Okada, Smith, Humphries, & Hickok, 2003).

With Experiment 1 finding that out-loud production made it more difficult to recall the meanings of hard-to-pronounce words even at first test, whereas the Control group only showed the effect for retention, the remaining experiments focus on the question of what it is about out-loud production that causes these differences.

Experiment 2

Experiment 2 asks whether the more immediate pronounceability effect found in the Out-loud Repetition participants resulted from actual production, or instead, from simply having focused the learner's attention on the difficulty of the word's form. We examined this by having a new group of participants perform Subvocal Repetition (repeating in one's head), and compared their learning with that of participants in the Out-loud Repetition and Control conditions from Experiment 1. If the effects of production we saw in Experiment 1 are caused by forcing learners to focus on characteristics of the stimuli, particularly the phonological form, performance should be similar in the Out-loud and Subvocal Repetition conditions. If instead the actual articulation of words is the source of the effect, then the Subvocal Repetition condition should show a different learning pattern, possibly similar to that of the Control group.

Method

Participants

Fifteen UC Berkeley undergraduates (8 male, 7 female) participated in the Subvocal Repetition condition for course credit.

Procedure

The procedure and stimuli were the same as those used in Experiment 1, except that participants were instructed to repeat each word in their head and only in their head.

Results

Recognition Test

Subvocal Repetition vs. Out-loud Repetition. The mean scores on the recognition task for the Subvocal and Out-loud Repetition groups are shown in Figure 3. On Day 1, although the pronounceability effect is apparent, with performance on easy-to-pronounce words being significantly better than hard-to-pronounce words ($F(1,28) = 19.47$, $p < 0.001$), performance was not equivalent between the two conditions; participants in the Subvocal Repetition condition performed significantly better than those in the Out-loud Repetition condition ($F(1,28) = 10.93$, $p = 0.003$). The same was true on Day 2; performance was again worse on hard-to-pronounce words ($F(1,28) = 8.42$, $p = 0.007$), and performance in the Subvocal condition remained significantly better than that of the Out-loud Repetition group ($F(1,28) = 8.18$, $p = 0.008$).

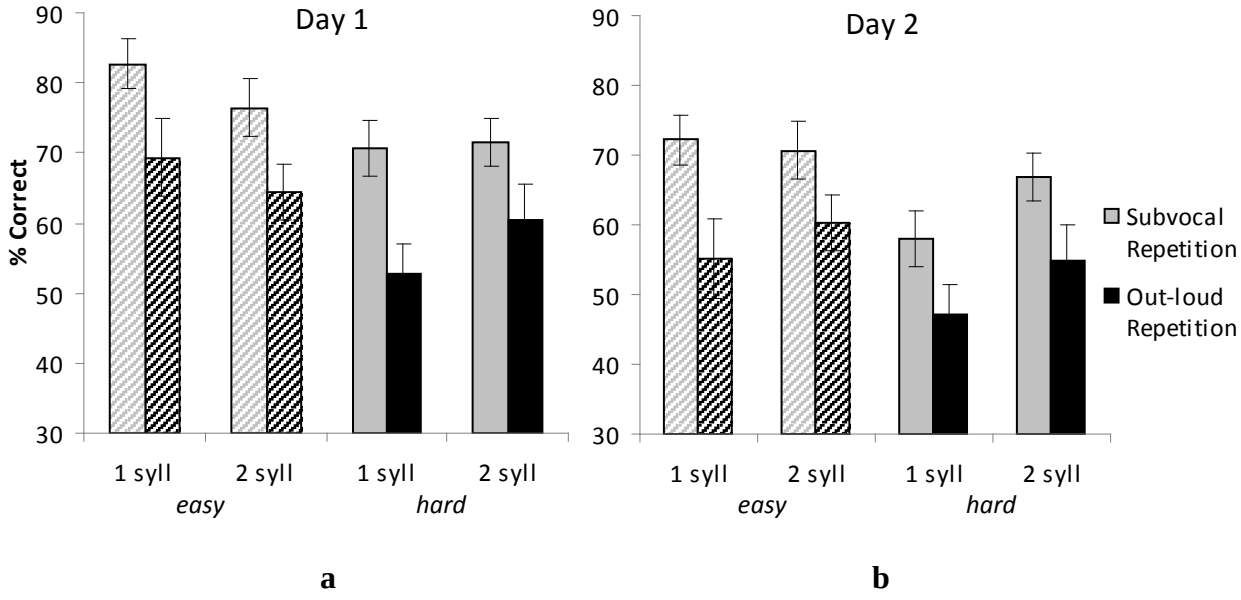

Figure 3. Percent correct for the Subvocal Repetition and Out-loud Repetition conditions on test 1(a) and test 2(b).

