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### **THE PHONOLOGICAL ILLUSION: THE QUALITY AND NUMBER OF EPENTHETIC VOWELS**

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*Adult speakers tend to have difficulties in perceiving non-native sequences of sounds as their perception is influenced by the features of their L1 phonological system. For example, previous studies have shown that Japanese speakers perceptually insert an illusory vowel /u/ in consonant clusters, which are phonotactically illegal structures in Japanese. While the phenomenon of phonological illusion also occurs in other languages, such as Brazilian Portuguese or Korean, the epenthetic vowels have been shown to be language-specific. Despite these findings, many questions concerning the number of illusory vowels possible in a language and their quality remain open. In this study we will present recent work on the topic and provide a critical comparison of those findings, concentrating on the role of context-sensitivity in the determination of the features of the illusory vowel.*

*KEY WORDS: phonological illusion, Japanese, speech perception, vowel epenthesis, context-sensitivity.*

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Our perceptual system gets attuned to native phonology at infancy inducing a difficulty of discriminating non-native language sounds (Kuhl *et al.* 2006; Werker & Tees 1984). Several studies have shown that this tuning concerns not only the segments of the L1 but its phonotactics as well (Juszyk *et al.* 1994; Mazuka *et al.* 2011). This explains why adults might face problems in perceiving sequences of segments that are illegal in their native language and use several ‘repair’ strategies to perceptually correct them (Davidson & Shaw 2012). This process is language-specific and several repair strategies are possible, such as deletion, epenthesis or segmental change. We will focus here on a way of perceptually repairing illegal sound structures, namely, on the phenomenon of the phonological illusion, which consists of inserting an epenthetic vowel in a sequence of segments that is disallowed by one’s native phonological grammar. It has been vastly studied in Japanese, where consonant clusters are illegal (except with nasals). Speakers of this language perceptually insert an illusory vowel /u/ when hearing consonant clusters. For example, they will perceive /ebuza/ when hearing /ebza/ (Dupoux *et al.* 1999).

Recent studies have concentrated on the quality of such vowels. A debate emerged concerning the factors that come into play when choosing which vowel(s) is inserted cross-linguistically and within a language. We will highlight some of those findings and discuss the sometimes contradictory views on this perceptual phenomenon. We will propose a modification to the experiment described in Monahan et al. (2009) that could allow to shed more light on the characteristics of illusory vowels and their dependency on particular phonological mechanisms.

### Language-specific epenthetic vowels: the role of coarticulation

Dupoux et al. (2011) showed that epenthetic vowels are language-specific. Japanese perceptually insert /u/ (more precisely /u:/), while Brazilian Portuguese listeners insert /i/. A reason for the epenthesis of those particular vowels comes from the fact that those are the shortest vowels of Japanese and Brazilian Portuguese. Importantly, in certain environments /u/ and /i/ undergo devoicing in Japanese and Brazilian Portuguese, respectively. As those are phonetically minimal vowels, they seem to be good candidates for epenthesis. The authors tested Japanese, Portuguese Brazilian and European Portuguese speakers for their perception of the illusory vowels. All of those languages have the same phonotactic constraint: no obstruents in coda positions are allowed. An interesting case is the Brazilian vs. European Portuguese. Both are varieties of the same language, they share the same phonology but show some differences phonotactically. European Portuguese “has a phonetic process that optionally deletes unstressed vowels in running speech. As a consequence, coda obstruents are common at the phonetic surface.” The authors predicted that if the phonotactics that constrain perception are defined at the level of the surface distribution of sounds (not lexically), European Portuguese listeners will perceive no phonological illusion.

This study also looked at whether vowel epenthesis could be influenced by coarticulation. The three groups of participants first performed a forced choice vowel classification, where they heard 2 sets of continua of /u/ and /i/, ranging from /*ebuzo*/ to /*ebzo*/ and /*ebizo*/ and /*ebzo*/. On each trial, subjects were asked to say which vowel ([a], [e], [i], [o], [u], or none) was in the middle of the stimulus [VC?CV]. The results showed a dominance of /u/ answers for Japanese listeners and /i/ answers for Brazilian Portuguese listeners. As predicted, no perceptual epenthesis was found for European Portuguese speakers.

In a second experiment, the authors investigated whether it is possible to modulate the quality of the epenthetic vowel. They created standard VCCV, /u/-coarticulated VC(u)CV, /i/-coarticulated VC(i)CV stimuli. It was predicted that coarticulatory traces are kept even after the removal of the vowel and that they influence which vowel listeners perceptually insert. The results reveal that the coarticulation effect was stronger for Japanese speakers as they perceive /i/ rather than their dominant epenthetic vowel /u/ in /i/-co-articulated clusters; on the other hand, Brazilian Portuguese listeners, perceive their primary epenthetic vowel /i/ even in /u/-co-articulated clusters.

