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Learning the Marshallese Phonological System: The Role of Cross-language Similarity on the Perception and Production of Secondary Articulations

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Abstract
The current study determines the influence of cross-language similarity on native English speakers' perception and production of Marshallese consonant contrasts. Marshallese provides a unique opportunity to study this influence because all Marshallese consonants have a secondary articulation. Results of discrimination and production tasks indicate that learners more easily acquire sounds if they are perceptually less similar to native language phonemes. In addition, the degree of cross-language similarity seemed to affect perception and production and may also interact with the effect of orthography.

Keywords
Second language, Marshallese, phonetics, secondary articulation

Introduction

One of the main questions in second language (L2) phonological learning is what factors affect how L2 vowels and consonants (phonemes) are perceived and produced (i.e., Piske, Mackay, & Flege, 2001). Many of these factors are learner-related, such as the learner's age at the time of L2 acquisition (Mackay, Flege, & Imai, 2006), amount of L2 use (Flege & Liu, 2001), or length of time in the target language country (Larson-Hall, 2006). However, other factors are language-related, such as the phonetic environment in which the L2 phoneme occurs (Broersma, 2010), word frequency (Trofimovich, Gatbonton, & Segalowitz, 2007), similarity of L2 phonemes to native (L1) phonemes (Baker, Trofimovich, Flege, & Mack, 2008), and type of linguistic feature examined (Trofimovich & Baker, 2006). Along with these factors, another important question is how L2 perception may relate to and predict L2 production (Baker & Trofimovich, 2006; Colantoni &

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Steele, 2008; Sheldon & Strange, 1982). The purpose of this study is to examine language-related factors on the acquisition of Marshallese by native English speakers. Specifically, we examined the effect of cross-language similarity and phonetic environment on the L2 perception and production of a little-studied L2 linguistic feature—secondary articulations.

1.1 Cross-language similarity

Cross-language similarity refers to how similar L1 and L2 phonemes are perceived to be. Most theories of L2 speech perception and production learning are based in part on how cross-language similarity affects L2 phonological learning. Two of these theories will be examined in this study.

The first of these, the Speech Learning Model (SLM) (Flege, 1995, 2003) is a phonetic model that postulates that the more similar L2 sounds are to L1 sounds, the more difficult they are to acquire. The SLM posits that similarity is defined in terms of auditory-acoustic differences between L1 and L2 sounds and that accurate production depends on accurate perception of these differences. For example, English /l/ and /ɹ/ are often confusable to native speakers of Japanese learning English, as both are similar to Japanese /ɾ/. However, Japanese speakers perceive the similarity between English /ɹ/ and Japanese /ɾ/ to be more similar than English /l/ and Japanese /ɾ/. This difference in similarity relates to how well Japanese speakers can accurately perceive and produce these two English phonemes (i.e., Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004).

The SLM posits that L2 sounds not found in the L1 (termed "new" in this model) are the least likely to be perceptually assimilated to L1 phoneme categories and therefore the most easily acquired. By contrast, L2 sounds that are "similar" to L1 sounds are the most likely to be assimilated and therefore will be the most difficult to acquire. Importantly, this model also assumes that phonetic context plays an important role in determining what L2 sounds are "new" or "similar"—L2 sounds can be new in one phonetic context but similar in another. For example, Flege and Wang (1989) demonstrated that native Mandarin, Shanghainese, or Cantonese speakers all had difficulty perceiving word final /t/, /d/ contrasts in English, even though these languages have this contrast word initially. Moreover, Cantonese speakers were the most accurate in perceiving this word final difference in English, perhaps because Cantonese has word final /p, t, k/, while the other languages do not.

The second model examined in this study is Best's Perceptual Assimilation Model for Second Language acquisition (PAM-L2), which also posits that accurate perception leads to accurate production and that the similarity of L2 phonemes with L1 phonemes is an important aspect of acquiring L2 phonemes (Best, 1995; Best & Tyler, 2007). Unlike the SLM, the PAM-L2 assumes that L1–L2 similarity is determined by gestures and that it determines how easily it is to perceive L2 *contrasts* (such as English /ɹ/ and /l/) instead of individual phonemes (like English /ɹ/). The PAM-L2 describes several types of relationships that can occur between L1 phonemes and L2 contrasts and how these relationships affect the relative ease or difficulty in learning L2 phonemes. For example, for one of these relationships, "two-category assimilation," the two phonemes of the L2 contrast assimilate to two different phonemes in the L1. An example of this occurs for native English speakers who assimilate German /i/ and /ɪ/ to their language's own /i/ and /ɪ/ (Strange, Bohn, Nishi, & Trent, 2005). The PAM-L2 predicts that this L2 contrast will be easy for listeners to discriminate. By contrast, another type of relationship between L1 and L2 phonemes occurs when listeners assimilate both L2 phonemes in a contrast to the same L1 phoneme category. This occurs for native Korean speakers when learning English /i/ and /ɪ/, since they assimilate them both to Korean /i/ (Baker et al., 2008). In this type of L1–L2 relationship, the two L2 phonemes can assimilate and be equally identified as good instances of the L1 phoneme category (single category assimilation) and can be quite difficult to acquire, since it is difficult to distinguish between the two

L2 phonemes. However, at times one of the members of the L2 phoneme contrast is a better exemplar of the L1 phoneme, termed a "category goodness assimilation" and this type of contrast may be either easily or more difficult to acquire, depending on whether and to what extent one member of the L2 contrast is a better exemplar of the L1 phoneme category.

Several studies have demonstrated success in predicting accurate L2 perception based on cross-language similarity. For example, Bohn and Best (2012) demonstrated that cross-language similarity accurately predicted the differences in L2 perceptual accuracy of English approximants by native speakers of Danish versus German. Similarly, Strange and her colleagues have demonstrated that cross-language similarity is robust in predicting Japanese learners' perception of American English vowels (Strange, Akahane-Yamada, Kubo, Trent, & Nishi, 2001; Strange, Hisagi, Akahane-Yamada, & Kubo, 2011). Escudero, Simon, and Mitterer (2012) have even demonstrated that a learner's dialect can affect the cross-language similarity between L1–L2 phonemes, which in turn affects the perceptual accuracy of L2 phonemes.

1.2 Phonetic environment and cross-language similarity

Previous research has demonstrated that, in general, cross-language similarity can predict the ease or difficulty of learning L2 phonemes. However, there are still many questions to be answered. One of these is how the phonetic environment may affect both cross-language similarity and accurate L2 perception and production (Colantoni & Steele, 2008). Several studies have found that listeners' *cross-language similarity judgments* are affected by phonetic environment. For example, Strange et al. (2005) demonstrated that American English listeners perceptually assimilated Northern German vowels differently depending on whether the vowels were in a b_p, d_t, or g_k context. Moreover, Strange, Weber, Levy, Shafiro, and Hisagi (2007) demonstrated that the effect of different contexts acoustically affects vowels differently depending on the language being examined. They examined American English, German, and French vowels and found that American English front vowels differ little across phonetic contexts, whereas back vowels differ more. Thus, listeners' judgments of perceptual similarity of American English vowels with German and French vowels (especially rounded and back vowels) differs substantially with phonetic context and may explain why American English listeners have difficulty accurately perceiving rounded front and back vowels in these languages. Similarly, Colantoni and Steele (2008) demonstrated that English speakers' accuracy in the production of French and Spanish rhotics differs depending on the phonetic environment in which they occur and propose that phonetic context take a more prominent role in models of L2 speech perception and production.

However, few studies have compared both cross-language similarity judgments across different phonetic contexts and how these differences may affect *L2 perception and production accuracy* across the same contexts. This is unfortunate, since such studies are needed to determine whether phonetic environment actually affects L2 perception and production and if this effect is the result of differences in cross-language similarity. Differences in phonetic contexts may be especially important to examine when allophonic variation found only in one phonetic context in the L1 is used in the L2 in another phonetic context. This occurs, for instance, with English /l/ for Korean learners of English. In Korean, /l/ is an allophonic variation for Korean /ɾ/ when it occurs in the final position of the syllable. Thus, it is possible that native Korean speakers have difficulty perceiving and producing English /l/ in some phonetic contexts (syllable initially) but not in others (syllable finally).

It is important to test theories of L2 phonological learning on many types of L1–L2 combinations and for linguistic features that are often not found in the most commonly taught languages (as in Best, McRoberts, & Sithole, 1987). These analyses allow for us to test the generalizability of such theories and can illuminate our understanding of how L2 speech perception and production occurs. Thus, one feature that has not been examined previously is secondary articulations. Because of this, one phonetic context that has not received adequate attention is different manners of articulation that occur with secondary articulations.