Looking at the effects of day of testing, scores were significantly lower on Day 2 than Day 1 ($F(1,28) = 22.75$, $p < 0.001$). However, there was also a significant interaction between syllable and day ($F(1,28) = 4.46$, $p = 0.044$); there was no significant difference between syllables on Day 1 ($F(1,28) = 0.10$, $p = 0.759$), but the difference approached significance on Day 2 ($F(1,28) = 3.55$, $p = 0.070$). As in Experiment 1, then, participants show better retention of 2-syllable than 1-syllable words.

Subvocal Repetition vs. Control. Given the significant difference between the Out-loud and Subvocal Repetition conditions, we went on to compare performance in the Subvocal Repetition condition with the Control condition from Experiment 1 (see Figure 4). As in the immediately previous analysis, on Day 1 the easy-to-pronounce words were more accurately remembered than the hard-to-pronounce words ($F(1,28) = 9.69$, $p = 0.004$). However, here, although participants in the Subvocal Repetition condition appear to consistently outperform those in the Control condition, condition was not significant ($F(1,28) = 2.16$, $p = 0.153$), neither was the interaction between difficulty and condition ($F(1,28) = 2.79$, $p = 0.106$). On Day 2, only the main effect of difficulty was significant ($F(1,28) = 12.37$, $p = 0.002$); performance was better on easy- than hard-words. As before, performance was worse on Day 2 than Day 1 ($F(1,28) = 23.40$, $p < 0.001$), and there was a significant interaction between syllable and day ($F(1,28) = 9.63$, $p = 0.004$). Here, however, the pattern was slightly different than in previous analyses; performance was better on 1-syllable words on Day 1 ($F(1,28) = 5.86$, $p = 0.022$), but there was no significant difference between 1- and 2-syllable words on Day 2 ($F(1,28) = 2.20$, $p = 0.149$). However, the overall pattern is the same, with greater decrements in performance on 1-syllable than 2-syllable words between tests.

