

1 Introduction

Research demonstrates that phonetic transfer is widespread in bilingual speech production (Bullock and Gerfen 2004; Baker and Trofimovich 2005; Mayr et al. 2015). In particular, phonetic convergence is predicted in similar sounds (Flege 1987), with the direction and degree of convergence mediated by a variety of sociolinguistic factors (Guion 2003; Nance et al. 2016; Kasstan 2019). Furthermore, in circumstances of widespread and long-term bilingualism, individual instances of phonetic transfer can result in community-wide sound change (Nagy and Kochetov 2013; Yao and Chang 2016). However, studies that simultaneously analyze synchronic and diachronic convergence, especially in minority Indigenous languages, remain rare. This paper examines whether English-Diné Bizaad (Navajo) bilinguals show evidence of phonetic transfer and intergenerational change, in their production of Diné [kx, tx], sounds with English counterparts [k^h, t^h] that are similar in certain, but not all, respects.¹

1.1 Similarity and phonetic transfer

Within multilingual populations, language contact is a source of novel variants, as speakers import features from one language into another (Thomason 2001). One prominent mechanism proposed to explain which features will be transferred is “interlingual identification”: the process by which bilingual speakers equate units across languages, due to perceived similarity, resulting in borrowing (Weinreich 1953). In the case of pronunciation, bilinguals may link similar phonemes and apply phonetic specifications of one language to an associated phoneme in a second language. Relatedly, phonetic convergence and phonemic substitution of similar sounds from a majority language are commonly documented in endangered languages (Campbell and Muntzel 1989; Goodfellow 2005; Babel 2009; Chang 2009).

Accordingly, similarity plays a central role in the Speech Learning Model (SLM) of bilingual speech production (Flege 1995). The SLM predicts that bilingual phonetic systems will interact through category assimilation and dissimilation based on equivalence; when sounds in a second language are sufficiently distinct from the first language, speakers establish a new phonetic category and maintain pronunciation distinctions, or phonetically diverge between sounds in their languages (Flege and Eefting 1987). However, when sounds are perceived to be identical or similar across languages, speakers associate sounds in their second language with an existing first language category. Such categorization results in non-native accents, as speakers pronounce second language phonemes with phonetic characteristics of their first language. Over time, with continued exposure to the second language, initial categorization may shift.

Regarding bilingual production of stops, timing cues are a frequent locus of transfer (Fowler et al. 2008). Studies report that, when compared to monolinguals, bilinguals produce stops with voice-onset times (VOTs) that are closer to sounds in their other language (Flege 1991; Maclagan and King 2007; Sleeper 2020). Attested effects are bidirectional; timing cues may be transferred from a first to a second language, or vice versa, even after a relatively short period of exposure (Chang 2010). However, stops that are presumed to be similar do not uniformly exhibit VOT convergence (Flege and Eefting 1987), and transfer may be constrained by sociolinguistic

¹Research is supported by the National Science Foundation (GRFP 2014178334; DDIG 1713793; SPRF 1907948). Thank you to the Diné participants, to Barsine Benally, Louise Ramone, and Melvatha Chee for their help in recruiting, and to Marianne Mithun, Matthew Gordon, Eric Campbell, and Lorene B. Legah for feedback on earlier versions of this analysis.

factors (Newlin-Lukowicz 2014). Based on previous findings, phonetic transfer of timing cues between similar stops is predicted, though not inevitable.

1.2 Diné Bizaad-English bilingualism

Diné Bizaad (Navajo, Navaho, ISO nav) is a Southern Dene (Athabaskan, Athabascan, Athapaskan) language spoken primarily in and around the Navajo Nation in the present-day American Southwest. Though Diné Bizaad maintains an active speaker population, ongoing settling of non-Native people on Indigenous land is causing shift, and bilingualism is widespread (House 2002; Spolsky 2002; Benally and Viri 2005). As is typical in communities undergoing shift, language usage tends to be age-graded: bilinguals over 60 predominantly identify as Diné Bizaad-dominant, bilinguals between 40–60 often consider themselves to be equally proficient in their languages, and many under 40 understand, but do not speak much Diné Bizaad (Lee 2007; Jacobsen 2017). Despite shift, speakers of all ages continue to value and use Diné Bizaad in a variety of domains (Lee and McLaughlin 2001).

