Perception and Recoverability of Modified English L2 Codas

Ali S. Alelaiwi and Steven H. Weinberger

Abstract Previous research has shown that when L2 learners are faced with illegal structures, they employ various modification strategies to avoid such structures. This chapter reports on a study that examined the perception of two of these strategies: deletion and epenthesis. The participants were presented with monosyllabic words with codas modified by either deletion or epenthesis and asked if they favored one modification strategy over the other. A hundred and thirty-seven listeners from three different language backgrounds—English, Spanish, and Japanese—were recruited to complete this perceptual task. Our findings revealed that epenthesis was significantly preferred over deletion regardless of the listeners' L1, which provides support for the Recoverability Principle.

Keywords Recoverability · Syllable modification · Epenthesis · Coda perception · Sonority

1 Introduction

Previous studies have shown that when second language (L2) learners are faced with structures that are illegal in their first language (L1), they tend to simplify such structures (Abrahamsson, 2003; Hansen, 2004; Osburne, 1996; Sato, 1984; Weinberger, 1994; Yavaş, 2011). This chapter examines two different strategies of syllable structure simplification, namely, consonant deletion and vowel epenthesis, from a perceptual perspective. Specifically, it reports on a perception study that we conducted to investigate the *Recoverability Principle* (Weinberger, 1994), which suggests that epenthesis is functionally superior to deletion because it results in relatively less ambiguous structures.

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This chapter is organized as follows. Section 2 reviews related studies on the production of English codas and provides the necessary theoretical background. Section 3 describes the purpose of our study, and the languages and predictions we tested. Section 4 explains the methodology we used to collect and analyze the perceptual data, including information about the participants, stimuli, and procedures. Section 5 presents and discusses our findings. Finally, Sect. 6 offers our conclusions and identifies areas of future research.

2 Literature Review

2.1 Theoretical Framework

2.1.1 The Recoverability Principle

Weinberger (1987) proposed the Recoverability Principle to guide preference structures resulting from phonological operations such as deletion and epenthesis. For example, if we examine a word with a CVC syllable structure such as *lead*, there are two possible simplification outcomes for the target word in (1):

(1) Target word	Deleted form	Epenthesized form
lead [lid]	[li]	[lidə]

The deleted form results in more ambiguity since it could be interpreted as *Lee* (proper name), *leaf, leave, lean, lead, leak, leash, lease*, etc. The epenthesized form [lidə], on the other hand, results in less potential ambiguity because it can only be interpreted as *lead,* or *leader* if the person speaks a variety of English where the deletion of final [ɹ] is acceptable. Hence, as this example illustrates, epenthesis is preferred when it comes to meaning preservation (Weinberger, 1994). The Recoverability Principle is formally expressed in (2):

> (2) Modifications resulting in recoverable outputs are preferred over modifications resulting in nonrecoverable outputs. (Weinberger, 1987)

According to Weinberger (1994), the Recoverability Principle is part of a universal grammar that matures following a preset schedule. He argues that children do not employ epenthesis as a simplification strategy because the Recoverability Principle is not yet active due to children's limited lexicon. By the time it becomes active, children whose native language allows coda consonants are already capable of producing the complex structures. Based on this claim, it can be predicted that adult L2 learners will employ epenthesis as their predominant simplification strategy since the Recoverability Principle is presumably active. However, studies investigating cluster simplification strategies show that this is not always the case (e.g., Abrahamsson, 2003; Benson, 1988; Sato, 1984; Weinberger, 1987).

2.1.2 Sonority

It is fairly well established that, cross-linguistically, the segments within a syllable pattern in a certain manner based upon sonority (Broselow & Finer, 1991; Carlisle, 2001; Clements, 1990; Hansen, 2001; Parker, 2002; Tropf, 1986). A universally preferred syllable is one in which the nucleus is the most sonorous constituent, whereas the sonority of the other segments in the syllable (coda and onset segments) decreases continuously outward from the nucleus. This organization of segments within a syllable is referred to as the *Sonority Sequencing Principle* (Clements, 1990; Parker, 2002), which is formally expressed in (3):

(3) Between any member *x* of a syllable and the syllable peak *p*, only sounds of higher sonority rank than *x* are permitted. (Kar, 2010)

One-member onsets and codas by definition must adhere to the Sonority Sequencing Principle since they must be comprised of segments that are less sonorant than the nucleus (Carlisle, 2001). However, one-member onsets and codas differ dramatically from each other according to which segments are preferred. If an onset consists of one segment, there is a universal tendency for this segment to be low in sonority, which results in obstruents being preferred over sonorants in that position. The reverse is true for codas where one-member codas that are high in sonority are preferred. This generalization is referred to as the *Sonority Dispersion Principle*, which requires sonority to be maximally dispersed in the initial demisyllable and minimally dispersed in the final demisyllable (Clements, 1990). In other words, the sharper the rise in sonority from the beginning of the syllable to the nucleus, the better the syllable. The opposite is true for the end of the syllable in which the fall of sonority from the nucleus needs to be minimal.

A number of different sonority scales has been proposed in the literature, but in this chapter, the scale in (4) will be used as a starting point. Each of the segments forming the syllable will take its place on this scale, according to its sonority properties.

(4) Stops < Fricatives < Nasals < Liquids < Glides < Vowels. (Morelli, 2003)

Affricates are not usually included in most common scales of sonority due to their complex nature. Some researchers suggest that they have the same sonority profile as stops (Bolinger, 1962; Cardona, 1988). Others suggest that affricates are between stops and fricatives, as in (5).