1.3 Secondary articulations

Secondary articulations, defined as an articulation that is produced "separate from and in addition to a primary articulation" (Laufer & Baer, 1988, p. 182), must be produced with less stricture than primary articulations, so secondary articulations are typically approximants or vowel-like in production (Ladefoged & Maddieson, 2004). The most common secondary articulations are palatalization (moving the tongue to the palate as another phoneme is produced, usually orthographically indicated with a superscript /j/ after the primary articulation, as in /C^j/), velarization (moving the tongue to the velum, or /C^γ/), and labialization (rounding the lips, or /C^w/). Secondary articulations can occur both phonemically and allophonically in languages. For example, in Russian, there is a phonemic difference between /l/ (as in /luk/ "onion") and /l^j/ as in /l^juk/ "manhole cover"), or between a /l/ without and with palatalization (see Larson-Hall, 2004, for a brief discussion of the Russian consonant system). By contrast, in American English, velarization of /l/ occurs allophonically at the ends of syllables (as in the word *ball*) but not initially (as in the word *light*), so that this contrast is not phonemic, but does occur.

Secondary articulations are an important area to study, since they have been found to be among the most difficult L2 linguistic features to acquire (Larson-Hall, 2006; Rysiewicz, 1987). Rysiewicz (1987) demonstrated that even young L2 learners have difficulty acquiring rules of secondary articulations. One of the reasons that they are difficult to acquire may be that they are often not marked in the orthography, as is the case in Marshallese. Another reason they are difficult to acquire is that, even if they are marked in the orthography, they can be difficult for L2 learners because they do not occur in the learner's first language and are unlike any phonemes produced in the L1. A final and important reason for their difficulty is that these secondary articulations may occur as an allophonic variation in the learner's first language, but do not occur in all phonetic contexts in the L1. For example, in American English, velarized laterals occur at the ends of syllables and words, but do not occur in the initial position of a syllable or word. By contrast, velarized laterals occur in Marshallese in both initial and final syllable position. Both the PAM-L2 and SLM have demonstrated that some of the most difficult L2 phonemes to acquire occur when two phonemes are in allophonic distribution in the L1, but are separate phonemes in the L2 (Best, 1995; Flege, 1995).

While there has been little research done on the acquisition of secondary articulations, previous research has revealed two findings that are important for the current study. Firstly, those that have examined the acquisition of secondary articulations have demonstrated their difficulty, even for those who have secondary articulations in their native language (Bettoni-Techio & Koerich, 2006; Martinez-Dauden & Llisterri, 1990). Secondly, it might be easier to acquire secondary articulations for some phonemes or in some phonetic contexts than for others. Larson-Hall (2004), who examined the acquisition of palatalized Russian consonants by native Japanese speakers, found that ease of acquisition was related to the type of primary articulation; while palatalization was difficult for the Japanese speakers to perceive, it was more difficult when accompanying trills and laterals than nasals. As with Russian, Marshallese has lateral, nasal, and trill palatalization. In addition, Marshallese has velarization and labialization of these same manners of articulation.

Marshallese is an especially interesting language for the study of the acquisition of secondary articulation because all of the consonants are accompanied by one of three secondary articulations: velarization, labialization, and palatalization. Therefore, we can examine these secondary articulations in several phonetic contexts, here defined as different manners of articulation. The three manners of articulation examined in this study are three manners of primary articulation: nasal, lateral, and trills.

1.4 L2 perception and production

A final question that is important to examine in cross-language similarity studies is how well cross-language similarity predicts both perception *and* production. Most previous studies have only examined how well cross-language similarity judgments affect accurate L2 perception (e.g., Bohn & Best, 2012; Escudero et al., 2012). Fewer studies have examined both perception and production (but see Baker et al., 2008; Wagner & Baker-Smemoe, 2013). This is unfortunate, since the link between accurate L2 perception and production, although assumed in L2 phonological theories, has been called into question (e.g., Baker & Trofimovich, 2006; Sheldon & Strange, 1982). These studies have found that often accurate L2 production can precede and perhaps help accurate L2 perception. In addition, since cross-language similarity judgments are a perceptual task, it may be that they are better predictors of L2 perception than production. Therefore, more studies comparing cross-language similarity judgments and L2 production are needed.

1.5 Current study

The current study seeks to build on past research in the following ways by examining the effect of cross-language similarity on the acquisition of secondary articulations. We also examine how different manners of primary articulation may affect the cross-language similarity of these L2 phonemes with the L1, as well as whether these cross-language similarity judgments affect accurate L2 perception and production. In particular, we examined the following research questions:

1. How do naïve listeners perceive the similarity between Marshallese consonants and English consonants?
2. Does this perceptual similarity between Marshallese and English consonants explain the L2 learners' discrimination of Marshallese consonant contrasts?
3. Does this perceptual similarity also predict L2 learners' production of these same Marshallese consonant contrasts?

Naïve listeners performed the first task of this study. They listened to Marshallese consonants and determined their similarity to English consonants. Next, native English speakers who were learning Marshallese performed two tasks: a perceptual discrimination task and a production task.

Before describing the tasks examined in this study, we first provide a brief description of Marshallese, the acoustics of secondary articulations, and possible acoustic effects of manners of primary articulation (nasal, laterals, trills) on the production of secondary articulations.

1.6 Marshallese

Marshallese, an Austronesian language spoken in the Pacific Island nation of the Republic of the Marshall Islands, provides a unique opportunity to study secondary articulation in the context of L2 learning, because all consonants have a secondary place of articulation. There are three possible

Table 1. Marshallese consonant inventory (adapted from Choi, 1992).

Manner of articulation	Secondary place of articulation	Primary place of articulation			
		Bilabials	Coronals		Velars
	Palatalized	pʲ	tʲ		
Stops	Velarized	pˠ	tˠ		kˠ
	Labialized				kʷ
	Palatalized	mʲ	nʲ		
Nasals	Velarized	mˠ	nˠ		ŋˠ
	Labialized		nʷ		ŋʷ
	Palatalized		lʲ	rʲ	
Liquids	Velarized		lˠ	rˠ	
	Labialized		lʷ	rʷ	

secondary places of articulation: palatalized, velarized, or labialized (Bender, 1963, 1968). The Marshallese consonant inventory is given in Table 1.[1] We chose three consonant types to examine in this study—nasals, laterals, and trills. We did so because they are the only three for which all three secondary places of articulation were represented (palatalized, labialized, velarized).

In addition, secondary articulations affect the quality of surrounding vowels (Bender, 1968). Vowels have three height qualities (low, mid, high), but the qualities of front/back and rounded/unrounded are determined by the secondary articulation of the surrounding consonants. For example, vowels that are surrounded by palatalized consonants are unrounded front (/i/ (high), /e/ (mid), /ɛ/ (low)). When surrounded by velarized consonants, vowels are unrounded back (/ɯ/ (high), /ʌ/ (mid), /a/ (low)), while when surrounded by labialized consonants, vowels are rounded back vowels (/u/ (high), /o/ (mid), and /ɔ/ (low)) (Choi, 1992).

Differences in the secondary places of articulation are orthographically opaque with respect to some phonemes. As a general rule, palatalized consonants do not have the same orthographic representation as their labialized or velarized counterparts.[2] However, most velarized and labialized consonants are represented by the same letter. For example *d* is the letter used for the palatalized alveolar trill, while both the velarized and labialized alveolar trills are represented by the letter *r*. For nasals and laterals, a cedilla (i.e., ļ) is attached to the graphemes n and l to represent velarized and labialized secondary articulation, which distinguishes them from palatalized consonants, but not from each other. However, in some texts the cedilla is not marked, and therefore all three secondary articulations are marked in the orthography with the same symbol.

Language learners are not typically taught that Marshallese has secondary articulations. The two most widely known Marshallese learning texts—*Spoken Marshallese* and *Practical Marshallese*—almost never mention secondary articulations. Instead, Marshallese phonemes are most often compared to English phonemes; for example, two common comparisons include orthographic *l* being "like lull, but NOT like lull" and orthographic *ļ* being "like lull, but NOT like lull" (Rudiak-Gould, 2004, p. 7). Such explanations are not helpful to English speakers, as they typically are not of aware of the differences between the two English types of l. To his credit, Rudiak-Gould does give more detailed information about places of articulation. In describing the two orthographic types of l, he states that for *l*, "the tip of the tongue touches the ridge behind the teeth," while for *ļ*, "the tip of the tongue touches the ridge behind the teeth, and the back of the tongue is pulled back and raised at the back of the mouth, giving it a 'darker' sound" (p. 7). However, note that his description for *ļ* neglects the fact that this letter represents two phonemes.

Table 2. Acoustic differences for F1, F2, and F3 for labialized, palatalized, and velarized consonants compared to their non-secondary articulation counterparts.

	Labialization	Palatalization	Velarization
F1	Unaffected	Unaffected	Relatively low
F2	Relatively low	Relatively high	Relatively low
F3	Relatively low	Unaffected	Relatively low

F1 (vowel height), F2 (vowel frontedness), F3 (lip rounding).

Thus, L2 learners acquiring Marshallese can help us understand how learners acquire secondary articulation. This is because, while English employs labialization word initially, palatalization and velarization (except for syllable final /l/) are not employed in English. Thus, it is possible that the positive influence of the L1 on labialized consonants may be greater than for velarized or palatalized secondary articulations as examined in this study, since we will only give examples of word initial consonants. We next also describe the acoustics of these sounds.