The targeted sounds are Diné [kx, tx] and English [k^h, t^h]. For alveolar and velar stops in syllable-initial position, English speakers contrast voiced unaspirated [g, d] with voiceless aspirated [k^h, t^h], while Diné speakers contrast voiceless unaspirated [t, k], voiceless aspirated/affricated [kx, tx], and voiceless ejective [k', t'] (McDonough 2003). Although they have been referred to as phonemically aspirated sounds in some publications (e.g., McDonough and Ladefoged 1993), subsequent phonetic analyses describe Diné [kx, tx] as affricates (McDonough 2003; McDonough and Wood 2008). Other sources report variation in the phonetic quality of the release periods [kx ~ k^h] and [tx ~ t^h] (Sapir and Hoijer 1967; Reichard 1945; Reichard 1951; Saville-Troiike and McCreedy 1980), or between places of articulation, with [tx] described as an affricate and [k^h] as an aspirated stop (Young and Morgan 1987).

Table 1 displays mean VOTs for the Diné and English alveolar and velar stops. The Diné Bizaad measurements, published in 1993, come from 119 words, mostly monosyllabic nouns, produced by seven native speakers who use the language daily. English measurements come from stops in word-initial position produced by four speakers. I omit cases of negative VOTs in English. While speakers of both languages use VOT, or duration of the affricated release, as a cue to contrast unaspirated and aspirated/affricated stops, release durations of Diné [kx, tx] are significantly longer than English [k^h, t^h].

Table 1. Mean VOT(ms) of syllable-initial stops

	Unaspirated	Aspirated/Affricated	Ejective
Diné Bizaad (McDonough and Ladefoged 1993:153)	[t] 6 [k] 45	[tx] 130 [kx] 154	[t'] 108 [k'] 94
English (Lisker and Abramson 1964:394)	[d] 5 [g] 21	[t ^h] 70 [k ^h] 80	

Though there are no empirical studies establishing a perceptual linkage between Diné [kx, tx] and English [k^h, t^h], the sounds are similar in several ways.² First, the sounds are produced at

²VOTs of Diné ejectives are closer to those of English aspirated stops, but ejectives are quite different from the English stops in other phonetic qualities. Most notably, they are produced with strong pulmonic releases (McDonough and Wood 2008). Such differences are expected to prevent equivalence classification from taking place.

the same places of articulation: velar and alveolar respectively (McDonough 2003). Second, the sounds phonemically contrast with unaspirated stops. Third, evidence from stereotypes of Navajo English suggest that speakers interchange these sounds. A famous example is the song “Rita”, performed by Diné comedian, Vincent Craig (Jacobsen 2017). In a clip of him introducing the song he says, “[People] always come up and say, “Mr. Craig, would y’all sing that song Rita?” And I said “No, no, no it’s not Rita, it’s Rithaaa.” I said. “You got to add that little last push that’s the way we say it, Rithaaa.” (retrieved from <https://www.youtube.com/watch?v=8YxeJ8HD-FU>). In this example, Mr. Craig’s pronunciation of English /t/ in [ɪtʰa] or [ɪra] with a long, affricated Diné [tx] is a central part of his humorous portrayal of strongly Navajo-accented English.

In view of this presumed similarity, the present analysis reports measurements of release period durations, updated from McDonough and Ladefoged (1993), to determine whether bilinguals show phonetic convergence—realized as shortening of Diné releases—to shift towards the VOTs of English [k^h, t^h]. Given an increase in community English usage since McDonough and Ladefoged (1993), if equivalence classification occurs between Diné [kx, tx] and English [k^h, t^h], effects of synchronic and diachronic convergence towards English are expected. The analysis focuses on changes in timing and does not address any phonetic transfer in the quality of the release periods. Phonetic convergence is examined through the testing of three hypotheses: 1) Participants will produce Diné [kx, tx] with shorter, more English-like releases than reported in McDonough and Ladefoged (1993); 2) Younger speakers will produce Diné [kx, tx] with shorter releases than older speakers; 3) Younger speakers will produce Diné [kx, tx] and English [k^h, t^h] with more similar release durations than older speakers.

2 Data and methods

Tokens come from interviews with self-identified bilingual participants.³ No proficiency metrics were used; recruited participants were asked that they be comfortable recounting a short story in Diné Bizaad. Measures of proficiency were intentionally avoided due to the sensitivity of this issue for many speakers of Indigenous languages, especially those who have experienced or inherited linguistic trauma in government run boarding schools. Table 2 presents the distribution of participants by age group and gender.

Table 2. Participants by age group and gender

Factors	Levels	Number
Gender	Men	n=20
	Women	n=31
Age	Younger (18-38)	n=14
	Middle-aged (39-58)	n=22
	Older (59-78)	n=15

³The study was approved by the Office of Research Human Subjects Committee at the University of California, Santa Barbara. Signed consent forms were collected from all participants. A statement of support was also obtained from the Navajo Nation Historic Preservation Department. Interviews and analyses are shaped by my position as a non-Indigenous linguist who has worked with Diné bilinguals since 2009. Interviews are accessible through the Alaska Native Language Archive.