(5) Stops < Affricates < Fricatives. (Goldsmith, 1995; Katamba, 1989; Puppel & Fisiak, 1992)

In our study (see Sect. 3), we treated affricates as a separate sonority group due to their debatable classification. Thus, we followed the scale in (6) and invoked sonority as one of the contributing factors in the deletion/epenthesis asymmetry.

(6) Stops < Affricates < Fricatives < Nasals < Liquids < Glides < Vowels.

2.2 Previous Studies on the Production of English Codas

Several studies have investigated the production of English codas by L2 learners. However, all have focused on production (Benson, 1988; Hansen, 2004; Sato, 1984; Wang, 1995; Weinberger, 1987; Yavaş, 2011). For example, Sato (1984) conducted a longitudinal study examining the production of two-member codas in spontaneous speech samples of two Vietnamese children at three different time points during a period of 10 months. The results showed that, of all non-target forms, 2.43% were modified by feature change, 84.14% were modified by cluster reduction, and 13.41% were modified by cluster deletion. Sato concluded that native speakers of Vietnamese tend to modify codas by single consonant deletion rather than epenthesis or deletion of the entire cluster.

Similarly, Benson (1988) examined the production of monosyllabic English words in informal conversations by two Vietnamese speakers of English. The results showed that the first participant had 396 attempted productions of monosyllabic closed syllable target words (CVC), of which 67 cases (16.91%) were modified by deletion. The second participant had 141 attempted productions of monosyllabic closed syllable target words (CVC), of which 25 cases (17.7%) were modified by deletion. Similar to Sato's study, Benson (1988) pointed out that none of the two participants used epenthesis as a modification strategy.

Weinberger (1987) examined the production of one-member, two-member, and three-member word-final codas by four intermediate Mandarin speakers of English and found that they exhibited 50% epenthesis and 50% deletion. Weinberger suggested that this finding may have been due to the participants' overall English proficiency. He argued that adult L2 learners with a more developed knowledge of the target lexicon could be more sensitive to the Recoverability Principle. Indeed, this has been shown to occur developmentally in L2 acquisition by Abrahamsson (2003).

Yavaş (2011) investigated the acquisition of two-member English coda clusters by 19 native speakers of Spanish. He looked at the production of 24 monosyllabic and mono-morphemic English words and concluded that L1 Spanish speakers only modified these target words by deletion. There were 139 cases of deletion out of 456 possible cases (30% deletion). This finding actually represents a challenge for the generalizability of Weinberger's (1987) proposal. If we apply Weinberger's proposal to an English word like *milk* [mɪlk] (i.e. a word with a two-member coda cluster similar to those used in Yavaş's study), we should end up with [mɪl.kV] or [mɪ.lV.kV] (i.e., the epenthesis form). Nevertheless, such outcomes were not produced by the Spanish speakers. However, it is worth pointing out that Yavaş (2011) did not mention anything regarding the learners' overall English proficiency. Thus, it is possible that they were non-advanced learners of English. Consequently, it is also possible that they had not yet developed the adequate linguistic knowledge of the target lexicon that would lead them to employ the Recoverability Principle proposed by Weinberger (1987). Nevertheless, the possibility that Spanish learners have a general preference for coda deletion as a simplification strategy cannot be ignored, either. That is to

say, regardless of the number of syllables in the target words or their overall English proficiency level, it is possible to predict, based on Yavaş's findings, that Spanish learners of English will choose deletion as the main strategy when faced with illegal codas.

The tendency of a certain language to systematically apply one repair strategy over another is not entirely unusual. For example, it has been observed that the English interdentals [θ, ð] are replaced either by [t] or [s], depending on the speaker's L1. Generally, the segment used for substitution is consistent for speakers of a given language. For example, L1 German speakers are reported to use [s], whereas L1 Russian speakers use [t] systematically (Lombardi, 2003). This area of research and, specifically, how repair strategies differ across languages and between speakers and listeners, needs further investigation. Based on the observation that speakers of a certain language may systematically apply one repair strategy over another and that it is not yet known whether speakers and listeners of the same language would use the same repair strategy, we conducted a study that examined the perception of structures modified by either epenthesis or deletion by listeners of three different L1s.

3 The Study

This study examined the preference between two strategies (vowel epenthesis and consonant deletion) of syllable structure simplification using a perceptual task (Boudaoud & Cardoso, 2009; Eckman, 1991; Edge, 1991). As far as we know, at the time of this study no previous study had examined the difference between epenthesis and deletion using a perceptual task. By conducting a perception experiment, we addressed this gap in the literature.

Based on functional approaches to phonology and phonetics, speakers are governed by two conflicting forces: (a) their tendency to minimize articulatory effort, and (b) their need to maximize intelligibility (Abrahamsson, 2003). The first is based on the speaker, and it manifests itself in phonological processes that result in unmarked structures. The second is oriented towards the needs of the listener, and it manifests itself in the need to maintain distinctness and understandability. With respect to the processes under examination (deletion and epenthesis), if adult speakers are to minimize articulatory complexity, deletion should be the strategy of choice. If, however, adult speakers ultimately want to be understood, they should employ epenthesis rather than deletion since it accommodates the listeners' needs by maintaining relevant information and avoiding ambiguous forms, as predicted by the Recoverability Principle (Weinberger, 1994). Nevertheless, as evidenced from the previously mentioned production studies, epenthesis is not always the strategy of choice by adult speakers. Thus, conducting a perception experiment allowed us test the implications of the Recoverability Principle on listeners by factoring out the vagaries of articulation concerns often associated with production experiments.

