L2 Nonword Recognition and Phonotactic Constraints

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1 Introduction

Infants are believed to be initially equipped with capacities for processing and subsequent production of all speech sounds of any of the world's languages; however, by the end of the first year of their life they seem to lose that universal capacity and become constrained by the so-called phonological filter of the first language to which they are exposed (L1). Thus, by adulthood monolingual speakers are believed to be constrained by L1 phonotactic rules in their processing of both native and non-native phones (Macken, 1995; Brown, 1998; Halle et al., 1998). This line of reasoning is informed by Lenneberg's (1967) Critical Period Hypothesis for language acquisition, and, when projected into Second Language Acquisition (SLA) research, it predicts that in post-puberty foreign/second (L2) language learning the grammar of the first language, including the phonological knowledge, constrains L2 acquisition at all stages of development (Bley-Vroman, 1989; Brown, 1998).

However, others contend that, while the constraints of L1 are crucial at the initial stage of L2 acquisition, with increasing proficiency, the L1 filter can be overcome. Consequently, attainment of implicit native-like knowledge, including the L2 constraints that are different from those of L1, is possible (Schwartz and Sprouse, 1996; Cook, 1991). This empirical study joins the latter line of research by testing the salience of the L2 phonological filter in fluent Russian-English bilinguals and shows that, while differing from monolingual native speakers of English in overall accuracy and response time, L2 English speakers do not differ in the patterns of their intuitions from native speakers.

2 Theoretical Background

The long-established controversy about the role and strength of the phonological filter has raised a number of questions relevant for the discussions of both L1 and L2 acquisition and processing mechanisms. For instance, if English monolingual listeners tend to interpret any spoken utterance as if it were constrained with the organization of L1, then the question remains: how are sound clusters or words that do not occur (normally) in English—or, in other words, are illegal for the phonological filter of the English language—processed and interpreted by native speakers? Halle et al. (1998) in their analysis of the perceptual assimilation of illegal clusters report a series of studies, including their own, which find that speakers tend to mispronounce and misinterpret illegal clusters in acoustic queues, consistently adapting them to the phonotactic constraints of their native language. The speakers tend to mispronounce illegal clusters more often than legal ones and to substitute impossible initial clusters for possible ones in transcription tasks.

Another question that arises is whether fluent bilinguals process foreign/second language material through their L1 filter and are, so to speak, forever impervious to certain L2 contrasts or constraints. That is, it is worth exploring whether a high proficiency in L2 makes bilinguals sensitive to the constraints of L2 in addition to the constraints of their L1.

Answers to these questions have practical implications for SLA research, in which views differ on the nature and learnability of certain linguistic phenomena. A study of Japanese and Chinese learners of English by Brown (1998) suggests a strong L1 filter in L2 perception and production of phonologically relevant material. More specifically, the study shows that learners whose language has the relevant contrastive feature perceive and produce the critical phonemic differences, unlike the learners in whose native language this feature is either absent or non-contrastive. The author admits, however, that even for those learners who are constrained by their L1 in comprehension, there is a possibility of learning to *produce* the same segments. Another problem with Brown's study is that it tested the salience of single consonants in L2. However, as Hale et. al. (1998) convincingly show in their study of perceptual assimilation, processing of consonant-consonant (CC) clusters in different positions is more informative about the work of the phonological filter because, while many individual consonants may be allowed in the language, few of them are allowed in combination, and because even allowable CC clusters may be positionally restricted.

In contrast to Brown (1998), a range of empirical research studies undermines the presence of a strong L1 filter in the phonological systems of bilinguals. Studies of Dutch-English bilinguals (Van Heuven, Dijkstra, and Grainger, 1998) and French-English bilinguals (Jared and Kroll, 2001) report evidence of activation of both L1 and L2 in lexical decision tasks, with the accuracy varying depending upon whether L2 items are presented in a block or mixed with L1 stimuli. Paradis (2006) also reports that bilinguals are sensitive to L2 phonologically-relevant material in their processing of consonant-vowel (CV) clusters in novel words.

Due to the presented controversy, the main aim of the current project is to test the salience of second language phonotactic constraints for fluent L2 speakers of English in a reading lexical decision task that measures accuracy and response time to nonwords which violate or conform to the phonotactic constraints of English. Although the main focus of this project is the salience of target language phonotactic constraints for fluent L2 speakers, the recognition and response time to nonwords which violate or conform to the target language phonotactic constraints may also inform the general discussions about the learnability of phonological knowledge.