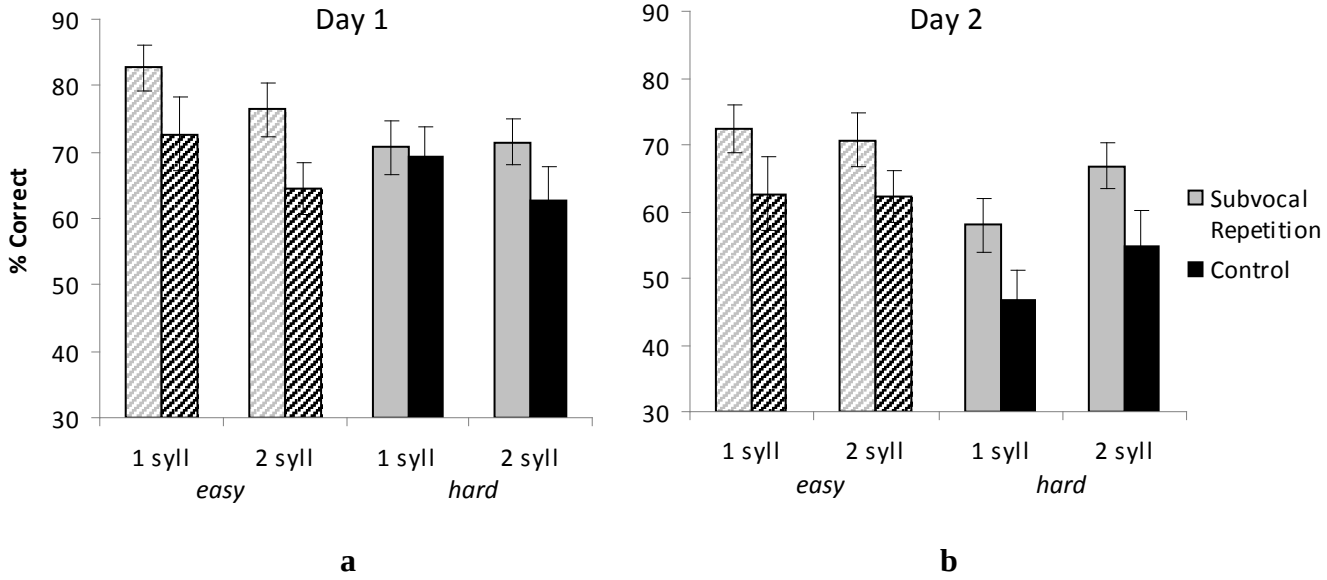

Figure 4. Percent correct for the Control and Subvocal Repetition conditions on test 1(a) and test 2(b).

Reaction Times The results for RT, shown in Table 2, mirror those from Experiment 1: On Day 1 participants responded significantly more quickly to easy-to-pronounce than hard-to-pronounce words ($F(1,14) = 35.95$, $p < 0.001$). The same was true on the second day ($F(1,14) = 17.09$, $p = 0.001$). No other factors or interactions were significant. When both days' results were analyzed together, day was not significant ($F(1,14) = 2.48$, $p = 0.138$), and no interactions involving day were significant. These data therefore again suggest that it was more difficult for

participants to access the representations of the hard-to-pronounce words. (Note that here we only analyze the RT data for the Subvocal Repetition condition, as the data for the Control and Out-loud Repetition conditions were previously presented and analyzed.)

Table 2

Mean Reaction Times (in ms) for Correct Responses for Experiments 2 - 4

		Easy-to-pronounce				*Hard-to-pronounce*			
		1 syllable		*2 syllable*		*1 syllable*		*2 syllable*	
Condition		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Subvocal Repetition	*Day 1*	2516	834	2685	641	3275	911	3282	813
	Day 2	2338	689	2598	675	2963	924	3092	742
Hear Another	*Day 1*	2680	555	2803	577	3234	836	3186	969
	Day 2	2739	776	2975	805	3434	1758	3199	1037
Articulatory Suppression	*Day 1*	2446	650	2801	714	3207	1282	3133	895
	Day 2	2750	879	2662	709	2991	640	2997	649

Discussion

In Experiment 1 we found a pronounceability effect on Day 2 for both the Out-loud Repetition and Control groups, but only in the Out-loud Repetition group when learning was assessed immediately after exposure. Here we examined whether this might be due to interference caused by a focus on the phonological form of the word by having a new group of participants focus on the form by doing Subvocal Repetition. For these new participants, difficulty was significant at both tests, indicating that indeed, a focus on form might be related to the immediate pronounceability effect. Interestingly, however, participants in the Subvocal Repetition condition performed better than other participants on both test days (although this difference was only significant compared to the Out-loud condition), suggesting that repeating subvocally, though leading to differences in memory for easy- and hard-to-pronounce words, overall leads to a stronger representation for both types of words.

Experiment 3

One of the goals of Experiment 2 was to understand the effects of drawing attention to the stimuli without actual articulation. However, when repeating a word subvocally one can

approximate what one heard without focusing on the details of articulation and so the actual degree of difficulty may be less apparent, which could lead to less interference. So in Experiment 3 we had participants focus on phonological form and pronunciation difficulty in a slightly different way that, while not requiring articulation, nonetheless made the difficulty of pronouncing the hard-to-pronounce words very apparent: participants listened to another native English-speaking 'learner's' attempts to repeat each word. This other learner had more difficulty pronouncing hard- than easy-to-pronounce words; thus, participants were made aware of the nature and degree of difficulty associated with the novel words without actually pronouncing the words themselves. Results are again compared to data from Experiment 1.

Method

Participants

Fifteen UC Berkeley students (8 male, 7 female), participated for course credit.

Materials

A 22 year-old male native English-speaker's attempts to repeat the stimuli were recorded. His productions of each word were added to the stimuli, following the productions of the Polish speaker by one second. He mispronounced 72% of the hard-to-pronounce items and 16% of the easy-to-pronounce words. (This is very similar to performance in the Out-loud Repetition condition in Experiment 1.)