1.7 Acoustic features of secondary articulations and manners of articulation

Most previous research on secondary articulation has demonstrated that all three of the secondary articulations used in Marshallese (labialization, velarization, palatalization) influence F2 (Formant 2) or tongue backness, since F2 and tongue backness are inversely related (Recasens & Espinosa, 2005; Yeou, 2001). In palatalized consonants, F2 typically raises indicating the tongue moving forward (Bhat, 1978; Chiosain & Padgett, 2012), whereas for velarization and labialization, F2 tends to lower, indicating the tongue moving back towards the velum (Casali, 1990; Ladefoged & Maddieson, 2004; Recasens, Fontdevila, & Pallares, 1996). In addition, velarization also affects F1 (Formant 1, tongue height); since the tongue raises towards the velum, F1 is usually lowered (Narayanan, Alwan, & Haker, 1997). In both labialization and velarization, F3 (Formant 3) is also often lower than for non-labialized and non-velarized counterparts, indicating more lip rounding (Stevens, 2000). Table 2 provides a summary of these typical acoustic features of the three articulation types.

As the first step in our study, these generalizations about secondary articulations were verified for Marshallese by asking six native speakers to produce the secondary articulations for nasals, laterals, and trills. The goal of this preliminary experiment was to determine how native Marshallese speakers produced different secondary articulations. In our analysis we found that for each manner of articulation (/l/, /n/, /r/), the palatalized versions had a significantly higher F2 than for the labialized and velarized consonants (all F values >7.05, all p values < .002, all η_p^2 values < .247). Moreover, the F3 of palatalized trill consonants was also higher than for labialized and velarized trills, $F(1, 2) = 5.16$, $p = .007$, $\eta_p^2 = .196$.

We also wanted to determine whether manner of articulation could affect how secondary articulations are acoustically manifested. That is, we wanted to determine whether palatalization, for example, was produced differently across the three manners of articulation discussed in this study—nasals, laterals, and trills. The relatively little research on this topic suggests that different manners of articulation may affect secondary articulations differently. A brief discussion of these differences is reported here.

1.7.1 Nasals. Several studies have examined acoustic differences between nasal and non-nasal phonemes, mostly for vowels. These studies suggest that nasalization lowers F1, F2, and F3, but especially lowers F2 (Dickson, 1962). Thus, it is possible that F1, F2, and F3 may be lowered even more in palatalized, velarized, and labialized nasals, than for similarly produced laterals and trills.

1.7.2 Laterals. The little research done on differences in lateral and non-lateral consonants suggest that they are resistant to co-articulatory effects—that is, they are produced similarly regardless of what phonetic context they are in or what secondary articulation may be applied to them (Bladon & Al-Bamerni, 1976).

1.7.3 Trills. Unlike laterals, trills appear to be influenced by phonetic context (and possibly secondary articulation) and can change depending on the following vowel, although they are not as affected by phonetic context as other phonemes, such as flaps (Dhananjaya, Yegnanarayana, & Bhaskararao, 2012). This is because the repetitive nature of the phonemes prevents coarticulatory effects to some degree. This may not be the case, however, for secondary articulations, since these articulations would occur as the trill is made.

Visual inspection of the data suggests that these three manners of articulation may be affected by secondary articulations differently. For example, although for all three manners of articulation, palatalized forms have a higher F2 than do labialized and velarized forms, this difference seems to be greater for trills than for the other two manners of articulations (see Figure 1).

2 Experiment 1: Cross-language similarity of English and Marshallese consonants

The goal of our first experiment was to determine the degree of similarity between English and Marshallese consonants, especially their degree depending on the Marshallese secondary articulation produced. This experiment would allow us to make specific predictions about the difficulty of learning secondary articulations in Marshallese. We asked native English speakers who had never heard Marshallese to compare English consonants to Marshallese consonants in a cross-language similarity identification task (explained below). Such cross-language identification and similarity ratings are common in the literature and usually do not involve statistical analyses (Aoyama et al., 2004; Mayr & Escudero, 2010; Strange et al., 2005).

2.1 Participants

Seven native English speakers (three males, four females; age range: 20–58; average age: 22) from a beginning linguistics course at Brigham Young University in Utah, USA, were recruited for this experiment. None had prior exposure to Marshallese before participation.

2.2 Stimuli

Seventy-five monosyllabic Marshallese words, spoken by three native Marshallese speakers (all males in their 20s) were used as the stimuli for this experiment. The speakers were recorded using *Audacity* on a laptop and a unidirectional microphone. Each native speaker produced 25 words, approximately three from each of the consonant categories examined in this study (three palatalized nasals, three velarized nasals, three labialized nasals, etc.). Each word began with one of the nine consonants examined in this study and each consonant was followed by either a high, mid, or low vowel. The words used for this study were the same words used in the production task used in Experiment 3 and they are found in Table 3.

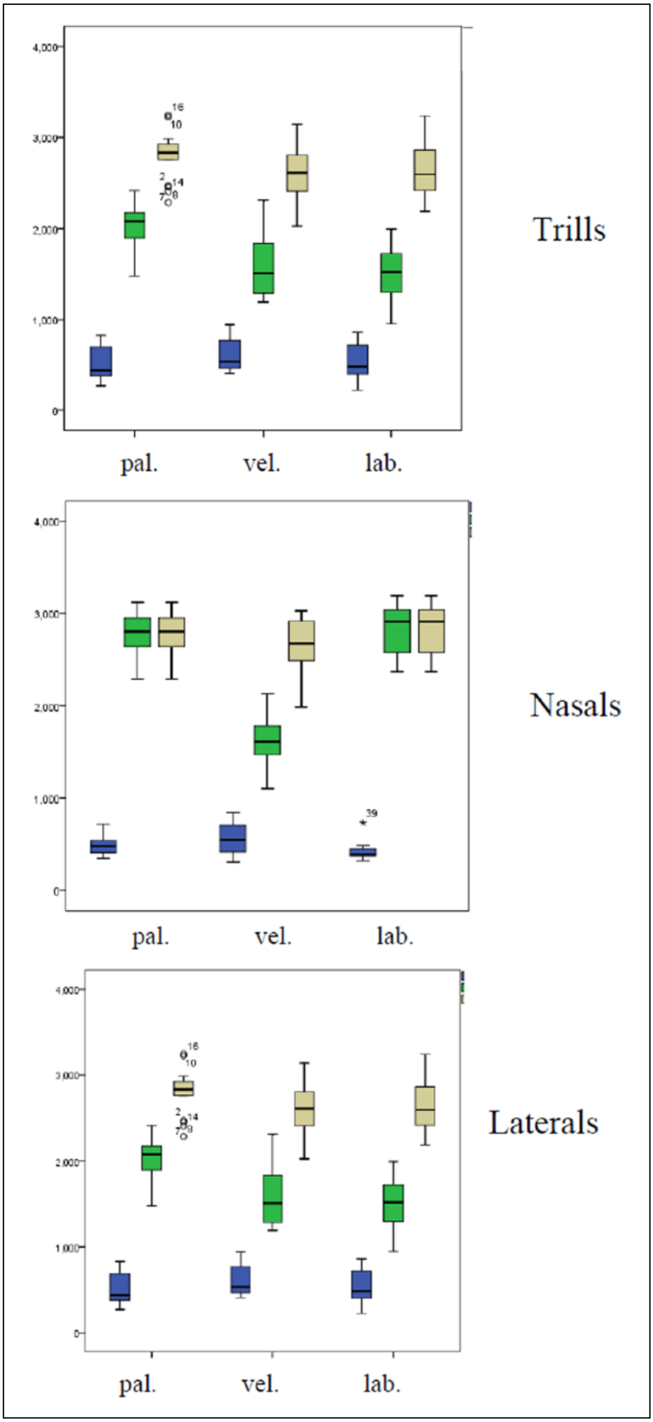

Figure 1. F1 (blue), F2 (green), and F3 (yellow) for trills, laterals, and nasals spoken by native Marshallese speakers. (Color online only.)

Table 3. Complete list of analyzed stimuli—Experiment 1, cross-language similarity, and experiment 2, production.