Thus, this study confirmed that the basic epenthetic vowel in Japanese is /u/, and in Brazilian Portuguese it is /i/. However, the coarticulation patterns may significantly impact perception, and can even induce a shift towards another illusory vowel.

### Contextually induced variability of illusory vowels

The results of Dupoux et al. (2011) have been at least partly contested by the study of Durvasula & Kahng (2016). They carried out three experiments on native Korean listeners to show that several vowels, and not only the shortest one, can be perceived in one language in different phonological contexts, depending on the phonological alternations that happen in that language. The authors argue that in speech perception the listener has to make reverse inferences, that is, inferring what underlying categories map to what surface categories. “When no relevant phonological alternations bias listeners towards a certain vowel in the particular segmental context, the best vowel guess that repairs the particular phonotactic violation is indeed the phonetically minimal/shortest vowel in the inventory. However, when relevant phonological alternations do bias listeners towards particular vowel percepts in specific segmental context, the best guess depends on both the phonetics of the acoustic token and also the phonological alternations themselves”. One of those processes could be vowel deletion. For example, the vowel /i/ in Korean undergoes deletion in vowel hiatus situations with another vowel (/khi + əto/ → [khədo]), and also in weak non-initial open syllables. Moreover, it is the shortest vowel of the language. This is why in an illegal consonantal context, where the repair by a vowel is required, the best vowel is the phoneme that usually maps to nothing in the phonetic representation. In this case this is /i/.

Another process that can bias the listener and induce a qualitatively different illusory vowel is one that involves allophonic mappings before a specific vowel. In Korean this is reflected in the palatalization of alveolar consonants before /i/; for example, the phoneme /s/ surfaces as [ʃ] before /i/. This results in such a reasoning: if a listener hears [ʃ], he infers that phonologically this is a /s/. As the only way to get a phonetic [ʃ] from a phonemic /s/ is to have a following phoneme /i/, the illusory vowel perceived after a [ʃ] must be an /i/. The results of the experiments confirmed those predictions. The generally more perceived illusory vowel was /i/, and for contexts where palatalization takes place (such as in [ɛʃma]), they perceived an illusory /i/.

### Interaction of context-sensitivity and category relevance

The possibility of having several illusory vowels in Japanese was explored by Monahan et al. (2009). The authors noted that the experiments by Dupoux et al. (2011) did not use such contexts where the presence of the vowel /u/ would be restricted by its consonantal context. Namely, high vowels are not allowed after coronal consonants, resulting in the sequences \*[tu] and \*[ti] being illegal in Japanese. However, the mid-back vowel /o/ is attested after coronals. The study investigated whether the “preceding consonant in Japanese

dictates the vowel category that is epenthesized to repair a syllable structure violation". In order to find out if Japanese speakers epenthesize the vowel /o/ or whether they chose /u/ by default despite the phonotactic restrictions, the authors tested the discrimination of strings of type *etoma* vs. *etma*. The results demonstrated that Japanese speakers are able to distinguish between the two. Thus, they do not epenthesize /o/. An explanation for this could be that /o/ is not reducible in Japanese and is more sonorant than /u/ therefore it is not a "minimal vowel" in the language and cannot be inserted to repair illegal structures. However, the study also showed another intriguing result: the participants were able to discriminate between *etuma* and *etma*, thus they were not inserting an illusory /u/. An explanation given in the article is that when hearing *etma* the perceptual system of a Japanese listener knows that the syllable structure is violated and that repair is needed. As the /o/ cannot be an epenthetic vowel, the only option is /u/. Nevertheless the [tu] sequence is illegal in Japanese, therefore no vowel is inserted. Importantly, this shows that listeners are at the same time aware of the phonological context and of the relevant vowel category that can be perceptually inserted.

## Discussion

Durvasula & Kahng (2016) demonstrate that in contexts where a different vowel than the default one is required by the phonological alternations (e.g. palatalization in Korean) a vowel of different quality, not necessarily a minimal one, can be perceptually inserted. In contrast, Monahan et al. (2009) claim that in contexts where repair by epenthesis is needed, but the default vowel is not allowed (in Japanese no /u/ after coronals), an alternative non-minimal vowel cannot be inserted. Thus, in both cases the phonological illusion is proved to be dependent from the context. However, Durvasula & Kahng (2016) assigns a stronger role to the context as it can even "neutralize" the requirement that an epenthetic vowel should be minimal. An explanation could be that in the case of palatalization there is a stronger "need" for a particular vowel, otherwise the sequence cannot be phonologically parsed. In the case described by Monahan et al. (2009), the non-minimal vowel is needed but only to repair the illegal consonant cluster; nevertheless, it is not necessary for the preceding coronal.