Procedure

The learning task and recognition tests were the same as in previous experiments, except for the recordings added to the exposure. Participants in the Hear-another condition were told that for each word-object pair they would hear the name of the object followed by another English-speaking learner trying to say the word. They were instructed not to produce the word with the other learner, but rather that they should only listen to his production. Note that participants were tested on their ability to recognize the word as spoken by the Polish speaker.

Results

Recognition Test

Percent correct scores. The means for the Hear-another and Out-loud Repetition conditions are shown in Figure 5. On Day 1, performance was better for easy- than for hard-to-pronounce words ($F(1,28) = 20.96$, $p < 0.001$). However, a significant interaction between difficulty and syllable ($F(1,28) = 9.82$, $p = 0.004$) showed that, as in Experiment 2, the difference between hard- and easy-words was significant for 1-syllable ($F(1,28) = 27.51$, $p < 0.001$), but not 2-syllable, words ($F(1,28) = 3.01$, $p = 0.094$). Condition was not significant ($F(1,28) = 0.67$, $p = 0.420$), nor was the interaction between difficulty and condition ($F(1,28) = 0.13$, $p = 0.720$). On Day 2, difficulty was again significant ($F(1,28) = 18.48$, $p < 0.001$), but none of the interactions were significant. Overall, performance worsened on Day 2 ($F(1,28) = 17.62$, $p < 0.001$), but unlike previous analyses, there was no significant interaction between day and syllable ($F(1,28) = 3.20$, $p = 0.084$).

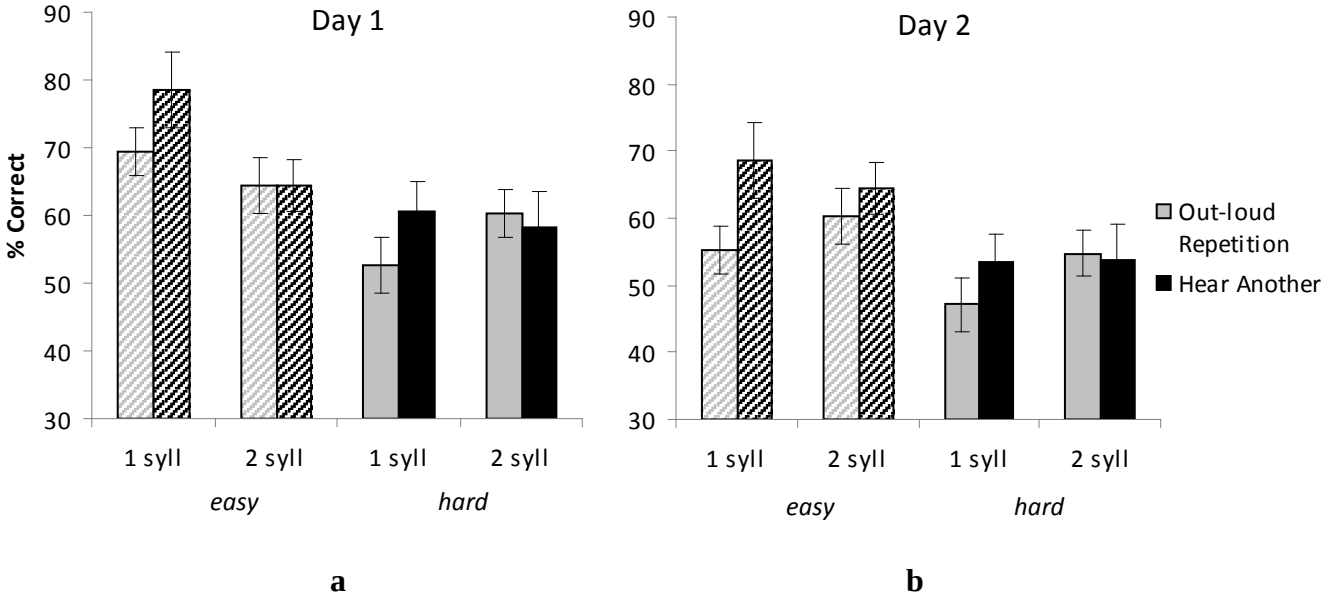

Figure 5. Percent correct for the Out-loud Repetition and Hear Another conditions on test 1(a) and test 2(b).