3.1 Languages Under Examination

In our study, we examined the perception of structures modified by either epenthesis or deletion by listeners whose L1 was Japanese, Spanish, and English. Prior research has shown that Japanese listeners perceive a vowel when presented with words containing illegal structures even when the vowel was not actually present (Dupoux et al., 1999).

Furthermore, Japanese is more restrictive in the range of coda consonants it allows compared to English. For example, Japanese only allows codas in two cases: (a) if the segment is a nasal, or (b) if it is the first part of a geminate which can only appear word-medially (Tsuchida, 1995). In contrast, as previously discussed, Yavaş (2011) has shown that Spanish speakers favor deletion when it comes to modifying illegal codas with two consonants. Since Yavaş (2011) only examined two-member coda clusters in a production study, it is unknown whether this finding can be generalized to the perception of singleton codas. Our study attempted to fill this gap. Similar to Japanese, Spanish has a very limited set of coda possibilities. It only allows five consonants in the coda position [d, s, n, ɾ, l] (Núñez-Cedeño et al., 2014). English, on the other hand, allows for a much larger set. Most English consonants can occur in the coda position [p, b, t, d, k, ɡ, m, n, ŋ, f, v, θ, ð, s, z, ʃ, ɹ, l, dʒ, tʃ] (Gregová, 2010). Finally, since the stimuli in our study consisted of English words modified by either epenthesis or deletion, the perception of English listeners was examined as a control group.

3.2 Predictions

Based on prior research, we hypothesized that:

- The Recoverability Principle operates in the perception grammar.
  - Words modified by epenthesis will be chosen more frequently by adult listeners of all languages (Weinberger, 1994).
- Sonority of the coda consonant will influence the modification strategy.
  - If the original word ends on a segment with low sonority (e.g., [t]), listeners will choose the word modified by epenthesis. This is because epenthesis creates another syllable in which the segment previously in the coda will be the onset of the new syllable, and onsets with low sonority are preferred (Clements, 1990).
  - If the original word ends on a segment with high sonority, listeners will choose the word modified by deletion.
- There will be native language bias.
  - Spanish listeners will choose words modified by deletion more often (Yavaş, 2011).

  - Japanese listeners will choose words modified by epenthesis more often (Dupoux et al., 1999).

- Proficiency matters.
  - Listeners with higher English proficiency will choose words modified by epenthesis more frequently (Weinberger, 1994).

4 Methodology

4.1 Participants

Our study examined listeners from three different language backgrounds: English, Japanese and Spanish. A total of 137 listeners were recruited via Amazon Mechanical Turk, and each was given $1.50 as compensation. Participants who reported having hearing or speaking issues were excluded from the study. In addition, Japanese and Spanish participants were asked to self-rate their English proficiency and frequency of English use using a five-point scale (1 = very low proficiency/frequency of use, and 5 = high proficiency/frequent language use). The percentages were calculated by summing up all the proficiency scores for each language group and then dividing the actual outcome by the total possible proficiency score for that particular language. The obtained decimal value was then multiplied by 100 to get the percentage. Table 1 displays participants' demographic information and obtained scores.

The three groups were similar in terms of listeners' mean age. In addition, independent-samples *t*-tests revealed that there were no significant differences with respect to age of onset, $t(74) = 0.648$, $p = 0.519$, and self-reported English proficiency, $t(74) = 0.346$, $p = 0.731$, between the Japanese and Spanish groups. However, the Japanese participants reported a higher frequency of English use (70.52%) compared to the Spanish participants (48.75%), and this difference was statistically significant, $t(37) = -5.29$, $p < 0.001$. Such difference could be related to participants' differences in length of residence, with the Japanese participants averaging 11 years and the Spanish averaging only two years, which was also found statistically significant: $t(74) = 5.69$, $p < 0.001$.

Table 1 Participants' demographic information

L1	*N*	Age	Gender	Age of onset	Length of residency	English proficiency	Frequency of English use
English	51	(21—70) *M* = 29.47	M = 27 F = 24	NA	NA	NA	NA
Japanese	38	(18—43) *M* = 31.83	M = 21 F = 17	(3—21) *M* = 8.39 *SD* = 4.99	(0—35) *M* = 11.1 *SD* = 8.25	84.73% *M* = 4.24 *SD* = 0.542	70.52% *M* = 3.53, *SD* = 0.830
Spanish	48	(19—52) *M* = 31.58	M = 34 F = 14	(1—25) *M* = 7.71 *SD* = 4.18	(0—25) *M* = 2.16 *SD* = 4.69	82.5% *M* = 4.18 *SD* = 0.766	48.75% *M* = 2.50 *SD* = 0.191

4.2 Stimuli

The stimuli consisted of 38 monosyllabic monomorphemic English nouns with a CVC syllable structure. In each session, the participants were presented with two modified forms of each word of the original 38 words, one with vowel epenthesis (CVCV) and the other with consonant deletion (CV). This means that they listened to 76 (38 × 2) forms of the experimental words, and they had to choose one variant per question.