Secondary articulation	Word	IPA (International Phonetic Alphabet)	Definition
Palatalized	dān	rʲɛnʲ	water; liquid; beverage
	dej	rʲetʲ	steal away; flee
	dim	rʲimʲ	tight
	lāj	lʲɛtʲ	cruel; fierce; mean
	lep	lʲepʲ	egg
	lim	lʲimʲ	fold (transitive verb form)
	nām	nʲɛmʲ	smell; taste; flavor; odor; scent
	nel	nʲelʲ	to dry under the sun
	nin	nʲinʲ	pound
Velarized	rar	rˠarˠ	to dry leaves by fire
	rōm̧	rˠʌmˠ	to crumble a mound of sand
	rak	rˠɯk	south summer
	ļañ	lˠaŋ	storm; typhoon
	ļōļ	lˠʌlˠ	moldy; smell moldy
	ļūb	lˠɯbˠ	mallet; hammer
	ñak	ŋˠak	not know
	ņam̧	nˠamˠ	mosquito
Labialized	ņaņ	nʷɔnʷ	a fish
	ror	rʷorʷ	to bark of dogs
	ro̧ñ	rʷoŋʷ	hole
	rur	rʷurʷ	pick flowers
	ļoñ	lʷoŋʷ	ant
	ļo̧ñ	lʷɔŋʷ	fly
	ņo̧ņ	nʷɔnʷ	nonce word
	ñuņ	ŋʷunʷ	nonce word

2.3 Procedure

Participants logged into the web-based program *Qualtrics* to participate in the study. After agreeing to the consent form and filling out a brief demographic questionnaire asking their age and experience with L2s, including Marshallese, they were instructed that they would hear a Marshallese word and should listen to the first consonant and decide which English consonant it sounded most similar to. They were given a list of the following English consonants to choose from and clicked a button to choose the appropriate one: m, n, l, r, t, d, s, and z. The participants were also allowed to choose the option "other." Next they were asked to rate the similarity between the Marshallese consonant they heard and the English consonant they chose by ranking the similarity on a scale from 1 (not similar at all) to 7 (very similar). This type of cross-language similarity task is often used in the literature (i.e., Aoyama et al., 2004).

2.4 Results

Table 4 provides the percentage of times each English consonant was chosen for each Marshallese consonant. For example, English /ɹ/ was chosen 27% of the time when listeners heard Marshallese

Table 4. Cross-language similarity judgments of Marshallese consonants compared to English consonants. Judgments are listed in percentages with ratings (on a scale from 1 to 7) in parentheses.

	Eng /m/	Eng /n/	Eng /l/	Eng /r/	Eng /t/	Eng /d/	Eng /s/	Eng /z/	Other
Mar/r^j/				.27 (3.57)	.11 (3.13)	.19 (3.29)			.17 (3.00)
Mar /r$^{\gamma}$/				.54 (4.29)		.10 (5.14)			.11 (3.14)
Mar /r^w/				.51 (2.83)		.09			.19 (2.44)
Mar /l^j/			.69 (4.14)						
Mar /l$^{\gamma}$/			.70 (4.64)						
Mar /l^w/			.71 (4.96)						
Mar /n^j/		.65 (4.50)	.10						
Mar /n$^{\gamma}$/	.10 (3.50)	.60 (4.85)	.15 (2.75)						
Mar /n^w/	.21(3.87)	.49 (3.56)							.13 (3.33)

/r^j/. In parentheses, the rating of the similarity between the Marshallese consonant heard and the English consonant chosen is given. Ratings are only given for consonants chosen at least 10% of the time.

As demonstrated by the results shown in Table 4, English /ɹ/ was chosen the majority of the time for each of the secondary articulations for the trill /r/. However, the percentage of times English /ɹ/ was chosen and the similarity ratings for each secondary articulation were quite different. For Marshallese /r^j/, both the similarity ratings and the percentage of times English /ɹ/ chosen was lower than for the other two secondary articulations. In addition, although the percentage of time English /ɹ/ was chosen for the velarized and labialized consonants were approximately the same, the similarity ratings for the two were quite different (/r$^{\gamma}$/, 4.29 and /r^w/, 2.83).

Nasals follow a somewhat different pattern. Two of the secondary articulations have a similar percentage of time that a single English consonant was chosen and provide similar ratings; however, the two secondary articulations are different for nasals than for trills. For nasals, listeners identified the palatalized and velarized counterparts as having similar cross-language similarity identification and ratings to English /n/ (/n^j/, 65%, 4.50; /n$^{\gamma}$/, 60%, 4.85). By contrast, for the labialized n (/n^w/), listeners chose English /n/ less frequently (49%) and rated this match lower in similarity (3.56).

Unlike Marshallese trills and laterals, the three secondary articulations for the laterals were identified with and rated to English /l/ to a similar degree (/l^j/, 69%, 4.14; /l$^{\gamma}$/, 70%, 4.96; /l^w/, 71%, 4.96).

These results allow for testable hypotheses for the perception and production of both manners of articulations and the types of secondary articulations based on perceptual judgments. First of all, these results suggest that Marshallese L2 learners would be able to perceive and produce the difference between the secondary articulations in trills more easily than secondary articulations for laterals and nasals. This is because, although all three are identified with English /ɹ/, the rates and ratings of this similarity are different for each of them. These results suggest that L2 learners of Marshallese will have more difficulty perceiving and producing differences between these secondary articulations with laterals than with nasals. In addition, it should be easier for Marshallese L2 learners to perceive and produce labialized nasals than the other two secondary articulations, since the similarity ratings were lower for labialized nasals than for the other two types of secondary articulations. Finally, it should be most difficult for L2 learners to perceive and produce differences in secondary articulations for laterals, since all three secondary articulations were rated and identified with English /l/ similarly.

3 Experiment 2: Perceptual same/different discrimination

The goal of the second experiment of this study was to determine whether Marshallese L2 learners are better able to perceptually discriminate between Marshallese consonants that have been perceived to be less than rather than more similar to English consonants.

3.1 Participants

Twenty-six non-native Marshallese-speaking volunteers who had learned Marshallese as a L2 were paid to participate in this study. Participants had spent on average 30 months (i.e., three years and six months) in the Marshall Islands (range: 3–252 months) and were on average 22 years of age (range: 19–46) with an average age of first exposure as 19 (range 0–46). All participants spoke English as their L1, although four of the participants were bilingual and had spoken another language since birth. The same L2 participants participated in both of the two experiments described below.

Twenty-three of the participants were give no formal instruction before arriving in the Marshall Islands. Upon arrival, each speaker was given a packet with lessons on the alphabet, pronunciation, vocabulary, and grammar and was also given informal instruction by a non-native Marshallese-speaking partner they were paired to work with during their stay in the Marshall Islands. Of these 23 participants, 16 reported that they were given instruction on the phonemes of Marshallese either by their partner or by native speakers. Methods they reported using varied and included being taught the alphabet, being given instruction on tongue placement, and listening to and repeating native speakers. The remaining three speakers reported having been given explicit instruction on Marshallese before arriving in the Marshall Islands either during 2 weeks of informal classes or in an elementary school setting. Each speaker reported that the amount of time he/she had been speaking, reading, and writing Marshallese was the same.

In addition, participants were asked to rate their proficiency at speaking, reading, understanding, and writing Marshallese (on a scale of 1–10, 1 being very poor and 10 being excellent). Their average responses for each are speaking (4.04), reading (4.30), listening (4.12), and writing (3.65).

3.2 Stimuli

The stimuli for experiment 2 included nonce words beginning with one of the three manners of articulation examined in this study (/l n r/). The stimuli were spoken by two male native speakers of Marshallese who immigrated to the United States as adults. Words were elicited by asking the participants to produce each nonce word from a written list twice in isolation. (See Table 5 for a list of stimuli.) As described above, in Marshallese there are severe restrictions on which vowels can occur with each consonant. For example, front unrounded vowels only occur between consonants with a palatalized secondary place of articulation; back unrounded, only with velarized; and back rounded, only with labialized.[3] Therefore, there are no true minimal pairs in Marshallese (since consonants influence vowel quality). As a result, we were unable to have native speakers produce the three-way minimal pair contrasts because they found it difficult to produce words that violated their native language phonotactics. Instead, we created three-way minimal pair contrasts by splicing in different onset consonants into the same coda. For example the nonsense word dād (r^{j}ɛr^{j}) was elicited. To create a three-way contrast for each of the secondary places of articulation, we spliced velarized and labialized consonants produced by the same speaker in place of the first phoneme of the word, as in /r^{j}ɛr^{j}/, /r^{w}ɛr^{j}/, /r^{ɣ}ɛr^{j}/. We spliced in the first consonant from the beginning of voicing to the first three pulses of the following vowel. Although it is not ideal to splice words for a perception task, these new words were checked for naturalness by a trained phonetician and verified by a

Table 5. Complete list of stimuli—Experiment 2 discrimination.