Reaction times. The RT results for the Hear Another condition are shown in Table 2. On Day 1 participants responded significantly more quickly to easy- than hard-to-pronounce words ($F(1,14) = 8.87$, $p = 0.010$). Though response times follow a similar pattern on Day 2, the difference between the two word groups was not significant ($F(1,14) = 3.62$, $p = 0.078$). When both days' results were analyzed together, day was not significant ($F(1,14) = 0.37$, $p = 0.552$), and no other factors or interactions were significant. Though the difference between word groups was not significant for the second test, the results continue to support the idea that representations of hard-to-pronounce words were more difficult to access, even when they accurately recognized the meaning.

Discussion

Here we were testing whether the difference on Day 1 between the Out-loud Repetition and Control conditions in Experiment 1 might be due to drawing the Out-loud participants' attention to word form (and therefore pronunciation difficulty) by having another group of participants listen to another learner's attempts to produce the novel words and assessing learning. We found that the performance in the Hear-another condition did not differ from the Out-loud Repetition condition. That is, listening to another person attempt to produce the words had the same effect on learning as attempting to produce the words oneself. Thus, actually producing the words does not appear to be necessary for the immediate pronounceability effect to emerge.

Experiment 4

The results of the previous experiments support the hypothesis that words with more difficult phonological forms (from the perspective of the L1) are more difficult not only in terms of learning to produce them, but also in terms of learning what they mean. This was true of retention (Day 2) for all conditions, and for the three conditions that were led to focus on the phonological forms (Out-loud Repetition, Subvocal Repetition, and Hear-another) the effect also emerged when participants were testing immediately after learning (Day 1). In the introduction we proposed that the pronounceability effect results from greater difficulty linking up hard-to-pronounce words with meanings due to their having weaker representations. However, it is possible that it is not about representational strength, but rather, direct interference in making the link (between meaning and form) introduced by difficulty in mental rehearsal. On this story, it is not about the phonological form per se, but rather, the interference introduced by the task, which happens to be greater for the hard-to-pronounce words.

To assess this possibility, we ran one further experiment in which participants were engaged in a secondary task that interfered with participants' ability to mentally rehearse words in working memory, thereby impairing the formation of stable representations and links, but in a way that was independent of phonological form; participants performed an articulatory suppression task during learning. Articulatory suppression is a way to manipulate phonological working memory (and thereby mental rehearsal) by repeatedly articulating a syllable or sequence. Moreover, articulatory suppression has previously been shown to interfere with learners' abilities to acquire the forms of words (Papagno, Valentine, & Baddeley, 1991). If the pronounceability effect found in Experiments 1-3 is a product of direct interference, with processing constraints more adversely affecting hard-to-pronounce words, then we should also expect to see a pronounceability effect for the Articulatory Suppression condition. If, however, the pronounceability effect is a result of a focus on the form causing distraction from learning the meanings for more difficult word forms, then we should not.

Method

Participants

Fifteen UC Berkeley undergraduates (5 male, 10 female) participated for course credit.

Procedure

Participants were told to repeat the sequence "1, 2, 3, 4, 5" constantly during learning and to try to maintain a constant rate while doing so.[4] They were told that this counting should be done quietly so they could still hear the presentation of the stimuli, but should be aloud. They were instructed to stop counting during the ten-second break between blocks. Participants were recorded to confirm that they had indeed counted throughout the learning phase.[5] All other aspects of the procedure were the same as in the previous experiments.

[4]Although this seems like a very easy task, it is actually quite difficult to do while attempting to learn new words.
[5]One participant's data was not included because she did not perform articulatory suppression throughout the learning task.