The experimental words were chosen to cover all consonants that can occur in the English coda position. Nineteen different coda consonants were included: [p, b, t, d, k, g, f, v, θ, s, z, ʃ, tʃ, dʒ, m, n, ŋ, l, ɹ]. One consonant, the voiced interdental fricative [ð], was not included because it was not found in coda positions in monosyllabic nouns. Each of the coda consonants appeared twice in two different words. This resulted in a total of 38 target words per participant. In addition, the participants were presented with 15 nonexperimental words (fillers). These fillers consisted of words with onset clusters, such as *flake*, for which each question contained two forms: the original form [fleɪk] and another that was modified by deleting one member of the onset cluster [leɪk]. Of these 15 fillers, three were used in a brief training session.

All experimental words and fillers (see Appendix) were produced by a phonetically-trained male native speaker of English. The speaker's age was 62. He was born in Pittsburgh, PA, USA, and he reported having knowledge of Mandarin. The speaker was asked to produce two forms of each word. For the words modified by deletion, he was asked to drop the coda. For the words modified by epenthesis, he was asked to add the vowel [ə]. The words were recorded with a 44.1 kHz sampling rate using Zoom H2 Handy Recorder in the Acoustics Lab at George Mason University. The recorded words were normalized at 3db, and the epenthesized vowels were checked for duration consistency.

4.3 Procedure

The experiment was designed in Qualtrics, and then it was linked to Amazon Mechanical Turk. All participants first completed a consent form. Once they agreed, they were asked to provide some demographic information: native language, age, gender, English proficiency, frequency of English use, length of residency, age of onset, place of birth and method of learning English (naturally or academically). Participants who did not meet the requirements for the study, such as those who reported having hearing problems, were excluded from the analysis. All participants were required to wear headsets and enter the model name of the headset they were using. Those who failed to provide this information were excluded from the study. Once they completed the background information, they were presented with three stimuli containing filler words as part of a training session. After the familiarization trials, the actual experiment started. Each participant was presented with 50 stimuli containing

38 experimental words and 12 fillers with corresponding pictures in a randomized order (see Appendix). For each word, participants heard two forms. For example, for the English word *couch*, participants were shown a picture of a couch, and heard the two modified forms [kaʊʧə] and [kaʊ] denoting the picture. They were instructed to choose the word that best matched the picture based on their judgment.

4.4 Analysis

Jamovi (Datalab.cc, n.d.) was used to perform the statistical analysis. A mixed model regression test was conducted to see if the listeners' native language and the sonority of coda consonants significantly influenced the choice of repair strategy (deletion vs. epenthesis). In this model, *deletion* was set as the dependent variable; *language*, *sonority* and *sonority*language* (the interaction between language and sonority) were the fixed factors; *participant* and *word* were the random structures. We also performed a post-hoc test to compare sonority profiles. We report the results in Sect. 5.

5 Results and Discussion

The results of the mixed model regression test indicate that the choice of strategy (epenthesis vs. deletion) was significantly influenced by the participants' native language [$F(2, 142) = 14.12$, $p < 0.001$] and the sonority profile [$F(4, 33) = 2.86$, $p = 0.038$]. The interaction between language and sonority was also statistically significant [$F(8, 5024) = 4.88$, $p < 0.001$].

In order to examine the combined performance of all groups in relation to specific sonority profiles, a Bonferroni post-hoc analysis was conducted. The results showed that liquid was the only sonority level that significantly exhibited deletions ($p = 0.005$) compared to other sonority levels. Furthermore, when we examine the performance of a specific language in relation to specific sonority profiles compared to the other languages, we find that Spanish participants had a significant tendency for deleting stops ($p < 0.001$), fricatives ($p = 0.017$), nasals ($p = 0.008$), and liquids ($p = 0.018$). Moreover, Japanese participants had a significant tendency for deleting stops ($p = 0.017$) and nasals ($p = 0.027$) (see Table 2).

Figure 1 displays the deletion frequency for all examined languages across all sonority profiles.

In the following subsections, we discuss the results of each language group in more detail.

Table 2 Fixed effects parameter estimates

Names	Effect	Estimate	95% CI			*Df*	*T*	*p*
			SE	Lower	Upper			
(Intercept)	(Intercept)	0.09186	0.01405	0.06433	0.11939	98.8	6.540	< 0.001
Language1	Japanese—(English, Japanese, Spanish)	0.03884	0.01554	0.00839	0.06929	141.6	2.500	0.014
Language2	Spanish—(English, Japanese, Spanish)	0.03766	0.01463	0.00898	0.06634	141.6	2.573	0.011
Sonority1	fricative—(affricate, fricative, liquid, nasal, stop)	− 0.02292	0.01589	− 0.05406	0.00822	33.1	− 1.443	0.158
Sonority2	liquid—(affricate, fricative, liquid, nasal, stop)	0.07049	0.02356	0.02430	0.11667	33.1	2.991	0.005
Sonority3	nasal—(affricate, fricative, liquid, nasal, stop)	− 0.01505	0.02010	− 0.05444	0.02434	33.1	− 0.749	0.459
Sonority4	stop—(affricate, fricative, liquid, nasal, stop)	0.00872	0.01589	− 0.02242	0.03986	33.1	0.549	0.587
Language1 ✻ Sonority1	Japanese—(English, Japanese, Spanish) ✻ fricative—(affricate, fricative, liquid, nasal, stop)	0.00406	0.00881	− 0.01321	0.02133	5024.0	0.461	0.645
Language2 ✻ Sonority1	Spanish—(English, Japanese, Spanish) ✻ fricative—(affricate, fricative, liquid, nasal, stop)	− 0.01979	0.00830	− 0.03606	− 0.00352	5024.0	− 2.384	0.017
Language1 ✻ Sonority2	Japanese—(English, Japanese, Spanish) ✻ liquid—(affricate, fricative, liquid, nasal, stop)	0.00276	0.01307	− 0.02286	0.02838	5024.0	0.211	0.833
Language2 ✻ Sonority2	Spanish—(English, Japanese, Spanish) ✻ liquid—(affricate, fricative, liquid, nasal, stop)	0.02917	0.01231	0.00503	0.05330	5024.0	2.369	0.018