Furthermore, the coarticulation seems to affect the perceptual insertion of vowels in Dupoux et al.'s (2011) study but has no effect in Monahan et al.'s (2009) study. The later study also used stimuli where the VCCV non-words have been created by excising the vowel /o/ or /u/ from VCu/oCV non-words. Thus, according to Dupoux et al.'s (2011) predictions, Japanese speakers should be influenced by the remaining coarticulatory cues and perceive more of /o/ or /u/ tokens according to what was the original word. However, there was no effect of coarticulation on the perception of participants. One reason for that could be that /o/ does not undergo reduction in Japanese and therefore it is not a candidate for the epenthesis. On the other hand, /i/ can be considered as a minimal vowel in Japanese and can be epenthesized. However, another question occurs: why the coarticulation did not affect the perception of *etma* vs. *etuma* and the perceptual illusion didn't happen even if /u/ is indeed a minimal vowel in Japanese? If the findings of Monahan et al.'s (2009)

study are correct, this would mean that the phonotactical constraints ( $[*tu]$ ) are stronger than effects of coarticulation. Thus, despite hearing the cues for /u/, Japanese listeners cannot insert an epenthetic vowel in a non-u context.

One possible way to understand better this rather complex pattern could be to replicate Monahan et al.'s (2009) experience with different target vowels. For example, we could look for contexts where /u/ is not allowed but where another vowel that undergoes reduction is legal (VCxCV, where contextually  $x \neq u$ , but x can be another reduced vowel). We could make such predictions: 1. if only one default illusory vowel is possible per language, and if the perceptual system is actually sensitive to context, Japanese listeners would still be able to distinguish VCxCV from VCCV as they know that the only vowel to be inserted is /u/ but it is illegal in this particular case; 2. if several illusory vowels are possible, but they necessarily have to be minimal, Japanese listeners would have difficulty in discriminating VCxCV from VCCV. This would mean that in order to correct the illegal consonant cluster they could choose from /u/ or /x/. As /u/ is illegal in this context, the perceptually inserted vowel would be x. Such a context could probably be a palatalized alveolar consonant followed by /i/ as Japanese seems to have a similar process of palatalizing alveolar consonants before /i/ as in Korean (Durvasula & Kahng (2016)). If the second prediction was true, and Japanese had a second illusory vowel /i/ it could also be an explanation for why Dupoux et al. (2011) found that Japanese speakers perceive /i/ rather than their dominant epenthetic vowel /u/ in /i/-co-articulated clusters.

## Conclusion

The studies discussed above shed some light on the mechanisms that govern the insertion of illusory vowels. Although the phenomenon of the phonological illusion has been vastly studied, further investigation is necessary to understand what particular factors influence the quality of the epenthetic vowel. Another question that remains unclear is whether several illusory vowels are possible in all languages, or only in some of them. Therefore, further studies should focus on the impact of such factors as phonotactics, phonetic characteristics and phonological alternation on the vowel epenthesis and pay a particular attention to their interaction.

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### Summary

Numerous studies have shown that speech perception becomes attuned to the contrastive sound units of a particular language very early in life. This attunement also occurs at the level of phonotactics, which restricts sound sequences and syllable structures that are possible in a language. As a result, when speakers hear speech sound sequences that are not allowed in their native language, their perceptual system might try to “correct” those sequences and induce phonological illusions. One of the examples of such illusions is vowel epenthesis in a sequence of segments that is illegal in the phonotactics of a particular language. Such a phenomenon happens in languages like Japanese, where consonant clusters are not allowed. Due to this constraint, Japanese speakers perceptually insert an illusory vowel /u/ when they hear a consonant cluster.

Despite recent findings on this phenomenon in several languages, the characteristics of illusory vowels are still much argued about. According to Dupoux et al. (2011), illusory epenthetic vowels are language-specific, the best candidate for insertion being the shortest and phonetically minimal vowel of the particular language. In contrast, Durvasula & Kahng (2016) show that several vowels and not necessarily a minimal one, can be perceptually inserted in contexts where a different vowel than the default one is required by phonological alternations. On the other hand, Monahan et al. (2009) claim that in contexts where repair by epenthesis is needed, but the default vowel is not allowed (because of specific context restrictions), an alternative non-minimal vowel cannot be inserted. These studies emphasize the role of the phonological context in the choice of the quality of the vowel to be inserted. We discuss those sometimes contradictory findings and focus on the example of Japanese in order to propose a way of testing how many illusory vowels there can be per language and what their quality should be.

KEY WORDS: phonological illusion, Japanese, speech perception, vowel epenthesis, context-sensitivity.