Results

Recognition Test

Percent correct scores. Data from the Articulatory Suppression and Out-loud Repetition conditions are shown in Figure 6. On Day 1, the main effect of difficulty was again significant ($F(1,28) = 11.61$, $p = 0.002$). However, so was the three-way interaction between difficulty, syllable, and condition ($F(1,28) = 4.68$, $p = 0.040$). When the results of each condition are analyzed separately, difficulty is significant in the Out-loud Repetition condition ($F(1,14) = 9.32$, $p = 0.009$), but not the Articulatory Suppression condition ($F(1,14) = 3.31$, $p = 0.090$). The interaction between difficulty and syllable was not significant for the Articulatory Suppression condition ($F(1,14) = 1.21$, $p = 0.290$), but as discussed previously, was for the Out-loud Repetition condition. On Day 2, only the main effect of difficulty ($F(1,28) = 5.20$, $p = 0.030$) was significant. Thus, the Articulatory Suppression participants showed a similar pattern of results to the Control condition; no pronounceability effect immediately following exposure, but more trouble with hard- than easy-to-pronounce words when tested after a delay. As before, participants performed significantly worse on the second test than the first (Day: $F(1,28) = 28.05$, $p < 0.001$).

Reaction times. The RT results for the Articulatory Suppression condition, shown in Table 2, again show a similar pattern to those from Experiment 1. On Day 1 response times were significantly faster for easy- than hard-to-pronounce words ($F(1,14) = 10.67$, $p = 0.006$). The same was true on the second day ($F(1,14) = 8.14$, $p = 0.013$). Again, the day between tests did not affect response times ($F(1,14) = 0.10$, $p = 0.795$), and no other factors or interactions were significant. These data again suggest that it was more difficult for participants to access the representations of the hard-to-pronounce words.

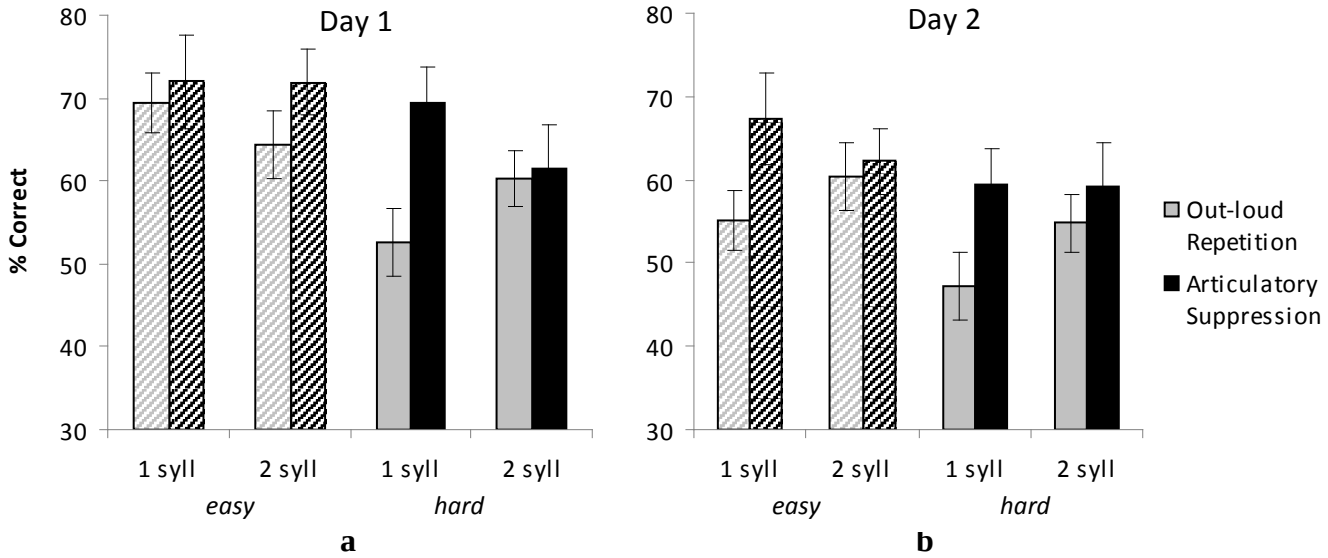

Figure 6. Percent correct for the Out-loud Repetition and Articulatory Suppression conditions on test 1(a) and test 2(b).

Discussion

The result of this last experiment suggests that it is specifically the attention to difficult word forms interfering with learning the link between form and meaning in the short term, not general interference from producing each word.