(continued)

Table 2 (continued)

Names	Effect	Estimate	95% CI			*Df*	*T*	*p*
			SE	Lower	Upper			
Language1 ✻ Sonority3	Japanese—(English, Japanese, Spanish) ✻ nasal—(affricate, fricative, liquid, nasal, stop)	0.02470	0.01115	0.00285	0.04655	5024.0	2.216	0.027
Language2 ✻ Sonority3	Spanish—(English, Japanese, Spanish) ✻ nasal—(affricate, fricative, liquid, nasal, stop)	− 0.02766	0.01050	− 0.04824	− 0.00708	5024.0	− 2.634	0.008
Language1 ✻ Sonority4	Japanese—(English, Japanese, Spanish) ✻ stop—(affricate, fricative, liquid, nasal, stop)	− 0.02100	0.00881	− 0.03827	− 0.00373	5024.0	− 2.383	0.017
Language2 ✻ Sonority4	Spanish—(English, Japanese, Spanish) ✻ stop—(affricate, fricative, liquid, nasal, stop)	0.03364	0.00830	0.01737	0.04991	5024.0	4.053	< 0.001

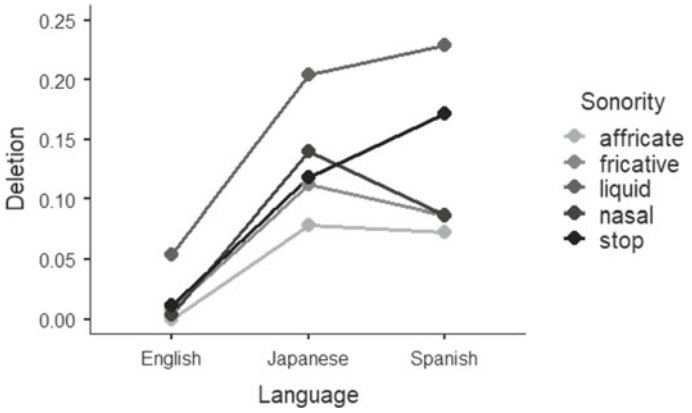


Fig. 1 Deletion-choices based on language and sonority

5.1 English Participants

A total of 51 native speakers of English participated in this study. They were each presented with 38 experimental words and were asked to choose between words that were modified by epenthesis or deletion. This resulted in a total of 1,938 tokens. Out of 1,938 tokens, words modified by epenthesis were chosen 1,914 times (98.76%) and words modified by deletion were only chosen 24 times (1.23%).

The difference between epenthesis and deletion was statistically significant ($\beta = 0.091$, $p < 0.001$). Native speakers of English had a dominant preference for words modified by epenthesis, which provides support for the Recoverability Principle that states that words modified by epenthesis are easier to disambiguate. Based on these findings, we could argue that in real communication, with all else being equal and from a listener's perspective, native English speakers would find words modified by epenthesis preferable to those modified by deletion. And as we continue to argue in this chapter, language users pay attention to lexical ambiguity.

We also examined the specific segments in the coda position. Based on a sonority perspective, we predicted that, if the coda had a segment with low sonority, listeners would choose the word modified by epenthesis since the original coda would be transformed into an onset where segments with lower sonority are preferred. On the contrary, if the original word ended on a segment with high sonority, listeners would choose the word modified by deletion based on the Sonority Dispersion Principle (Clements, 1990). Table 3 lists the exact number of epenthesis and deletions produced by the English participants based on sonority profile. The column labeled *possible total* indicates the total number of tokens for each sonority profile. This number is the result of the original number of words ending in segments in a particular sonority profile multiplied by the number of participants.

As mentioned previously and shown in Table 3, epenthesis was predominantly more frequent than deletion for the English participants. When it comes to sonority,

Table 3 English: Total epenthesis vs. deletion based on sonority profile

Sonority	Possible total	Epenthesis	Deletion
Stops	12 × 51 = 612	605 (98.85%)	7 (1.14%)
Affricates	4 × 51 = 204	204 (100%)	0 (0%)
Fricatives	12 × 51 = 612	607 (99.18%)	5 (0.81%)
Nasals	6 × 51 = 306	305 (99.67%)	1 (0.32%)
Liquids	4 × 51 = 204	193 (94.60%)	11 (5.69%)
Totals	1938 (100%)	1914 (98.76%)	24 (1.23%)