The choice of nonwords rather than real words as stimuli for the experiment is motivated by the desire to isolate effects of lexical knowledge and word frequency as possible confounds. As Rastle, Harrington and Coleheart (2002) point out in the report on their ARC Nonword Database, a close look at nonword processing is useful in the study of visual word recognition and reading aloud. Their earlier findings show that pseudohomophones (nonwords that sound like words) like *brane* are read aloud more quickly and rejected in lexical decision tasks more slowly than "control" nonwords like *brame,* which do not correspond phonetically to real words. The authors also point out that research findings show that decisions in word-naming tasks show influence of nonword distracters. Thus, they emphasize the necessity of approaching the study of nonword processing in a principled and systematic way, which is exactly the approach taken in this project.

As Andrews and Scarratt (1998) point out, the quasi-regular relationships between the orthographic and phonological forms of English words make it difficult to study mechanisms of word recognition as it becomes difficult to define what exactly constitutes a regular pronunciation of a word. According to the rule-based approaches (Coleheart, 1981; Rastle et.al., 2002), word and nonword pronunciations are based on the grapheme-phoneme relationship that occurs in the majority of words. In contrast, under analogy-based approaches (Glushko, 1979; Plaut et al., 1996), pronunciation is influenced by the frequency of word neighbors. Although both frameworks have unresolved disadvantages, both are reported to have high predictive power. Seidenberg, Plaut, Petersen, McClelland, and McRae (1994) compared the predictive capacity of the analogy-based and the rule-based computational models with results of human performance on word and nonword naming and found that both models accurately simulated the proportion of plausible pronunciations of nonwords produced by people (80% of a large set of nonword items).

Andrews and Scarratt (1998) also undertook a series of experiments aimed at examining the two approaches to studying nonword pronunciation. However, they focused on pronunciations assigned to nonwords that are based on inconsistent words because that is where the main difference between the two models lies. The pronunciations generated by the analogy model are sensitive to the frequency of the nonword's neighbors. This reflects the model's general assumption that total frequency of exposure (token frequency) is responsible for the strength of a particular orthographic-phonological connection. In contrast, the dual-route model's rule-based model is insensitive to frequency of word neighbors and bases its prediction on what occurs in most words, regardless of their frequency. Andrews and Scarratt's results confirm the predictions of rule-based generalization procedures and show that most people pronounce nonwords by assigning each grapheme the pronunciation that occurs in the majority of words, even when the nonword is similar to a common irregular word (e.g., *jood*). Their results show minimal evidence in support of the analogy frameworks as there are almost no influences of common word neighbors on nonword pronunciation.

Hence, the current study relies on the ARC Nonword Database and the MRC Psycholinguistic Database as a source of words and nonwords that are both orthographically and phonotactically legal. However, in order to control the possibility of analogy-based processing effects, the critical items also have similar neighborhood density (traditionally understood as the number of words that differ by only one sound segment, which may be added, subtracted or substituted) and comparable frequency of segments, as do items used as fillers and distracters.

Russian, unlike Japanese, is both sufficiently similar to and different from English, allowing a study design that keeps the above-mentioned methodological concerns in mind. More specifically, both English and Russian have a large number of monosyllabic words which start and/or finish with consonant clusters. That is, unlike Japanese, both English and Russian allow a range of consonant clusters both in the onset and in the coda of a syllable. At the same time, although some clusters like *sm*, *tr*, and *kl* are allowed in both languages, Russian allows clusters like *dv*, *mr*, and *vk*, which are disallowed in English. Note that individual consonants in these clusters are allowable in both languages. Also, despite the differences in the alphabetic systems, both languages have words with one-to-one phoneme-grapheme correspondence, like English *stand* and Russian *smert'*. In short, testing whether Russian native speakers are sensitive to English constraints establishes a good ground for comparison.

More specifically, this study tests whether monosyllabic illegal nonwords that violate phonotactic constraints of English as L2 (*dvind*) (which are at the same time legal for Russian L1), are sooner recognized as such than those nonwords that do not violate phonotactic constraints of either L1 or L2 (*flind*). Also, since, for literate participants, spelling conventions might serve as another confounding factor, the study only uses orthographically legal letter clusters for phonotactically legal English items. All the illegal items are divided based on the place of violation (word-initially or word-finally) because processing, both in native and second language, has been found to be incremental (Halle et al., 1998; Rastle et al., 2002; Hagiliassis, 2006); thus, how early the participants encounter the violation may play a role in accuracy and processing time.

The study tests the control group of monolingual English speakers and the test group of Russian-English bilinguals. Testing the control group of native speakers of English serves two purposes: to establish the base line for comparison with Russian-English bilinguals and to make sure that the battery of stimuli, especially the critical items devised with English and Russian phonotactic rules in mind, yields the overall results reported in previous research.