	Final palatalized consonant	Final velarized consonant	Final labialized consonant
/n/	nʲipʲ	nˠɯpˠ	nʷulʷ
	nʷipʲ	nʲɯpˠ	nʲulʷ
	nˠipʲ	nʷɯpˠ	nˠulʷ
	*nʲenʲ	nˠʌpˠ	*nʷokʷ
	nʷenʲ	nʲʌpˠ	nʲokʷ
	nˠenʲ	nʷʌpˠ	nˠokʷ
	nʲɛrʲ	nˠatˠ	nʷɔrʷ
	nʷɛrʲ	nʲatˠ	nʲɔrʷ
	nˠɛrʲ	nʷatˠ	nˠɔrʷ
/l/	lʲipʲ	lˠɯrˠ	lʷukʷ
	lʷipʲ	lʷɯrˠ	lʲukʷ
	lˠipʲ	lʲɯrˠ	lˠukʷ
	*lʲepʲ	lˠʌnˠ	lʷoŋʷ
	lʷepʲ	lʷʌnˠ	lʲoŋʷ
	lˠepʲ	lʲʌnˠ	lˠoŋʷ
	lʲɛrʲ	lˠanˠ	*lʷɔkʷ
	lʷɛrʲ	lʷanˠ	lʲɔkʷ
	lˠɛrʲ	lʲanˠ	lˠɔkʷ
/r/	rʲipʲ	rˠɯtˠ	rʷutʷ
	rʷipʲ	rʲɯtˠ	rʲutʷ
	rˠipʲ	rʷɯtˠ	rˠutʷ
	rʲenʲ	rˠʌpˠ	*rʷoŋʷ
	rʷenʲ	rʲʌpˠ	rʲoŋʷ
	rˠenʲ	rʷʌpˠ	rˠoŋʷ
	rʲɛlʲ	rˠapˠ	rʷɔkʷ
	rʷɛlʲ	rʲapˠ	rʲɔkʷ
	rˠɛlʲ	rʷapˠ	rˠɔkʷ

native Marshallese speaker, both of whom were able to identify the secondary place of articulation for each of the consonants. Since both a native and proficient non-native Marshallese speaker were able to identify the secondary places of articulation and stated that the stimuli sounded like natural speech, we felt that it was justifiable to use these tokens in a perception task. We also felt it was necessary to include a vowel segment in the stimuli to make the stimuli seem more like natural speech (more like actual words).

However, using spliced stimuli may have affected how the listeners perceived the consonants examined in this study. For one, all the spliced stimuli were nonce words, which may have affected their processing of these words. In addition, it is also possible that the spliced stimuli sounded somewhat unnatural (although every precaution was taken to make sure they sounded as natural as possible). This may have also caused some participants to find this task difficult. For these reasons, using spliced stimuli was a limitation of this study and therefore these results must be treated with some caution.

In total there were 162 tokens (three consonant types /l r n/ × three secondary places of articulation (labialized, velarized, palatalized) × nine vowel phonetic environments [i ɯ u e ʌ o ɛ a ɔ] × two speakers). Of the 81 tokens listed in Table 5, 27 do not violate the phonotactics of Marshallese and are therefore possible Marshallese words. Of those 27, only five are actual Marshallese words: *nen* [n^{j}en^{j}]; *ņok* [n^{w}ok^{w}]; *lep* [l^{j}ep^{j}]; *ļǫk* [l^{w}ɔk^{w}]; and ron̄ [r^{w}oŋ^{w}]. These five words are marked with an asterisk in Table 5.

3.3 Procedure

Participants performed an same/different task. Half of the trials were "same" trials and half were "different" trials. In either case, both trials were composed of two words: one of the tokens of the pairs was spoken by one native speaker and the other word was spoken by another native speaker. This was done to overcome the effects of within-talker variability (Newman, 2001).

Participants were seated in front of a computer with headphones in a quiet room and were tested one at a time. They heard two words with an interstimulus interval of 150 ms and were asked to determine whether the first phonemes in the words were the same or different. On the computer screen there were two buttons. If the participants thought the first phoneme in each word was the same, then they clicked on the button labeled "same;" if the participants thought the two phonemes were different, then they clicked on the button labeled "different." Participants were allowed to listen to the phonemes as many times as they liked. Once they had chosen to click one of the two buttons, however, they were not allowed to change their answer.

If cross-language similarity influences L2 perception of secondary articulation, then these specific predictions can be made. For trills, learners should be better able to perceive differences between palatalized trills and the other two secondary places of articulation (i.e., r$^{\gamma}$ – r^{j}, r^{w} – r^{j} should be better discriminated than r$^{\gamma}$ – r^{w}), but should be better in general in perceiving these contrasts for trills than for the other manners of articulation (l and n). By contrast, for nasals, listeners should be better able to distinguish labialized nasals from the other two secondary articulations (i.e., n^{w} – n^{j} and n$^{\gamma}$ – n^{w} should be better discriminated than n$^{\gamma}$ – n^{j}). For laterals, the discrimination of these three secondary articulations should be very difficult to discriminate.

3.4 Results

We tabulated the number of times each participant correctly discriminated each of the consonant pairs. We then calculated A', a measurement often used to control response bias based on hits and false alarms (Snodgrass, Levy-Berger, & Haydon, 1985). The results of the analysis are provided in Figure 2.

We examined the results of each of the manners of articulation separately. We first examined the discrimination of the secondary articulations for the alveolar trill. To do so, we ran a one-way repeated measures analysis of variance (ANOVA) on the A' scores for the discrimination of palatalized, velarized, and labialized trills. The results of this analysis did reach significance $F(2,25) = 5.20$, $p = .04$, $\eta_p^2 = .03$. Further post hoc analyses revealed that the participants were most accurate at discriminating between palatalized and velarized alveolar trills (.53), then labialized versus palatalized trills (.46), and were least accurate at discriminating velarized from labialized alveolar trills (.41).

Similar analyses of the lateral secondary articulations found little difference between the discrimination of palatalized versus velarized (.49), velarized versus labialized (.48), and labialized versus palatalized (.43) consonants. An examination of the nasals revealed that the L2 learners seemed slightly better at discriminating palatalized nasals from velarized (.56) and labialized consonants (.55) than they were at discriminating velarized from labialized consonants (.49). However, when statistical analyses were run on the laterals and nasal secondary articulations, neither analysis reached significance (all F values < 2.44, all p values > .104, all η_p^2 values < .02). In other words,

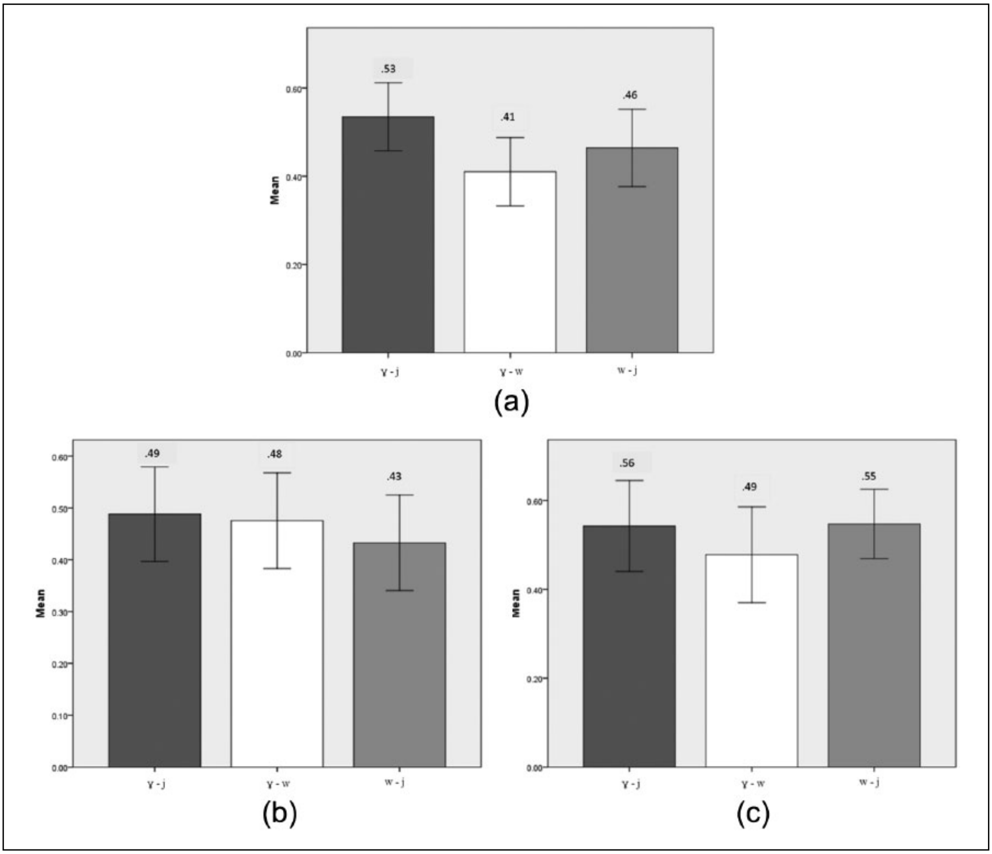

Figure 2. A' scores for discrimination of secondary articulations for (a) alveolar trills, (b) laterals, and (c) nasals.

it was only for the trills that listeners were able to discriminate palatalized consonants from the other two secondary articulations.

4 Experiment 3: Production

The goal of the final experiment of this study was to determine whether cross-language similarity also predicted the production of consonants in Marshallese. The same participants from experiment 2 also participated in this experiment. Six native Marshallese speakers, who had lived only in the Marshall Islands, also participated. Although they had all learned English in school, none of the Marshallese speakers could carry on a conversation in any language besides Marshallese. Native Marshallese speakers were on average 30 years of age, and the group consisted of three males and three females.