General Discussion

Various factors are known to affect the ease with which learners acquire the meanings of words in a new language, e.g. imageability of meanings and similarity among L2 word forms. We here examined the potential effect of the form of the word, asking if words with more difficult phonological forms, as defined by a learners' native language, are harder to learn meanings for; we hypothesized that it would be more difficult to form representations of hard-to-pronounce words because of their novel phonological patterns, and thus, more difficult to link them with meaning in memory, something we call the pronounceability effect. Over several experiments we found that this was indeed that case; harder to pronounce words were harder to learn meanings for than words that are easy to pronounce.

However, the effect manifested differently between conditions; sometimes there was an immediate effect of pronounceability, other times (e.g. the Control condition) it emerged only when participants were tested a day later. The results from Experiments 2-4 suggest that focusing a learner's attention on the forms rather than just the meanings exacerbates the effect and leads to an immediate difference between easy and hard words. There are several possibilities for why this might be the case. For instance, the focus on form may distract learners from the task of learning meanings. Alternatively, the ways in which we drew attention to form all involved either hearing or saying the word in (sometimes multiple) ways that differed from the original form, which could have made it more difficult to link forms and meanings. Although the present results cannot distinguish between these possibilities, they can rule out more general interference: when we interfered with all forms equally with articulatory suppression, participants did not show the immediate pronounceability effect.[6]

A trend common across experiments was a greater decrement in performance (between tests 1 and 2) for 1-syllable words than 2-syllable words. Perhaps although it is easier to recall a shorter word in the short term, the more long-term representation formed is no stronger for shorter than for longer words, so that when memory is tested after a delay there is no longer a difference. These results also highlight that the pronounceability of words is a more enduring factor than word length, since difficulty continued to be a significant factor on the second day of testing. Reaction times painted a similar picture – although word length should have an effect on reaction times, pronounceability proved to be a stronger factor in how quickly one could come to

[6] Interestingly, articulatory suppression did not lead to an overall decrease in performance. In fact, there was actually an (non-significant) advantage. This is somewhat surprising given the research stressing the crucial role of mental rehearsal in forming representations of novel phonological forms (e.g., Baddeley, et al., 1998). It is possible that the difference between our findings and others may be due to the fact that our participants did not have to recall the words, only recognize them.

a correct response.

Interestingly, there is a parallel finding in studies with infants. Werker and colleagues (Stager & Werker, 1997; Werker, Cohen, Lloyd, Casasola, & Stager, 1998) found 14-month old infants fail to discriminate two sounds that other studies show they can discriminate when visual stimuli are present. That is, when looking at visual stimuli they appear to no longer hear the difference between sounds we know they can distinguish. They explain this phenomenon in terms of insufficient processing resources; infants cannot both attend to phonetic detail and make a link between form and meaning (Werker, Fennell, Corcoran, & Stager, 2002). The results of our experiments show that a similar pattern may apply to L2 learners, that attending to word forms with phonological patterns distinct from the L1 takes away from the task of learning meanings.

Our results also have some interesting implications for teaching foreign languages. In particular, they suggest that repeating words aloud may not initially be beneficial for learning, as is often assumed. Instead, subvocal repetition may be ideal for learning the meaning of a novel word. Clearly, for learning to speak a language, out-loud repetition is necessary, but in the short-term, our results suggest that it may do more harm than good.

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Appendix: Stimuli

1 syllable easy-to-pronounce		*1 syllable hard-to-pronounce*	
blask	glin	chrzest	pchnąć
brać	jar	gmach	pstrzyć
dać	mig	kciuk	śeisk
druk	plik	któż	szczerk
farb	plusk	mgła	tknąć
gać	targ	mknąć	wchód

2 syllable easy-to-pronounce		*2 syllable hard-to-pronounce*	
fimfa	mimo	chłonąć	natchnąć
geba	nazad	chrzczony	spulchnić
jako	nerka	chwiejsność	szczeka
jego	plewa	dwieśćie	szczerość
kalosz	remiz	dżdżownik	szczwoł
kamasz	sumka	głuchnąć	tkliwość
klisza	tyfus	móżdżek	tłuścić
kozub	zalef	mroczość	ugrząźć
kropla	zamek	mruczeć	uiszczać