3 Hypotheses

Illegal nonwords (those violating phonotactic constraints of L2) should be recognized both by native English speakers and by Russian-English bilinguals more accurately and faster than legal nonwords (those without phonotactic violations of L2). Since word processing is incremental, I also hypothesized that nonwords with violations of English phonotactic constraints in the onset would be detected earlier than those with illicit consonant clusters at the word end. Naturally, I expected the overall accuracy of bilinguals to be lower and the average response time to be longer than that of monolingual English speakers. Consequently, since processing of legal items might involve access of lexical knowledge, I expected the accuracy of lexical decisions for legal nonwords to be lower for both groups, especially for bilinguals.

4 Method

4.1 Participants

The participant pool for this study includes graduate students and scholars at a public university as well as their spouses. The participants in the control group are 17 native speakers of English who do not know Russian, all enrolled in graduate level programs. The age of control group members ranges between 21 and 66, with the majority ranging between 25 and 40 years of age. The participants in the test group are 19 Russian-English bilinguals with varied self-reported proficiency. They have spent between 4 and 9 years in the US and either have, or are pursuing, graduate level education. The age of the bilingual participants ranges between 26 and 59 years of age.

4.2 Task

The lexical decision task performed by all participants was conducted via E-prime software. The task proceeds as follows: The participants see a single item appear on the screen after a fixation and are asked to press one key ([1]) if they see a real word and another key ([2]) if they see a non-word.

The lexical decision task involves 96 items: 48 critical items (12 for each condition) and 48 distracters. The critical conditions include: real English words, legal English nonwords, illegal English nonwords with word-initial violations, and illegal English nonwords with word-final violations. All the items in the critical conditions conform to the phonotactic constraints of Russian.

Before doing the experiment, there is a practice trial of 20 items. In the practice trial, the participants are provided with feedback on their accuracy and response time after each item. The main trial does not provide feedback.

The main limitation of this study is the difficulty in isolating phonotactic constraints from orthographic constraints. For this reason, the task manipulates only items which have single letter to single sound correspondences. Although a number of studies have relied on naming or transcription tasks, a lot of valuable information could be lost between perception and production. For future research, it would be useful to triangulate this experiment with an experiment in which the native and non-native speakers are asked to make lexical decisions about the same items *pronounced* by a native speaker rather than presented on a screen: the response time and accuracy may increase for both groups. Another means of triangulation could involve a pronunciation task, in which the native and non-native speakers would be asked to read out the words that appear on the screen. In this case response time would probably increase, especially for illegal items.

4.3 Materials

All the legal items are retrieved from the MRC Psycholinguistic Database and the ARC Nonword Database; all the illegal items are created by modifying the initial or final cluster of a legal word. The two databases are also used for reference in the selection of filler and distracter items.

As mentioned, the current study controls such factors as *frequency* and *neighborhood density* of words and segments. However, it also controls the segment duration of critical items. Kapatinsky (2005) argues that word duration (measured in segments) is equally important in the selection of stimuli. Thus, based on his studies that reveal speaker/hearer sensitivity to distant neighborhood, Kapatinsky assumes words to be neighbors if they share at least two-thirds of their total duration, measured in segments.

That is, to avoid duration confounds in response time measures, in this project, all critical items, as well as the majority of fillers and distracters have the same number of segments. Although I have not found reports of difference in processing time of consonants versus vowels, the consonant-vowel structure of all critical items is also controlled as CCVCC. Kapatinsky (2005) also emphasizes that segments in final and initial positions are more salient in neighborhood effects and might facilitate or hinder accuracy and processing time more so than those occurring in the intermediate position; hence my emphasis on word-initial and word-final violations. As far as neighborhood density is concerned, the word and nonword databases that I use as sources of stimuli only include items with relatively high neighborhood effect for word onsets and word body.

Critical items are monosyllabic nonwords with the CCVCC structure (consonant clusters at the end and beginning of the word, with a single vowel in the middle). Conditions one and two have nonwords with phonotactic violations of English (but not Russian) word-initially (*svasm*) and word finally (*fresv*) respectively. Conditions three and four, respectively, have legal nonwords and real words with no phonotactic violations of either language. None of the English nonwords resemble any Russian words. The items that serve as fillers and distracters include pseudo-homophones with the same CCVCC structure as the critical items as well as real words with a similar number of segments or letters but with slightly different segment/letter ordering (CCVCV, CVCCV, CCVVC etc.).