4.1 Procedure

Participants were asked to produce 58 Marshallese words in the carrier phrase "Naan in ej _____" ("This word is ________"). Each of the words was a consonant-vowel-consonant (CVC) monosyllabic word where the first phoneme of the word was either /l/, /n/, or /r/ and had either labialized, velarized, or palatalized secondary articulation. The participants' productions were recorded using the speech software Audacity. In most cases, three tokens that differed in vowel height (high, mid, low) of each of the three secondary articulations for each of the three consonants were used in the analysis. The exception was that only two words were used for the labialized nasals, both of which were nonce words. Thus 26 words were used in the actual analysis, and 22 words were used as distracters. A complete list of stimuli used for the analysis is provided in Table 3, which includes the Marshallese orthography, International Phonetic Alphabet (IPA) transcription, and a gloss for each word. These were the same words used in experiment 1.

4.2 Acoustic analysis

An anonymous reviewer suggested that we have native Marshallese rate the accuracy of the speakers' Marshallese word production. We did not do so for two reasons. Firstly, the notion of rating on a numeric scale is a task that is foreign to most native Marshallese because it is not a task that they have usually performed before. Secondly, asking Marshallese speakers to pass judgment on a L2 learner's use of Marshallese is something that makes many Marshallese feel uncomfortable and is seen as rude. In fact, in fieldwork many Marshallese speakers will state that an utterance is *eṃṃan* "good" when it is in fact ungrammatical, simply because doing so can be considered impolite in their culture. Therefore, it proved too difficult to find native Marshallese speakers who would provide reliable judgments on L2 speakers' use of Marshallese. Thus, we elected to rely solely on an acoustic analysis of the tokens.

Most research in secondary articulations compares consonants with no secondary articulation to those with a secondary articulation (such as velarized /l/ with its non-velarized counterpart as found in Catalan (Recasens & Espinosa, 2005)). This proved impossible in our study, since all Marshallese consonants are produced with a secondary articulation. Therefore, we compared the native speakers' and L2 learners' productions to each other, with the assumption that the native speakers correctly produce the consonants of their native language.

Acoustic analyses were performed following a typical methodology, which is used, for example, in Choisain and Padgett (2012). In these analyses, we examined the effect of secondary articulation on the following vowel's formants. As in Choisain and Padgett's (2012) analysis, we used a similar Praat algorithm, which found the first three formants (F1, F2, F3) in 10 locations across the vowel. We averaged across the first three of these 10 measurements (which were approximately 2.5 ms apart). Later, we conducted a visual inspection of the data and files to ensure that these measurements were accurate. Any measurements that were not accurate were also measured by hand.

As stated above, since all three secondary articulations affect F2 (either by lowering or raising it), we assumed that there might be differences in F2 height in the productions of the native Marshallese speakers and L2 Marshallese learners. In addition, we expected no difference in F1 and F3 across the two groups (the native speakers and L2 Marshallese learners) for palatalized consonants, but did expect differences in F1 for the velarized consonants and differences in F3 for both the labialized and velarized consonants. If these differences do exist, it would suggest that the L2 Marshallese learners had difficulty producing the secondary articulations required for the production of the Marshallese consonants. According to the predictions of the cross-language similarity judgments, we also expected that the learners would be best be able to accurately produce palatalized trills than the velarized and labialized trills; would more accurately produce labialized nasals than the palatalized and velarized nasals; and would be the least able to accurately produce the three secondary articulations for laterals.

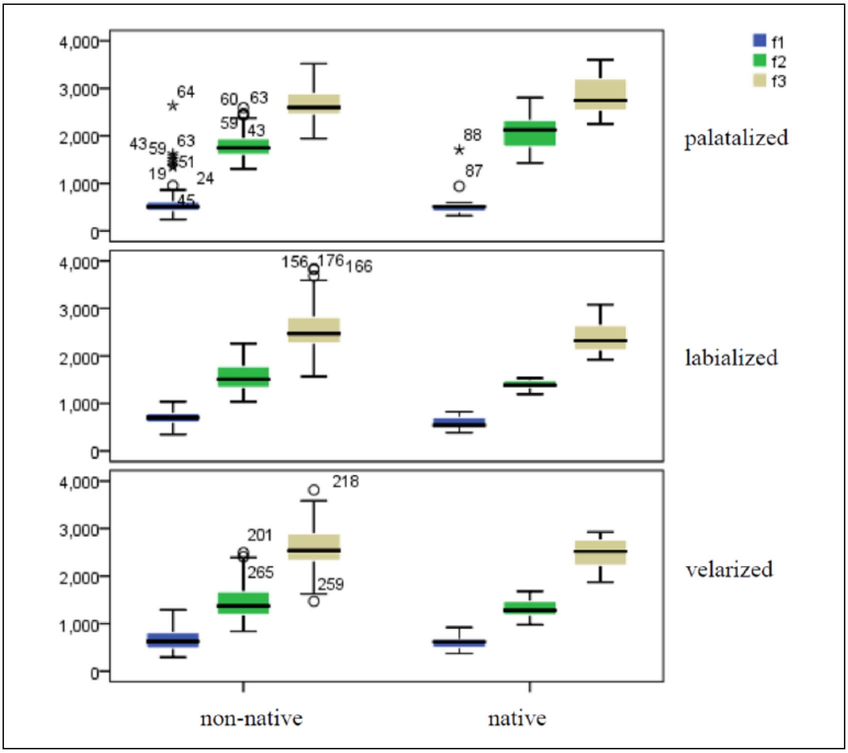

Figure 3. Trills, differences in F1(blue), F2 (green), and F3 (yellow) for non-native and native speakers' productions of trilled palatalized (panel 1), labialized (panel 2), and velarized (panel 3) consonants. (Color online only.)

For each of our analyses, we ran a series of two-way ANOVAs where the dependent variable was the average F1, F2, or F3 with group (native speaker versus L2 learner) and secondary articulation (palatalized, velarized, and labialized) as the independent variables. These were run separately for each of the three manners of articulation (trills, nasals, laterals) and are discussed in turn below.

In our analysis, we did not independently examine whether the L2 Marshallese learners also produced the primary articulations (/l/, /n/, and /r/) accurately. This analysis, while also important, is beyond the scope of this paper.

4.3 Results

4.3.1 Secondary articulation in trills. The analysis of F1, F2, and F3 for trill consonants found no significant effect of group (F1: $F(1, 30) = .2.12$, $p = .146$, $\eta_{p2} = .008$; F2: $F(1, 30) = .047$, $p = .828$, $\eta_p^2 = .001$, F3: $F(1, 30) = .144$, $p = .705$, $\eta_p^2 = .001$). There was a significant effect of secondary articulation for F2 and F3 (F1: $F(1, 2) = 47.65$, $p = .001$, $\eta_p^2 = .065$; F3: $F(1, 2) = 5.90$, $p =.003$, $\eta_p^2 = .041$). No interactions were significant. Post-hoc Tukey tests revealed that for both F2 and F3 there was a significant difference between the palatalized trills and the labialized and velarized trills for both native speakers and L2 Marshallese learners. Therefore, the two groups (native speakers and L2 learners) did not differ from each other in their ability to produce palatalized, velarized, or labialized trills (see Figure 3).

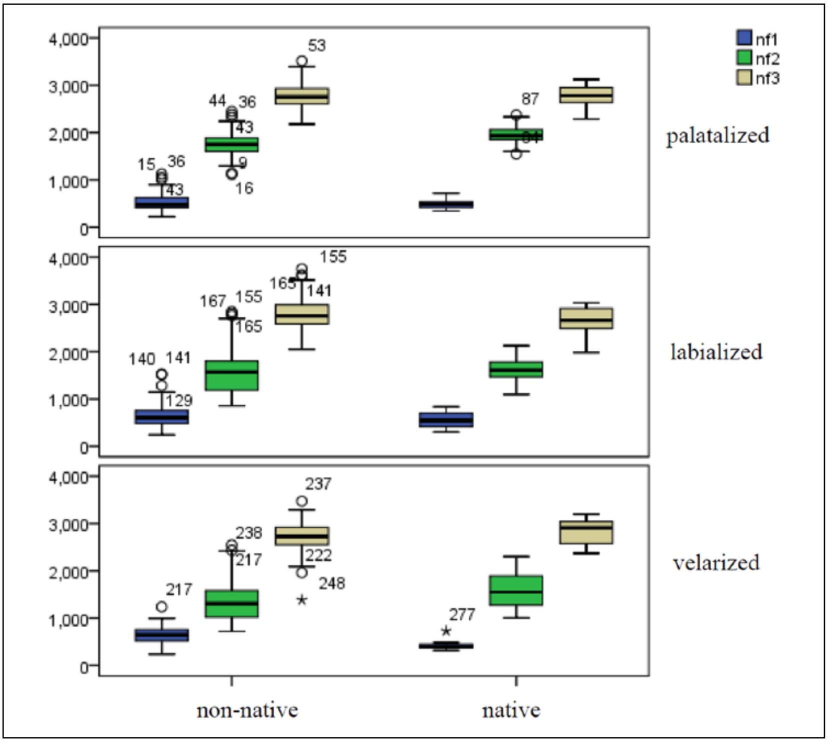

Figure 4. Nasals, differences in F1(blue), F2 (green), and F3 (yellow) for non-native and native speakers' productions of nasals that are palatalized (panel 1), labialized (panel 2), and velarized (panel 3). (Color online only.)