Because of community-wide sociocultural changes, the designated age groups tend to share similar language backgrounds. The older participants acquired Diné Bizaad as a first language, grew up in Diné Bizaad-speaking homes, and did not speak English until beginning school at around age six. Most middle-aged participants similarly acquired Diné Bizaad as a first language in the home, while two learned the language later in school. Among the younger participants, all were raised by, or spent significant time with, their Diné Bizaad-speaking grandparents, though not all participants spoke Diné Bizaad at home as children. Half of the younger participants attended Diné Bizaad immersion schools for some of their K-12 education.

Targeted sounds were measured in elicited words and connected speech. First, an oral translation task was used to elicit stem-initial [kx, tx], repeated twice, before different vowels. The employed wordlist was similar to the previous study (see McDonough 2003:194), and words were checked against dictionary citations (Young and Morgan 1987), and through consultation with a bilingual speaker, linguist, and instructor (Lorene B. Legah p.c). Seven speakers participated in a pilot study in 2016, while the remainder were interviewed in 2017. Elicited words differed slightly between interview sets, and some individual variation occurred in all interviews. Next, stem-initial [kx, tx] were extracted from discourse: a Pear Film retelling (Chafe 1980) and personal narrative, both transcribed by Kendralyn Begay, a bilingual speaker trained in linguistics and Diné literacy.

After transcription was completed, release periods of [kx, tx] were manually segmented in Praat (Boersma and Weenink 2017) using waveforms and wide-band spectrograms. Release durations were measured from the release of the stop closure until the beginning of voicing in the following vowel; this measurement is equivalent to voice-onset time in McDonough and Ladefoged (1993). For instances with multiple bursts, release periods were measured from the first burst. Due to variability between aspiration and affrication, release periods/VOTs were consistently measured, regardless of the quality of the fricative release; release periods may include periods of no aspiration or frication. After compiling the duration measurements, observations were annotated for predictors shown in Table 3.

Table 3. Annotated predictors

Predictors	Levels	[kx] n=	[tx] n=
SEGMENT	kx	1133	-
	tx	-	1792
SOURCE	Words	896	1405
	Discourse	237	387
FOLLOWING VOWEL	a	302	482
	e	392	344
	i	265	428
	o	174	538
PHONETIC ENVIRONMENT	Word-initial	373	467
	V_V	372	682
	C_	388	643
AGE GROUP	Younger	298	514
	Middle-aged	474	725
	Older	361	553

Additionally, tokens of Diné [k] (n=133) and [t] (n=181) were elicited in the same oral translation task and then measured to determine the updated duration contrasts between the

unaspirated and affricated stops. Comparable tokens of the ejectives were not available in this sample, though future work should include these measurements. Finally, to provide a coarse comparison with English [k^h, t^h], the VOT of 98 tokens of [k^h] and 466 tokens of [t^h] were measured in word-initial, stressed syllables, occurring in English discussions during the interviews. The appendix includes examples of measured sounds.

3 Results

Results address the aforementioned hypotheses. First, to determine whether release periods of [kx, tx] have shortened since McDonough and Ladefoged (1993), new measurements are presented. Second, statistical modeling is used to assess whether age groups significantly differ with respect to release durations of [kx, tx]. Third, measurements from English and Diné sounds are reported, to determine if speakers produce interlingually similar sounds with similar release durations.

3.1 Duration measurements

Table 4 presents mean release durations of Diné [kx, tx, k, t] in elicited words. Means are organized by phonetic environment and compared with earlier reported measurements. Standard deviations are shown in parentheses. A comparison limited to intervocalic segments—the focus of McDonough and Ladefoged (1993)—reveals that the mean release of [kx] is 49ms shorter than the earlier mean VOT, while the mean release of [tx] is 4ms shorter. Figure 1 presents boxplots of measured durations, along with measurements of [kx, tx] from discourse. Consistent with earlier descriptions, release periods of [kx, tx] are significantly longer than [k, t]. Based on these measurements, the first hypothesis is partially confirmed: participants produce Diné [kx], but not [tx], with a shorter release than reported in McDonough and Ladefoged (1993).