5 Results

As expected, accuracy was rather high for all the participants regardless of linguistic background, with significant differences between the groups. As shown in Table 1, among the control group of native speakers, there was a 98% mean of correct responses for all test items (including the fillers, but excluding the practice test items); their average accuracy for critical items was also 98%, ranging on the individual level between 90% and 100% of correct responses to critical items. Bilinguals, as the test group, showed 90% average accuracy for all stimuli; their average accuracy for the critical items was 93%, individually ranging between 85% and 100% of correct responses.

Stimuli	Bilinguals	Native
All	90	98
Critical	93	98

Table 1: Mean accuracy (% correct responses).

Table 2 reveals that there was both between-group and within-group variation in accuracy based on variable type. In spite of relatively high overall accuracy, as expected, the bilingual group had lower accuracy than the group of native speakers, especially on critical conditions word and legal nonword. Both groups showed lowest accuracy in identifying legal nonwords, i.e. with items which could satisfy the phonotactic constraints of both languages and which require lexical knowledge.

Condition	Bilinguals	Native
Word	93	99
badONSET	99	100
badCODA	100	98
legalNW	80	95
Mean	93	98

Table 2: Accuracy by condition (% correct responses).

According to the Paired Samples Test (Table 3), the difference between the control and test group in accuracy for legal conditions (Word and legalNW) is significant. In contrast, both groups were very similar in their high accuracy of rejecting all illegal items (badONSET and badCODA).

		Paired Differences					t	df	Sig.
		Mean	Std. Dev	MSe	95% Confidence Interval				
					Lower	Upper			
Pair 1	Word	.06	.09	.02	.022	.103	3.2	19	.005
Pair 2	badCODA	-.02	.04	.01	-.036	.004	-1.7	19	.104
Pair 3	badONSET	.00	.032	.01	-.011	.019	.57	19	.577
Pair 4	legalNW	.15	.22	.05	.045	.250	3.01	19	.007

Table 3: Bilingual vs. native speaker accuracy.

In terms of response time (RT), the control group shows an average RT of approximately 640 ms per item, with shorter RT for critical items (619 ms). Although the test group's response time to critical items (1022 ms) is also shorter than the average response time (1078 ms) to all stimuli, the bilinguals took almost twice as long as the monolinguals to make their lexical decisions. The average response time per item differed by almost 450; the differences between the test groups and the control groups in reaction time to all conditions are significant (Table 4).

		Paired Differences					t	df	Sig
		Mean	Std.Dev	MSe	95% Confidence Interval				
					Lower	Upper			
Pair 1	Word	-340.15	259.84	58.10	-461.76	-218.54	-5.85	19	.000
Pair 2	badCoda	-403.73	246.01	55.01	-518.86	-288.59	-7.34	19	.000
Pair 3	badOnset	-344.66	232.37	51.96	-453.41	-235.90	-6.63	19	.000
Pair 4	legalNW	-511.94	287.17	64.21	-646.34	-377.54	-7.97	19	.000

Table 4: Bilingual vs. native speaker response time.

Table 5 shows that by condition, the average RT of the control group and the test group was longest in reaction to legal nonwords (697ms and 1220ms respectively). The illegal items elicited a much shorter RT (604ms and 1001 ms respectively for bad codas and 590ms and 936ms respectively for bad onsets); RT was shortest for real words (583ms and 932ms respectively). The latter fact is not surprising, since the real words selected for this experiment had a high rate of frequency and neighborhood density.

Condition	Bilinguals	Native
Word	932	583
badOns	936	590
badCoda	1001	604
legalNW	1220	697
Mean	1022	619

Table 5. Mean Response Time (ms).

So, in support of the main hypothesis, illegal nonwords are rejected by both groups not only more accurately but also faster than legal items (perhaps because participants only need to rely on the phonotactic constraints for the former and already start accessing their lexical knowledge for the latter). As a Paired Sample Test shows in Tables 6 and 7, contrary to one of the hypotheses, the mean results for the control group do not show a significantly faster RT for nonwords with illegal onset than those with illegal coda.

		Paired Differences					t	df	Sig.
		Mean	Std. Dev	MSe	95% Confidence				
					Lower	Upper			
1	Word - badCODA	-3.90	69.62	14.52	-34.01	26.21	-.269	22	.791
2	Word - badONSET	1.63	59.82	12.47	-24.23	27.50	.131	22	.897
3	Word - legalNW	-93.15	92.87	19.36	-133.31	-52.99	-4.811	22	.000
4	badCODA - legalNW	-89.26	71.05	14.81	-119.98	-58.53	-6.025	22	.000
5	badCODA - badONSET	5.53	49.55	10.33	-15.89	26.96	.536	22	.598
6	badONSET - legalNW	-94.79	66.89	13.95	-123.71	-65.86	-6.796	22	.000

Table 6: Native Speaker Response Time.