4.3.2 Secondary articulation in nasals. A similar analysis on the nasals reveals no difference between the native speakers and L2 learners' production of F3, $F(1, 30) = 321$, $p = .571$, $\eta_p^2 = .001$, but the two groups did differ in their production of F1, $F(1, 30) = 12.44$, $p = .001$, $\eta_p^2 = .048$ and F2, $F(1, 30) = 5.09$, $p = .025$, $\eta_p^2 = .02$. Moreover, there was an effect of secondary articulation on F1, $F(1, 2) = 3.31$, $p = .04$, $\eta_p^2 = .026$ and F2, $F(1, 2) = 12.61$, $p = .001$, $\eta_p^2 = .093$. No interactions were significant. Post-hoc Tukey tests revealed a significant effect between the F1 and F2 of palatalized versus labialized, velarized nasals for both groups (palatalized F1 and F2 were higher). These same tests revealed a significant difference between all three secondary articulations ranging from the highest (palatalized) to velarized to labialized nasals. These results therefore revealed that the L2 learners differed from the native speakers in their tongue height (F1) and tongue frontedness for nasal consonants of all three secondary articulations. They did not differ from the native speakers in terms of lip rounding (F3) for any of the secondary articulations (see Figure 4).

4.3.3 Secondary articulation in laterals. In the analysis of F1 for labialized consonants, there was no significant effect of group, $F(1, 30) = 1.77$, $p = .184$, $\eta_p^2 = .007$, but there was an effect of group for F2, $F(1, 30) = 4.31$, $p = .039$, $\eta_p^2 = .016$ and F3, $F(1, 30) = 4.43$, $p = .04$, $\eta_p^2 = .016$. There was only one effect of secondary articulation, for F2, $F(1, 2) = 13.53$, $p = .001$, $\eta_p^2 = .091$. Post-hoc Tukey tests revealed that the F2 for palatalized laterals was higher than that for the velarized and labialized laterals. These results indicate that the native speakers and L2 learners differed from

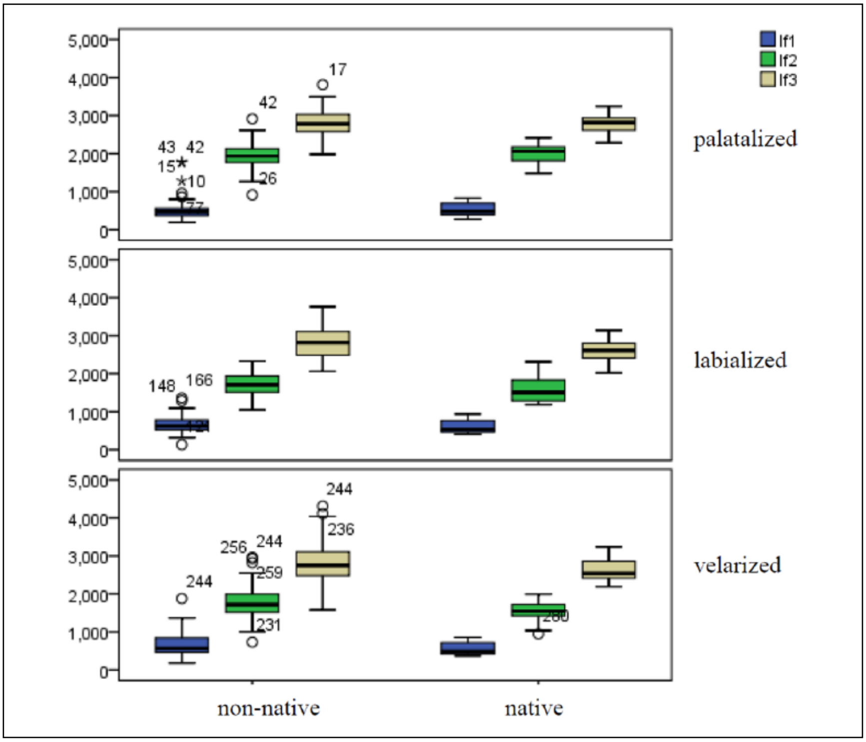

Figure 5. Laterals, differences in F1(blue), F2 (green), and F3 (yellow) for non-native and native speakers' productions of lateral palatalized (panel 1), labialized (panel 2), and velarized (panel 3) consonants. (Color online only.)

each other on F2 (tongue frontedness) and F3 (lip rounding) for all three secondary articulations: labialized, palatalized, and velarized. No interactions were significant (see Figure 5).

5 General discussion

The overall results of this study suggest, at least in part, that cross-language similarity can predict L2 perception and production of secondary articulations, but that it is much less accurate in predicting L2 learning for these secondary articulations with some manners of articulation than for others. In addition, this study also demonstrated the importance of examining phonetic context (in this study defined as different manners of primary articulation) when examining secondary articulations. A more detailed explanation of the results and their importance to L2 phonological speech learning and theories is provided below.

5.1 Cross-language similarity and L2 perception/production of secondary articulations

Previous research on secondary articulations suggested that palatalized consonants should be acoustically (and thereby perceptually) the most distinct from the other two types of secondary articulations examined in this study (labialized and velarized), since in palatalization F2 is raised while in the other two consonants F2 is lowered (Bhat, 1978; Chiosain & Padgett, 2012; Ladefoged & Maddieson, 2004; Recasens et al., 1994). However, after examining the acoustics of the Marshallese consonants as well as the cross-language similarity judgments of naïve native English listeners, it appeared that these secondary articulations were produced differently depending on which manner of primary articulation they accompanied: nasals, laterals, or trills.

In particular, we found three different patterns of cross-language similarity that differed by manner of articulation. Firstly, for trilled consonants, the palatalized forms were perceived by the naïve listeners to be the most distinctly different from English consonants (specifically /r/) and also the most different from the other two secondary articulations. Secondly, for laterals, all three secondary articulations were perceived to be equally similar to English /l/, suggesting difficulty in learning to perceive and produce differences across these phonemes. Finally, a third pattern developed for nasals—for these consonants, cross-linguistically and acoustically, palatalized and labialized nasals were perceived to be more similar to each other and to English /n/ than were velarized nasals.

These findings allowed for specific predictions about the perception and production of these Marshallese consonants by L2 Marshallese learners. In L2 perception, this pattern held true for the discrimination of Marshallese trills—learners were best at discriminating palatalized trills from the other two secondary articulations, as would be predicted by the cross-language similarity and acoustic analyses findings. We also found that the L2 learners did not differ from the native speakers in their production of any of the secondary articulations that co-occurred with trills. These results therefore were predicted for the most part accurately by the cross-language similarity judgments.

Similarly, cross-language similarity judgments predicted the relative difficulty of learning secondary articulations when they accompanied laterals. The L2 learners indeed were equally poor at discriminating all three secondary articulations when they were produced with laterals. Moreover, the L2 learners differed from the native speakers in their production of all three secondary articulations when they were produced with laterals. The L2 learners differed from the native speakers in terms of tongue frontedness (F2) and lip rounding (F3) for all secondary articulations for laterals.

While we were able to predict (at least in part) the L2 perception and production of secondary articulations with trills and laterals, this was not the case with nasals. In the case of nasals, the L2 learners were best at discriminating between palatalized and the two other secondary articulations, but these differences did not reach statistical significance. These results were puzzling, since cross-language similarity judgments suggested that the L2 learners should have been better at discriminating between labialized nasals and the other two secondary articulations. In addition, in L2 production, the L2 learners differed from the native speakers in their ability to produce tongue height (F1) and tongue frontedness (F2) for all the secondary articulations when the primary articulation were nasals. Interestingly, for both laterals and nasals, the L2 learners were able to produce a difference between the palatalized versus velarized and labialized consonants in terms of tongue frontedness (F2); however, they did not produce the palatalized consonants with enough forward of a tongue to mirror the productions of the native speakers.

5.2 Why did cross-language similarity judgments accurately predict the production of secondary articulations with laterals and trills, but fail to predict L2 perception and production of nasals?

One of the weaknesses of both the PAM-L2 and SLM is that they can predict the relative ease or difficulty of learning L2 phonemes without being able to be more specific than this. That is, while we can ask naïve listeners to match and rate the similarity of L1 and L2 consonants, we do not know what a match of "65%" actually means. We also do not know at what frequencies having two

L2 consonants matched with a single L1 consonant should be termed a "category goodness" versus a "category assimilation" in theories like the PAM-L2.

Thus, what may be occurring in the results of this study is that the different matching of the three secondary trill articulations to the English consonant /r/ were sufficiently different from each other to allow for L2 learners to perceptually distinguish between the three types of secondary articulations. That is, the palatalized trills were identified with English /ɹ/ only 27% of the time, while the other two secondary articulations were identified with English /ɹ/ 54% (velarized) and 51% (labialized) of the time. The palatalized trill was the one phoneme that was identified the least amount of time with a single English consonant across all the phonemes examined in this study. It also appears to be the best discriminated phoneme as well.