Table 4. Mean Diné release durations (ms)

	[kx]	[tx]	[k]	[t]
Overall	92(31)	118(28)	26(10)	14(6)
Word-initial	84(27)	111(28)	27(11)	14(6)
C_	92(29)	113(25)	30(2)	13(7)
V_V (present study)	105(35)	126(28)	24(9)	13(5)
V_V (McDonough and Ladefoged 1993)	154(43)	130(29)	45(9)	6(2)

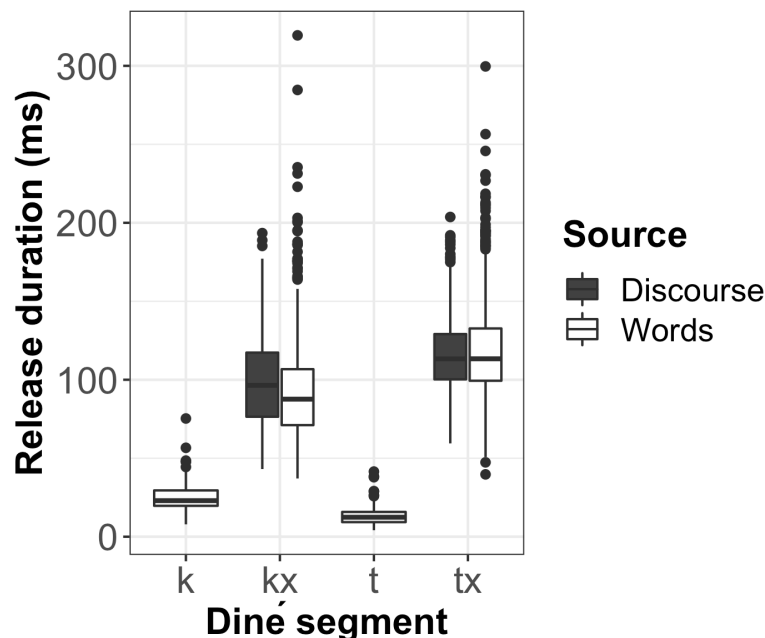


Figure 1. Release durations of Diné segments

3.2 Age group differences

Duration measurements of [kx, tx] were analyzed using mixed-effects linear regression. The model, fit with lme4 (Bates et al. 2014) in R (R Core Team 2017), includes random intercepts for Speaker and Word. A maximal model was constructed with all predictors from Table 3 and two-way interactions. Then, following Winter (2019), likelihood ratio tests were calculated using afex (Singmann et al. 2016), and non-significant interactions removed. The final model includes all tested fixed effects and four significant interactions.⁴ Regression models calculate predicted values based on input data; thus results are reported as predictions. The appendix contains the complete model output.

The interaction between Age and Segment (shown in Figure 2) addresses whether age groups significantly differ in release durations of each segment. This interaction was significant due to younger speakers producing [kx] with a shorter release period than older and middle-aged speakers. There are no significant age differences in the release durations of [tx]. Because differences in speech rate were not taken into account, it is possible that age group effects are a product of group differences in speech rate. However, because distinct patterns emerge between [tx] and [kx], I contend that these results can not solely be due to speech rate differences. These results confirm the hypothesis in part: younger participants produce Diné [kx], but not [tx], with shorter release periods than middle-aged and older speakers.

⁴Besides Age*Segment, the other significant interactions control for linguistic factors that impact duration. Phonetic environment*Source is significant because duration is longest intervocalically and shortest word-initially, especially in discourse. Age*Source is significant because younger speakers produce shorter releases than middle-aged speakers in both tasks. Age*Following vowel is significant because younger speakers produce shorter releases than middle-aged speakers before /a/ and /e/.