Table 4 Post hoc comparisons—English ✻ Sonority

Language	Sonority	Language	Sonority	Difference	*SE*	Test	*df*	Pbonferroni
English	Liquid	English	Nasal	0.05065	0.0394	1.2848	Inf	1.000
English	Liquid	English	Stop	0.04248	0.0353	1.2047	Inf	1.000
English	Nasal	English	Stop	–0.00817	0.0305	–0.2675	Inf	1.000
English	Affricate	English	Liquid	–0.05392	0.0432	–1.2485	Inf	1.000
English	Affricate	English	Nasal	–0.00327	0.0394	–0.0829	Inf	1.000
English	Affricate	English	Stop	–0.01144	0.0353	–0.3244	Inf	1.000
English	Affricate	English	Fricative	–0.00817	0.0353	–0.2317	Inf	1.000
English	Fricative	English	Liquid	–0.04575	0.0353	–1.2974	Inf	1.000
English	Fricative	English	Nasal	0.00490	0.0305	0.1605	Inf	1.000
English	Fricative	English	Stop	–0.00327	0.0249	–0.1311	Inf	1.000

liquids exhibited the greatest number of deletions totaling 5.69%. We further examined the 11 cases of liquid deletions and found that out of the 11 cases, 10 cases (90.9%) were instances of [ɹ] deletions. This higher percentage of [ɹ] deletions compared to other consonants could be attributed to the acceptability of [ɹ] deletions in many dialects of English.

To see if the differences between the sonority profiles were statistically significant, a post-hoc test was performed. The results showed that the English participants generally preferred epenthesis regardless of the sonority profile. Table 4 also shows that the slightly higher percentage of liquid deletions is not statistically significant. Based on these findings, we can conclude that native English speakers find words modified by epenthesis preferable regardless of sonority.

5.2 Japanese Participants

There was a total of 38 Japanese participants in this study. Each participant was presented with 38 experimental words and were asked to choose between words that were modified by epenthesis or deletion. This resulted in a total of 1,444 tokens.

Out of these 1,444 tokens, words modified by epenthesis were chosen 1,264 times (87.53%) and words modified by deletion were chosen 180 times (12.46%). This difference between epenthesis and deletion was statistically significant ($\beta = 0.038$, $p = 0.014$), which provides additional support for the Recoverability Principle (i.e., words modified by epenthesis are preferred).

We also examined the specific segments that underwent deletion. As Table 5 shows, similar to the English sample, epenthesis was predominantly more frequent across all sonority types.

With respect to deletions, the most sonorous categories, namely liquids and nasals, had slightly higher deletions compared to fricatives and stops. Specifically, liquids exhibited the highest percentage (20.39%), and nasals came immediately after (14.03%). A post-hoc test was conducted to see if there was a significant interaction between deletions and sonority. Table 6 shows that the Japanese participants' rate of deletion was not significantly influenced by the sonority profile. This indicates that, similar to English, Japanese speakers find words modified by epenthesis preferable regardless of sonority.

Compared to the Japanese sample, the English sample had a relatively greater preference for epenthesis. The English participants chose epenthesis 98.76% of the time compared to 87.53% in the Japanese sample. A post-hoc test showed that this

Table 5 Japanese: Total epenthesis vs. deletion based on sonority profile

Sonority	Possible Total	Epenthesis	Deletion
Stops	12 × 38 = 456	402 (88.15%)	54 (11.84%)
Affricates	4 × 38 = 152	140 (92.10%)	12 (7.89%)
Fricatives	12 × 38 = 456	405 (88.81%)	51 (11.18%)
Nasals	6 × 38 = 228	196 (85.96%)	32 (14.03%)
Liquids	4 × 38 = 152	121 (79.60%)	31 (20.39%)
Totals	1444 (100%)	1264 (87.53%)	180 (12.46%)

Table 6 Post hoc comparisons—Japanese ✻ Sonority

Language	Sonority	Language	Sonority	Difference	*SE*	Test	*df*	pbonferroni
Japanese	Liquid	Japanese	Nasal	0.06360	0.0414	1.5355	Inf	1.000
Japanese	Liquid	Japanese	Stop	0.08553	0.0370	2.3088	Inf	1.000
Japanese	Nasal	Japanese	Stop	0.02193	0.0321	0.6836	Inf	1.000
Japanese	Affricate	Japanese	Liquid	–0.12500	0.0454	–2.7552	Inf	0.616
Japanese	Affricate	Japanese	Nasal	–0.06140	0.0414	–1.4826	Inf	1.000
Japanese	Affricate	Japanese	Stop	–0.03947	0.0370	–1.0656	Inf	1.000
Japanese	Affricate	Japanese	Fricative	–0.03289	0.0370	–0.8880	Inf	1.000
Japanese	Fricative	Japanese	Liquid	–0.09211	0.0370	–2.4864	Inf	1.000
Japanese	Fricative	Japanese	Nasal	–0.02851	0.0321	–0.8886	Inf	1.000
Japanese	Fricative	Japanese	Stop	–0.00658	0.0262	–0.2512	Inf	1.000

difference was statistically significant ($\beta = 0.091$, $p < 0.001$). This difference could be attributed to the fact that the non-native Japanese participants did not possess the same linguistic proficiency (they self-reported an average of 84.73%) as the English participants, which may have prevented them from employing the Recoverability Principle as frequently as the English participants.

5.3 Spanish Participants

There was a total of 48 participants in this study. Each participant was presented with 38 experimental words and had to choose between words that were modified by epenthesis or deletion. This resulted in a total of 1,824 tokens. Out of these 1,824 tokens, words modified by epenthesis were chosen 1,593 times (87.33%) and words modified by deletion were chosen 231 times (12.66%). The difference between epenthesis and deletion was statistically significant ($\beta = 0.037$, $p = 0.011$). This finding provides additional support for the Recoverability Principle as it indicates that Spanish speakers found English words modified by epenthesis easier to disambiguate.