By contrast, all three of the secondary articulations of the laterals were identified with English /l/ approximately 70% of the time and had similar ratings. This percentage of identification with a single L1 phoneme and with the same degree of similarity rating for all three phonemes seemed too great for L2 learners to perceive a difference between the L1 phoneme (English /l/) and the three secondary articulations.

The secondary articulations in nasals examined in this study appear to be identified to a great enough extent with a single L1 phoneme to pose problems for L2 speech perception and production. Moreover, although the three secondary articulations were identified with the single L1 phoneme at different frequencies and similarity ratings (65% for palatalized; 60% for velarized; 49% for labialized), these differences did not seem great enough to allow for accurate discrimination of the phonemes nor for accurate production.

What is the degree of cross-language similarity needed to block the ability to perceive and produce L2 phonemes accurately? The results of this study can only suggest that this is a necessary next step in understanding how cross-language similarity can predict accurate L2 perception and production. Moreover, it is possible that this degree differs depending on the type of L2 phoneme (or phoneme contrast) examined, the phonetic context, and even the individual learner (Mayr & Escudero, 2010). However, the results of this study do, in general, verify the claim of the SLM and PAM-L2 that the more similar L2 phonemes are to L1 phonemes, the more difficult they are to produce. For example, secondary articulations in trills in general were identified much less frequently with any English L1 phoneme than they were in nasals and laterals and were also the most accurately perceived and produced, regardless of the secondary articulation associated with them. Of course it is possible that the production of actual trill was not produced accurately, since these articulations are very difficult for both L1 and L2 learners to acquire (Carballo & Mendoza, 2000; Solé, 2002; Walmunson, 2005).

5.3 Why is cross-language similarity easier in predicting perception than production?

We also found that L2 perception was easier to predict than was L2 production. Cross-language similarity judgments did accurately predict the perception of the secondary articulations of the trills and laterals, although they did not accurately predict the perception of the nasals. However, the results of the production were less accurate. Although cross-language similarity judgments accurately predicted that L2 learners would be more accurate in producing secondary articulations in trills than in laterals or (possibly) nasals, the actual results of the production were different than were the predictions by the cross-language similarity.

For example, the cross-language similarity judgments would have predicted that the palatalized trills would have been produced more accurately than the velarized and labialized ones—but all three were produced equally accurately. This occurred, in fact, for all three of the manners of primary articulation—all three secondary articulations were produced either equally accurately or equally poorly.

Few studies on cross-language similarity have tested these predictions on both the perceptual and production accuracy of L2 learners. Most have tested only the perceptual accuracy (i.e., Escudero & Vasiliev, 2011; Strange et al., 2011). Both the PAM-L2 and SLM predict that accurate perception should occur and cause accurate production.

At least three explanations are possible. Firstly, it is possible that the perception of the L2 learners examined in this study has outstripped the production abilities and that, with time, the learners' production of these Marshallese consonants will eventually align with the perception abilities shown in this study. Secondly, it is also possible that the relationship between cross-language similarity and L2 production is not as straight forward as the relationship between cross-language similarity and L2 perception. As stated above, several studies have called into question the relationship between L2 perception and production (Baker & Trofimovich, 2006; Sheldon & Strange, 1982). Indeed, since cross-language similarity judgments are a perceptual task, it may be that they are better predictors of perception than production.

Finally, it is also possible that acoustic measurements of the L2 learners' production are more difficult to determine than if we had native speaker judgments of their productions. For example, it is possible that the learners in this study were able to produce the secondary articulations with trills accurately, but failed in their production of the primary articulation—making trills more like alveolar approximants. Future research is needed to determine whether there would be differences in the findings we encountered using acoustic measurements versus those that would have been found if native speaker judgments would have been possible. In addition, in this study we had to use spliced stimuli to create a perception task with minimal pairs. As stated above, this may have made the task seem unnatural, and therefore the results of the first experiment should be treated with some caution.

5.4 What other factors may have affected the results?

Although not tested directly, other factors may have affected the results of this study. The most likely one of these is the orthography of the language. As stated in the introduction above, for trill consonants, the grapheme <d> is used orthographically for the trilled palatalized consonants, while the grapheme <r> is used to depict both velarized and labialized trills. Using the same grapheme for two phonemes had been found to have either a negative or positive effect on learning L2 phonemes, depending on how and whether the orthography marks specific contrasts (Bassetti, 2006; Escudero & Wanrooij, 2010; Hayes-Harb, Nicol, & Barker, 2010; Rafat, 2013, 2015). Thus, one reason the learners were better at discriminating between palatalized trills and the other secondary articulations may have been the facilitative effects of the orthography.

Unlike for trills, Marshallese orthography marks the difference between palatalized and the other two secondary articulations with a cedilla diacritic on the <l> or <n>, and in many situations these diacritics are not used at all. Thus, the difference between secondary articulations for trilled consonants is more marked in the orthography than for laterals and nasals. While we did not find any effects of orthography being facilitative for the discrimination of laterals, we did see a trend of this effect for nasals. That is, the L2 learners were better at discriminating palatalized nasals from the other two secondary articulations. This may have occurred at least in part because the difference between palatalized nasals and the other two types of secondary articulations is marked in the orthography. These results support the many other studies that have also found that L2 orthography can influence L2 perception (i.e., Escudero, Hayes-Harb, & Mitterer, 2008; Hayes-Harb et al., 2010). Therefore, for palatalized consonants, it is possible that the orthography caused the learners to pay attention to differences between palatalized consonants and the other two secondary articulations. By contrast, since both velarized and labialized consonants have the same orthography in Marshallese, it is possible this prevented the learners from being able to accurately perceive and produce a distinction between these two secondary articulations.

These results are especially interesting considering that the learners were not given any specific instruction on how to produce the secondary articulations—indeed they were not even taught that there were secondary articulations to learn. It also demonstrates that orthography may be one means of helping learners to better acquire secondary articulations and is the first study to examine the effect of orthography on learning (not just perceiving) secondary articulations.

What is interesting is that the possible facilitative effects of the orthography did not help the L2 learners perceive and produce the laterals more accurately. That is, these results (which need to be verified by more research) may suggest that the effects of cross-language similarity and orthography may interact, so that if the cross-language similarity is too great (as was the case with the laterals), then the orthography will not have any facilitative effects on learning the L2 phonemes. Rafat (2011, 2013) recently demonstrated that, in the case of a shared grapheme, similarity between L1 and L2 phonemes can affect the strength of the orographic effect. Rafat (2011, 2013) examined the effect of exposure to orthographic input on production of a number of Spanish sounds by naïve English-speaking participants and, based on the results, argued that the smaller the acoustic/phonetic distance between L1 and L2 phonemes, the stronger the possibility of L1-based phonological transfer. Such transfer, Rafat (2011, 2013, 2015) demonstrates, can have both facilitative and hindering effects.

6 Conclusions

The results of this analysis demonstrate that cross-language similarity can influence L2 phonological learning, even when learning secondary articulations. Moreover, and importantly, these results demonstrate that the manner of the primary articulation exerts a great influence both on cross-language similarity and on the accuracy of perceiving and producing these phonemes. These results also highlighted the importance of understanding not only cross-language similarity of L1 and L2 phonemes, but also the degree of this similarity—a finding that, if examined in future research, could provide a more powerful model of L2 phonological learning.

These results also suggest that orthography may also influence L2 phonological learning, even when learning secondary articulations. We found that native English speakers were better able to perceive Marshallese palatalized consonants than velarized and labialized forms. We also found that the learners were able to perceive differences between palatalized trills and their velarized and labialized counterparts, but were not able to do so for laterals and nasals. Again, these findings can be explained by Marshallese orthography. Such findings, however, need to be explored in greater detail in further research. In any case, the results of this study suggest that orthography should be examined in more detail in L2 acquisition research. These results also underscore the complex nature of L2 acquisition and the interaction of factors that affect it.

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Notes

1. Bender also posits three semi-consonants, /j/, /w/, and /ɰ/, in order to account for certain facts regarding the phonotactics of Marshallese. See Bender (1968) for a discussion of these three consonants.
2. While the official Marshallese orthography employs both macrons and diacritics, our Marshallese speakers report that only older speakers readily use the official orthography employed in the Marshallese-English Dictionary. This is most likely due to the fact that, prior to a few years ago, there was no standard orthography taught in schools. Instead, many Marshallese speakers learned to spell without using the diacritics and macrons employed in the official orthography and, while these speakers can use the diacritics and macrons, they often exclude them when they write.
3. If a vowel is surrounded by consonants that have different secondary places of articulation, a diphthong results (Bender, 1968; Choi, 1992; Hale, 2000). For example, a vowel between a palatalized consonant and a velarized consonant would result in the smooth transition from a front unrounded vowel to a back unrounded vowel.

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