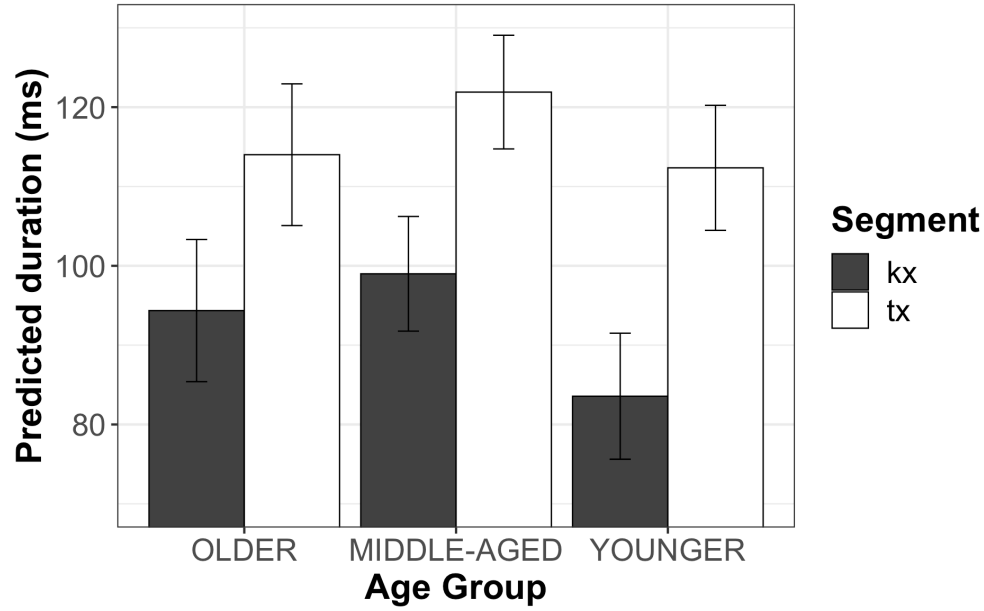


Figure 2. Predicted duration by segment and age group

3.3 Interlingual comparisons

Table 5 presents release durations of English and Diné sounds in discourse. Means are displayed for each age group with standard deviations in parentheses. Figure 3 shows the accompanying boxplots. Measurements reveal that speakers from all age groups produce Diné [kx] and English [k^h] with more similar release durations than Diné [tx] and English [t^h]. As observed in 3.2, younger speakers produce Diné [kx] with a shorter release than other speakers. This pattern also renders their release durations of Diné [kx] and English [k^h] the most similar. These findings somewhat support the third hypothesis: younger speakers produce Diné [kx] and English [k^h], but not Diné [tx] and [t^h], with more similar release durations. Again, a caveat in interpreting these results is that speech rate was not analyzed, and bilinguals from different age groups may speak one of their languages consistently faster or slower than the other.

Table 5. Mean interlingual release durations (ms)

	Older	Middle-Aged	Younger	n=
English [t ^h]	74(27)	74(20)	67(24)	466
Diné [tx]	117(24)	117(23)	115(27)	387
English [k ^h]	64(23)	68(25)	65(10)	98
Diné [kx]	105(33)	101(31)	85(25)	237