Since the items in this experiment are relatively short and consist of only one syllable, joint results neither support nor question the hypothesis that RT depends on the place of violation. Had the items been polysyllabic or at least contained more letters, the difference might have been more pronounced. Moreover, for the bilingual test group this hypothesis is supported by the significant difference of 65 ms.

		Paired Differences					T	df	Sig.
		Mean	Std. Dev	MSe	95% Confidence				
					Lower	Upper			
1	Word – badCODA	-59.17	146.10	32.67	-127.55	9.21	-1.811	19	.086
2	Word – badONSET	-.65	155.24	34.71	-73.31	71.99	-.019	19	.985
3	Word – legalNW	-264.81	177.20	39.62	-347.74	-181.88	-6.683	19	.000
4	badCODA – legalNW	-205.65	104.11	23.28	-254.37	-156.92	-8.834	19	.000
5	badCODA – badONSET	58.51	104.58	23.38	9.57	107.46	2.502	19	.022
6	badONSET – legalNW	-264.16	159.77	35.73	-338.93	-189.38	-7.394	19	.000

Table 7: Bilingual Speaker Response Time.

Also, the legal nonwords elicited significantly longer response times from both groups than either of the illegal conditions. This suggests that processing is indeed incremental and items with illicit phonological material are rejected very early. Similarly, the fast response times for real words suggest that the high frequency of items also allows participants to make correct lexical decisions quickly, while indeterminate material is more difficult to process for both monolingual and bilingual speakers.

6 Discussion

Overall, the findings suggest that native English speakers are indeed sensitive to the phonotactic constraints of English and promptly use their L1 phonological filter to reject words containing illegal consonant clusters. It is also not surprising that among legal items, real words were identified as such quicker than legal nonwords because the participants could rely both on their lexical knowledge and the high frequency and neighborhood density of the real items. Since the control group's results of the experiment support a number of previous claims on processing of nonwords in general and illegal clusters in particular, it leads to two important conclusions: the phonological filter does, indeed, affect the way people (at least monolinguals) process nonwords; and the critical items for this experiment are well-suited for testing the proposed hypotheses. It is worth noting that after checking if any critical items were more than two standard deviations away from the average for a specific condition, all items were within the limits based on RT, but 5 items could be excluded based on accuracy results. Nevertheless, upon exclusion of outliers from the data pool, the overall pattern remains the same.

As expected, for the test group of fluent non-native speakers, the overall pattern was the same as in the control group but with slower response times and lower accuracy. Specifically, as expected, there was a considerable increase in processing time for legal nonwords as compared to illegal nonwords. Also, the non-native speakers were slower than the native speakers at distinguishing the real words and less accurate. Also, as expected, the word-initial violations were spotted earliest of all. Perhaps the fact that only bilinguals had a significant effect in terms of place of violation supports the idea that they need to be especially aware of the relevant L2 material and that learned constraints are evaluated incrementally rather than all at once.

Since the results of both groups support my main hypothesis, they challenge the assumption about the strength of L1 phonological filter, at least for bilingual speakers. On the one hand, the results show the effects of the L1 filter for monolinguals, but on the other hand, these results also support the evidence of activation of both L1 and L2 in bilinguals provided by Van Heuven, Dijkstra, and Grainger (1998) and Jared and Kroll (2001). Although such results do not necessarily deny the L1 constraints on production and comprehension of some L2 material, they put Brown's (1998) findings in the realm of linguistic performance, rather than linguistic competence. More specifically, if L2 speakers are able to judge stimuli that are allowed in L1 but violate phonotactic constraints of L2, it shows their knowledge of phonetically relevant information that is never formally taught and cannot be attributed to transfer from L1. Such results do not resolve the dispute whether the nature of processing is rule-based or analogy-based, but they provide evidence that regardless of the learning/acquisition path, L2 material that is not accessible in the L1 can be internalized by fluent L2 speakers.

In sum, the results of this study serve as evidence against Bley-Vroman's (1996) claims about fundamental differences in the nature of L1 and L2 linguistic behavior and in favor of the full access view (Swartz and Sprouse, 1996) as well as Cook's (1991) idea of multi-competence. Under this latter view, L2 users are not ever-failing approximations of an idealized native speaker, but rather multi-competent users of both languages, who resort to both native and L2 linguistic repertoires and, thus, have to juggle a larger pool of linguistic constraints.

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