We also examined the specific segments that had undergone deletion (see Table 7).

Epenthesis was the most frequent regardless of the sonority profile, reaching a total of 1593 cases (87.33%). This is consistent with what we found in the English and Japanese samples. Also, similar to the other groups, liquids exhibited the highest percentage of deletions (22.91%). A post-hoc test revealed that the Spanish participants deleted liquids significantly more than nasals ($p = 0.036$), fricatives ($p = 0.007$) and affricates ($p = 0.036$). However, there was no significant difference between liquids and stops. A possible explanation for the high frequency of liquid deletions could be due to the acceptability of [ɹ] deletions in many English dialects. A close inspection at the types of deletions uncovered that out of 44 deletions, 38 cases (86.36%) were instances of [ɹ] deletions whereas only 6 cases (13.63%) were instances of [l] deletions. It is worth pointing out that, unlike the Japanese participants, the nasal was not the coda type with the second most deletions in the Spanish group. In Spanish, stop deletions amounted to 17.36%, which comes immediately after liquids (22.91%).

Table 7 Spanish: Total epenthesis vs. deletion based on sonority profile

Sonority	Possible Total	Epenthesis	Deletion
Stops	12 × 48 = 576	476 (82.63%)	100 (17.36%)
Affricates	4 × 48 = 192	178 (92.70%)	14 (7.29%)
Fricatives	12 × 48 = 576	528 (91.66%)	48 (8.33%)
Nasals	6 × 48 = 288	263 (91.31%)	25 (8.68%)
Liquids	4 × 48 = 192	148 (77.08%)	44 (22.91%)
Totals	1824 (100%)	1593 (87.33%)	231 (12.66%)

Table 8 Post hoc comparisons—Spanish ✻ Sonority

Language	Sonority	Language	Sonority	Difference	*SE*	Test	*df*	pbonferroni
Spanish	Liquid	Spanish	Nasal	0.14236	0.0398	3.5772	Inf	0.036
Spanish	Liquid	Spanish	Stop	0.05729	0.0356	1.6095	Inf	1.000
Spanish	Nasal	Spanish	Stop	–0.08507	0.0308	–2.7596	Inf	0.608
Spanish	Affricate	Spanish	Liquid	–0.15625	0.0436	–3.5841	Inf	0.036
Spanish	Affricate	Spanish	Nasal	–0.01389	0.0398	–0.3490	Inf	1.000
Spanish	Affricate	Spanish	Stop	–0.09896	0.0356	–2.7801	Inf	0.571
Spanish	Affricate	Spanish	Fricative	–0.01389	0.0356	–0.3902	Inf	1.000
Spanish	Fricative	Spanish	Liquid	–0.14236	0.0356	–3.9994	Inf	0.007
Spanish	Fricative	Spanish	Nasal	–1.60e–15	0.0308	–5.19e–14	Inf	1.000
Spanish	Fricative	Spanish	Stop	–0.08507	0.0252	–3.3798	Inf	0.076

Table 8 shows that liquid deletions were not statistically significant when compared to other sonority profiles. Liquid deletions approached significance, nevertheless, only when compared to fricatives ($p = 0.007$). This finding is interesting because, based on sonority, one would not expect stops to be the second highest to exhibit deletions since they make ideal onsets. A possible explanation for this outcome could be that stops are the least marked segments (de Lacy, 2002). Unmarked segments may be easier to produce due to their articulatory simplicity, yet they have less perceptual salience. Such features make unmarked segments subject to change. Hume (2004) points out that phonologically unmarked segments in a system are considered to be the least stable phonetically. That is, they are most likely to undergo processes such as reduction, deletion, and assimilation. Our findings seem to support this explanation.

5.4 Findings Across Groups

We also looked at the results of epenthesis frequency across the three language groups. We found that, similar to the Japanese listeners, Spanish participants had a relatively lower epenthesis frequency (87.33%) compared to the English sample (98.76%). A post hoc-test indicated that the difference between the Spanish and English samples was statistically significant ($p < 0.001$). Just as with the Japanese listeners, this difference could be attributed to the difference in proficiency levels since Spanish participants reported an average English proficiency of 82.5%. Thus, the findings from the two L2 speaker groups (the Spanish and Japanese participants) seem to suggest that English proficiency influences the choice of modification strategy. These findings are consistent with previous production studies (Abrahamsson, 2003; Weinberger, 1987).

Moreover, another interesting finding is that there was no statistical significance between the Spanish and Japanese groups with respect to their choice of forms modified by epenthesis: Spanish speakers chose these forms 87.33% of the time, whereas Japanese speakers chose them 87.53% of the time. Based on Yavaş (2011), we predicted that Spanish participants would choose deletion more frequently than epenthesis as the Spanish participants in his study predominantly deleted consonants to modify two-member coda clusters in their production of English words. Yet, this was not the case in our perceptual study. A possible explanation is that the choice of strategy is dependent upon the length of the coda such that singleton codas are modified by epenthesis whereas two-member codas are modified by deletion. If that is the case, then the findings in Yavaş (2011) with two-member codas cannot be extended to the singleton codas used in our study. Another possible explanation is that, since both the Japanese and Spanish listeners in our study reported a similar high English proficiency, they may have reached the same level of competence that is needed to exploit the Recoverability Principle. In contrast, the participants in Yavaş's study may not have had the English level needed to exploit the Recoverability Principle. This hypothesis needs to be tested with further research as, unfortunately, Yavaş did not report the English proficiency level of his study participants. These are all issues for future study.