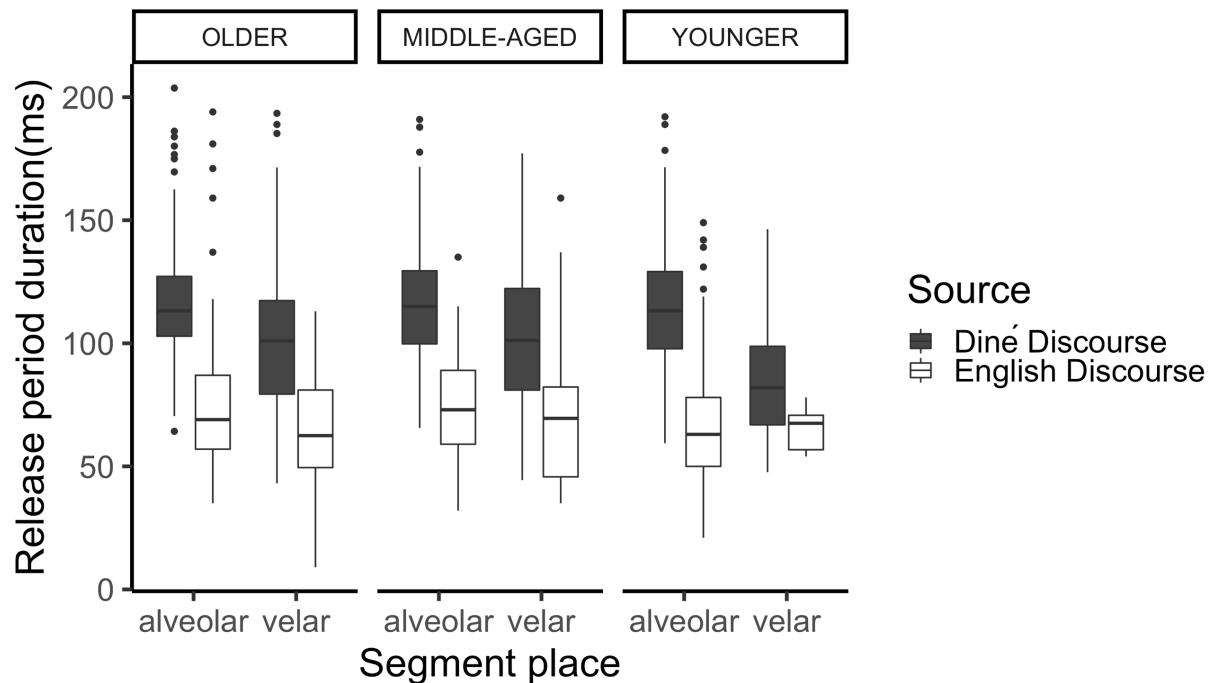


Figure 3. Interlingual durations by age group

4 Discussion

Together, findings support the hypotheses for velar sounds. When compared with earlier measurements, updated values suggest that Diné [kx] has undergone subphonemic shortening. Consistent with the Speech Learning Model, it is presumed that speakers have equated Diné [kx] with English [k^h], leading to phonetic convergence, in which speakers have shortened their release period durations to align more with English VOT targets. The younger participants, who are the most exposed to English, produce [kx] with the shortest releases, and with releases most similar to their English velar stops. Convergence is unidirectional: Diné [kx] has converged with English [k^h], but English [k^h] shows no evidence of simultaneous convergence towards Diné [kx]. Convergence has taken place despite the fact that Diné [kx] is phonemically characterized as an affricate, and English [k^h] a stop.

However, results for the alveolar sounds disprove the hypotheses. Present measurements of [tx] resemble those reported in McDonough and Ladefoged (1993), younger speakers do not produce [tx] with significantly shorter releases than other speakers, nor do they produce Diné [tx] with release durations that are more similar to English [t^h] than those produced by other participants. Given the recorded asymmetry in the literature (see Section 1), whereby [tx] is described as being more strongly affricated than [kx], I propose that equivalence classification has not taken place between Diné [tx] and English [t^h]. In line with the Speech Learning Model, these results appear to demonstrate that the alveolar sounds are categorized as dissimilar by bilinguals, and therefore are not expected to phonetically converge. Perceptual work is needed to confirm these explanations.

5 Conclusions

Overall, results are consistent with predictions of the Speech Learning Model and attested phonetic transfer in minority languages. Due to increased contact with English, effects of diachronic and

synchronic phonetic convergence are documented in similar sounds: Diné [kx] and English [k^h]. Studies of this nature that link research on Indigenous languages to broader research on bilingual populations have the potential to inform community-based teaching of pronunciation and to contribute to knowledge about language contact effects, in contexts beyond more widely discussed larger languages.

References

- Babel, Molly. 2009. The phonetic and phonological effects of obsolescence in Northern Paiute. In James Stanford and Dennis Preston (eds.), *Variation in Indigenous minority languages*. 23–46. Philadelphia: John Benjamins.
- Baker, Wendy & Pavel Trofimovich. 2005. Interaction of native and second-language vowel systems in early and late Bilinguals. *Language and speech* 48(1). 1–27.
- Bates, Douglas, Martin Mächler, Ben Bolker, & Steve Walker. 2015. *Journal of statistical software* 67(1). 1–48.
- Benally, AnCita, & Denis Viri. 2005. Diné bizaad [Navajo language] at a crossroads: Extinction or renewal? *Bilingual research journal* 29(1). 85–108.
- Boersma, Paul & David Weenink. 2017. Praat: doing phonetics by computer. Version 6.0.29, <http://www.praat.org/>,
- Bullock, Barbara & Chip Gerfen. 2004. Phonological convergence in a contracting language variety. *Bilingualism: Language and cognition* 7(2). 95–104.
- Campbell, Lyle & Martha Muntzel. 1989. The structural consequences of language death. In Nancy Dorian (ed.), *Investigating obsolescence: Studies in language contraction and death*. 181–196. Cambridge: Cambridge University Press.
- Chafe, Wallace (ed.). 1980. *The Pear Stories: Cognitive, cultural, and linguistic aspects of narrative production*. Norwood, NJ: Ablex.
- Chang, Charles. 2009. Convergence and divergence in language obsolescence. In Manghyu Pak (ed.), *Current issues in unity and diversity of languages*. 933–952.
- Chang, Charles. 2010. *First language phonetic drift during second language acquisition*. Berkeley, CA: University of California, Berkeley dissertation.
- Fowler, Carol, Valery Sramko, David Ostry, Sarah Rowland, & Pierre Hallé. 2008. Cross language phonetic influences on the speech of French-English bilinguals. *Journal of phonetics* 36(4). 649–663.
- Flege, James. 1987. The production of “new” and “similar” phones in a foreign language: evidence for the effect of equivalence classification. *Journal of phonetics* 15. 47–65.
- Flege, James. 1991. Age of learning affects the authenticity of voice-onset time (VOT) in stop consonants produced in a second language. *Journal of the acoustical society of America* 89. 395–411.
- Flege, James. 1995. Two methods for training a novel second-language phonetic contrast. *Applied Psycholinguistics* 16. 425–442.
- Flege, James & Wieke Eefting. 1987. Cross-language switching in stop consonant perception and production by Dutch speakers of English. *Speech communication* 6. 185–202.
- Flege, James & James Hillenbrand. 1984. Limits on phonetic accuracy in foreign language speech production. *Journal of the acoustical Society of America* 76. 708–721.
- Goodfellow, Anne. 2005. *Talking in context: Language and identity in Kwakwaka’wakw society*. Montreal, QC: McGill-Queen’s University Press.
- Guion, Susan. 2003. The Vowel Systems of Quichua-Spanish Bilinguals. *Phonetica* 60. 98–128.
- House, Deborah. 2002. *Language shift among the Navajos*. Tucson, AZ: UArizona Press.
- Jacobsen, Kristina. 2017. *The sound of Navajo Country: Music, language and Diné belonging*. Chapel Hill, NC: UNC Press.
- Kasstan, Jonathan. 2019. Emergent sociolinguistic variation in severe language endangerment. *Language in Society*, 48(5). 685–720.

- 324 Lee, Tiffany. 2007. "If they want Navajo to be learned, then they should require it in all
325 schools": Navajo teenagers' experiences, choices, and demands regarding Navajo
326 language. *Wicazo Sa Review* 22(1). 7–33.
- 327 Lee, Tiffany & Daniel McLaughlin. 2001. Reversing Navajo language shift, revisited. In Joshua
328 Fishman (ed.), *Can threatened languages be saved?* 23–43. Tonawanda, NY:
329 Multilingual Matters.
- 330 Lisker, Leigh & Arthur Abramson. 1964. Cross-language study of voicing in initial stops:
331 acoustical measurements. *Word* 20. 384–422.
- 332 Maclagan, Margaret & Jeannette King. 2007. Aspiration of Plosives in Māori: Change Over
333 Time. *Australian journal of linguistics* 27(1). 81–96.
- 334 Mayr, Robert, Jonathan Morris, Ineke Mennen, & Daniel Williams. 2017. Disentangling the
335 effects of long-term language contact and individual bilingualism: The case of
336 monophthongs in Welsh and English. *International journal of bilingualism* 21(3). 245–
337 267.
- 338 McDonough, Joyce & Peter Ladefoged. 1993. Navajo stops. *UCLA Working Papers in Phonetics*
339 84. 151–164.
- 340 McDonough, Joyce & Valerie Wood. 2008. The stop contrasts of the Athabaskan languages.
341 *Journal of phonetics* 36. 427–449.
- 342 McDonough, Joyce. 2003. *The Navajo sound system*. Dordrecht, The Netherlands: Kluwer.
- 343 Nagy, Naomi & Alexei Kochetov. 2013. Voice-onset time across the generations. In Peter
344 Siemund, Ingrid Gogolin, Monika Schulz, & Julia Davydova (eds.), *Multilingualism and*
345 *language diversity in urban areas: Acquisition, identities, space, education*, 19–38.
346 Philadelphia, PA: John Benjamins.
- 347 Nance, Claire, Wilson McLeod, Bernadette O'Rourke, & Stuart Dunmore. 2015. Identity, accent,
348 aim, and motivation in second language users: New Scottish Gaelic speakers' use of
349 phonetic variation. *Journal of Sociolinguistics* 20(2). 164–191.
- 350 Newlin-Lukowicz, Luiza. 2014. From interference to transfer in language contact: Variation in
351 voice-onset time. *Language variation and change* 26. 359–385.
- 352 Reichard, Gladys. 1945. Linguistic diversity amongst the Navaho Indians. *International journal*
353 *of American linguistics* 11(3). 156–168.
- 354 Reichard, Gladys. 1951. *Navaho grammar*. New York: Augustin.
- 355 Sapir, Edward & Harry Hoijer. 1967. The phonology and morphology of the Navaho Language.
356 *University of California publications in linguistics*, 50. Berkeley: UC Press.
- 357 Saville-Troike, Muriel & Lynn McCreedy. 1980. Synchronic variation in Navajo: Regional,
358 social, and developmental evidence from child language. *Final Project Report NSF 1979-*
359 *1980*.
- 360 Singmann, Herik, Ben Bolker, Jake Westfall, & Frederik Aust. 2016. afex: Analysis of factorial
361 experiments. Version 0.16–1. <https://CRAN.R-project.org/package=afex>
- 362 Sleeper, Morgan. 2020. Contact effects on voice-onset time in Patagonian Welsh. *Journal of the*
363 *international phonetic association* 50(3). 153–167
- 364 Spolsky, Bernard. 2002. Prospects for the survival of the Navajo Language: A reconsideration.
365 *Anthropology and education quarterly* 33(2). 139–162.
- 366 Thomason, Sarah. 2001. *Language contact*. Edinburgh, Scotland: Edinburgh University Press.
- 367 Weinreich, Uriel. 1953. *Languages in contact*. New York: Publications of the Linguistic Circle
368 of New York.