5.5 Implications

The significance of this research is that it contributed to the body of knowledge in linguistics by examining the Recoverability Principle using a perceptual perspective. Previous research on the Recoverability Principle was only done on production data. We believe that this type of perceptual study gives us further insight into the grammatical knowledge that L2 learners have about the lexicon of their target language without the complication of articulatory behavior.

Furthermore, we have shown that the two modification strategies of epenthesis and deletion are not equal when examined from the perspective of listeners—that is, the choice of behavior is dependent upon other factors. This finding may serve as a useful diagnostic for language teachers and language assessment professionals. For example, it is true that language learners proceed through the stages of syllable-simplification behaviours in their production; that is, first using consonant deletion, and then using vowel epenthesis. Yet, we have found that this is not necessarily the case in perception. We therefore believe that it is beneficial for a teacher/assessor to understand that their students' production does not faithfully reflect their true grammatical (perceptual) knowledge of the target lexicon.

6 Conclusion

The purpose of this study was to examine the preference between two common modification strategies, vowel epenthesis and consonant deletion, using a perception experiment. Specifically, we hypothesized that if the Recoverability Principle plays a role in determining the modification strategy employed, epenthesis will be significantly more preferred by listeners compared to deletion. To test this hypothesis, we targeted participants from three different linguistic backgrounds: English, Japanese, and Spanish. The results showed that epenthesis was significantly more preferred in all examined languages.

We also wanted to test the hypothesis that sonority would influence the choice of the modification strategy; however, our findings did not show such effects. Only liquids were found to behave according to our hypothesis, and this may turn out to be due to the acceptability of dialectal variation. Furthermore, our current findings do not support the hypothesis that Spanish employs deletion as a main strategy in perception. This leads to the suggestion that perceptual grammars are not identical to production grammars. Finally, our findings suggest that linguistic proficiency may influence the choice of modification strategy as our non-native samples had slightly, but significantly, higher rate of deletion than native English speakers.

Overall, these findings provide evidence in favor of the presence of the Recoverability Principle in adult grammars since all examined groups were found to favor epenthesis over deletion. However, we could argue that these findings could be also explained by an overall preference for bisyllabic forms (Wang, 1995). That is, since the stimuli used consisted of only monosyllabic words, epenthesis would result in two syllable words. Because our current study only tested monosyllabic words, we cannot be certain that listeners have a preference for bisyllabic words. A future study could include stimuli containing bisyllabic words. Such an experiment could reveal whether listeners have a preference for epenthesis or for bisyllabicity.

Appendix. Stimuli Words Used in the Study

See Figs. 2 and 3.

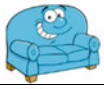
1. [ɹoʊpə] - [ɹoʊ] 	2. [supə] - [su] 	3. [ɹɪbə] - [ɹɪ] 	4. [læbə] - [læ] 
5. [butə] - [bu] 	6. [ʃitə] - [ʃi] 	7. [bɛdə] - [bɛ] 	8. [lɪdə] - [lɪ] 
9. [bʊkə] - [bʊ] 	10. [nɛkə] - [nɛ] 	11. [lɛgə] - [lɛ] 	12. [wɪgə] - [wɪ] 
13. [lifə] - [li] 	14. [ɹifə] - [ɹi] 	15. [lʌvə] - [lʌ] 	16. [keɪvə] - [keɪ] 
17. [dɛθə] - [dɛ] 	18. [maʊθə] - [maʊ] 	19. [aɪsə] - [aɪ] 	20. [ɹeɪsə] - [ɹeɪ] 
21. [ɹoʊzə] - [ɹoʊ] 	22. [noʊzə] - [noʊ] 	23. [fɪʃə] - [fɪ] 	24. [liʃə] - [li] 
25. [kaʊʧə] - [kaʊ] 	26. [piʧə] - [pi] 	27. [bædʒə] - [bæ] 	28. [ɹɪʤə] - [ɹɪ] 
29. [hoʊmə] - [hoʊ] 	30. [taɪmə] - [taɪ] 	31. [sʌnə] - [sʌ] 	32. [munə] - [mu] 
33. [ɹɪŋə] - [ɹɪ] 	34. [wɪŋə] - [wɪ] 	35. [silə] - [si] 	36. [milə] - [mi] 
37. [ʃɔɹə] - [ʃɔ] 	38. [fɔɹə] - [fɔ] 		

Fig. 2 Experimental stimuli words

1. [stɪk-tɪk] 	2. [brɛd-bɛd] 	3. [kreɪm-keɪm] 	4. [kreɪm-keɪm] 
5. [glæs-gæs] 	6. [swɪŋ-wɪŋ] 	7. [skɑɹ -kɑɹ] 	8. [stɔɹ-sɔɹ] 
9. [spɪl-pɪl] 	10. [snoʊ-noʊ] 	11. [slɪp-lɪp] 	12. [tɹæk-ɹæk] 
13. [fleɪk-leɪk] 	14. [dɹeɪk-ɹeɪk] 	15. [stil-sil] 	16. [sneɪl-neɪl] 
17. [klɑk-lɑk] 	18. [bɹum-ɹum] 		

Fig. 3 Fillers

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