- Wickham, Hadley. 2009. *ggplot2: Elegant graphics for data analysis*. New York: Springer-Verlag.
- Winter, Bodo. 2019. *Statistics for linguistics: An introduction using R*. New York and London: Routledge.
- xXJustinDArealXx. September 27, 2010. Vincent Craig “Rita”, retrieved from <https://www.youtube.com/watch?v=8YxeJ8HD-FU>
- Yao, Yao & Charles Chang. 2016. On the cognitive basis of contact-induced sound change: Vowel merger reversal in Shanghainese. *Language* 92(2). 433–467.
- Young, Robert & William Morgan. 1987. *The Navajo language: A grammar and colloquial dictionary*. Albuquerque: UNM Press.

Appendix

1 Examples⁵

(1) Diné [tx] [audio-1.wav]

Sétal. [sɪtxal]

sé-taɬ

1SINGULAR.PERFECTIVE-PERFECTIVE.kick.it

‘I kicked it.’

(2) Diné [t] [audio-2.wav]

Sédá. [sɪta]

sé-dá

1SINGULAR.PERFECTIVE-PERFECTIVE.sit

‘I sit.’

(3) English [tʰ] [audio-3.wav]

for some time [fəɪ sʌm tʰaɪm]

(4) Diné [kx] [audio-4.wav]

’Atoo’ naa deeshkáál. [ʔatʰo:ʔ na: tɛ:ɭkxa:l]

atoo’ n-aa deesh-káál

stew you-to 1SINGULAR.FUTURE-FUTURE.carry.open.container

‘I will bring you stew.’ (Elsie Whitehorse Walck Interview 00:15:31)

(5) Diné [k] [audio-5.wav]

gah [kah]

gah

‘rabbit’

(Elsie Whitehorse Walck Interview 00:08:59)

(6) English [kʰ] [audio-6.wav]

of where they come from [əv ɥeɪ ɰeɪ kʰʌm fɪʌm]

(Elsie Whitehorse Walck Interview 00:42:01)

⁵ Citations refer to *Variation in Diné Bizaad*, an archived collection at the Alaska Native Language Archive. Examples 1-3 are left anonymous per interviewee request.

2 Statistical model output

Table 1. Random effects output

Group	Name	Variance	Standard deviation	
Words	(intercept)	102.7	10.13	n=94
Speaker	(Intercept)	229.3	15.14	n=51
Residual		496.9	22.29	

Table 2. Fixed effects output

		Estimate	Std. Error	df	t-value
(Intercept)	[kx], C_, Following vowel a, middle-aged, discourse	99.44	4.46	177.62	22.28
Segment [tx]	[tx]	22.91	3.10	66.85	7.38
Phonetic environment	Word-initial	-15.58	3.39	2021.42	-4.60
	V_V	10.08	2.61	1469.06	3.86
Age	Older	-2.92	5.67	90.36	-0.52
	Younger	-21.43	4.32	897.04	-4.96
Source	Words	1.32	2.61	1922.35	0.50
Following vowel	e	-5.19	4.02	60.28	-1.29
	i	0.51	4.24	58.77	0.12
	o	1.38	4.39	103.67	0.32
Segment*Age	[tx]:Older	-3.26	2.10	2851.76	-1.55
	[tx]:Younger	5.89	2.20	2844.74	2.68
Age*Source	Older:Words	-6.62	2.65	2865.08	-2.50
	Younger:Words	-0.55	2.88	2896.20	-0.19
Phonetic environment *Source	Word-initial:Words	7.89	3.44	2485.40	2.30
	V_V*Words	-5.56	2.97	2054.81	-1.87
Age*Following vowel	Older:e	4.59	2.81	2852.75	1.63
	Younger:e	5.44	3.02	2851.02	1.80
	Older:i	5.29	2.88	2846.08	1.84
	Younger:i	9.07	2.98	2854.45	3.04
	Older:o	4.44	2.85	2854.09	1.56
	Younger:o	11.97	3.06	2842.52	3.91