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Seeing Speech: Ultrasound-based Multimedia Resources for Pronunciation Learning in Indigenous Languages

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Pronunciation is an important aspect of Indigenous language learning, and one which requires creative community-oriented solutions. Towards this end, we have developed a pronunciation learning tool that incorporates ultrasound technology to give learners a visual aid to help them articulate unfamiliar and/or challenging sounds. Ultrasound is used to create videos of a model speaker's tongue movements during speech, which are then overlaid on videos of an external profile view of the model's head to create ultrasound-enhanced pronunciation videos for individual words or sounds. A key advantage of these videos is that learners are able to see how speech is produced rather than just hear and try to mimic it. Although ultrasound-enhanced videos were originally developed for commonly taught languages such as Japanese and French, there has been widespread interest from Indigenous communities in Western Canada to develop their own customized videos. This paper reports on three collaborations between linguists and communities in British Columbia to develop ultrasound-enhanced videos for the SENĆOTEN, Secwepemc, and Halq'emeylem languages. These videos can give learners a new way to learn pronunciation that focuses on seeing speech, and can create new documentation of understudied sound systems for future generations.

1. Introduction¹ Anyone who has had the experience of learning a new language knows that pronunciation is important. Even with a degree of mastery over the grammar and vocabulary of a new language, it can be intimidating for a learner to speak in a new language if they are unsure about their pronunciation, particularly since it is typically the first cue that people rely on to assess one's linguistic abilities (Derwing et al. 2004). Conversely, good pronunciation can improve one's self-confidence and intelligibility, and potentially lead to greater overall competency, sense of identity, and communicative abilities in the language (Piller 2002; Rindal 2010). In the context of language revitalization, pronunciation can take on a particularly important role, as learners strive to pronounce words and sentences in a way that honours their elders' speech (Bird & Kell 2017).

Although many language revitalization efforts are currently focused on developing new speakers (e.g., mentor-apprentice programs), very little work has been done to create resources for teaching and learning pronunciation in Indigenous languages. In this paper, we document our experiences of developing multimedia pronunciation resources for three critically endangered Salish languages spoken in British Columbia, Canada: SENĆOFEN, Halq'emeylem, and Secwepemc. The project has been carried out collaboratively with teams of linguists and community members working together. The resources we developed rely on ultrasound imaging technology to create videos that demonstrate how to articulate certain challenging sounds in the languages, particularly sounds that are not found in English and are produced with the tongue raising to specific areas at the back of the mouth (e.g., the velum, the uvula), out of plain sight. Ultrasound affords learners an opportunity to see these otherwise invisible articulations, and by doing so they can model their own articulations accordingly in order to improve their pronunciation. More generally, ultrasound can help learners to increase their overall awareness of what their tongue is doing during speech (see Shawker & Sonies 1985).

The paper proceeds as follows. In §2, we provide some background context for this project, with a discussion of pronunciation in Indigenous language revitalization. In §3, we outline our objectives for the project, by discussing how the project began, what specific pronunciation challenges Salish language learners face, and the potential role that ultrasound imaging technology can play in developing pronunciation resources. §4 explains the methodology we followed for developing the videos, and §5 describes the outcomes, namely the video libraries we developed. In §6, we discuss broader community impacts of the project.

¹HÍŠW̱KE to the elders who gave generously of their time and knowledge, Lou Claxton, Ntlola Emmeline Felix, and Siyamiyateliyot Elizabeth Phillips. HÍŠW̱KE to many other collaborators for their contribution to this work, including Phoenix Cardinal, ÍYIXELṮW̱ Nick Henry, Tiffany Šwxeloselwet Joseph, Matthew Law, Aaron Leon, Katia Olsen, Murray Schellenberg, Christine Schreyer, Rosalind Williams, and Yik Tung Wong. HÍŠW̱KE to the audience at ICLDC 5 for helpful feedback on this project. This work has been supported by NIH Grant DC-02717 to Haskins Laboratories and a Banting Postdoctoral Fellowship to H. Bliss.

2. Context In many Indigenous language learning programs, there is a strong focus on orality. Few if any Indigenous languages used written language before colonial contact, and today communities differ in terms of whether they have developed and/or adopted a writing system for their language, how widely used it is, and what the literacy goals and outcomes are amongst the speakers and learners. Even for those communities who place a high value on literacy, oral proficiency is still widely regarded as the primary goal for language revitalization (Hinton 2003). Recent research has shown that learners and educators are indeed concerned about pronunciation (Bird & Kell 2017), and educational materials created in the context of Indigenous language revitalization have recognized that pronunciation is a major component of proficiency, e.g., McIvor & Jacobs' (2016) NETOLNEW 'one mind, one people' Language Learning Assessment Tool includes pronunciation components, referring both to oral production of sounds in the language and auditory perception of other speakers' pronunciation. Nonetheless, there has been very little discussion around how best to learn and teach pronunciation in Indigenous language contexts.

One of the reasons for this general lack of discussion around pronunciation in Indigenous language revitalization is that, over the past half-century or so, pronunciation has not been a main focus of second language (L2) pedagogy more generally, although Munro & Derwing (2015) point out that this is changing (see Saito 2012 and Lee et al. 2015 for recent reviews). The dominant model of language teaching has been the Communicative Approach, which emphasizes the communicative functions of language, rather than linguistic forms themselves (Celce-Murcia et al. 1996; Grant 2014). Generally speaking, this shift towards communicative functions was positive, as it helped to de-stigmatize foreign accents and placed more emphasis on inter- and cross-cultural communication. However, the downside is that pronunciation instruction fell to the wayside (e.g., Derwing & Munro 2005), and throughout the field of L2 teaching and learning, not enough attention was paid to the fact that pronunciation plays an integral role in intelligibility and communicative competence (Levis 2005). This left many "on-the-ground" language teachers and learners, who recognized the importance of pronunciation in language learning all along, with a paucity of resources for pronunciation instruction.

In the context of Indigenous language revitalization in particular, the Communicative Approach also over-simplifies both the *challenges* related to learning pronunciation, and the *importance* of pronunciation for the speech communities involved. In terms of challenges, we know that rates of sound change can increase in the context of language endangerment (e.g., Dorian 1994; King et al. 2009), meaning that learners' pronunciation will often differ from that of their elders in this context more so than in other contexts (see also Goodfellow 2003). This is partly because, when there are few speakers providing input, learners do not have the advantage of speaker variability for converging on phonetic targets. In communities where no fluent speakers remain, language revival is dependent exclusively on existing documentation, meaning that learners must acquire the skills to interpret phonetic descriptions and writing systems, and hypothesize about authentic pronunciation (e.g., Leonard 2007; Hinton 2011).

Since the Communicative Approach focuses primarily on widely spoken languages like English, these challenges have remained largely unaddressed.

The Communicative Approach also underestimates the intrinsic importance of pronunciation in language revitalization contexts, in two ways: first, at a relatively concrete level, pronunciation plays an important social role, as a way of honoring the elders' way of speaking (Bird & Kell 2017). At a more abstract level, the Communicative Approach does not take into consideration the potential impact of L2 pronunciation on the language as a whole. For example, in British Columbia, the majority of Indigenous language speakers are currently adult L2 learners (Gessner et al. 2014), and these are the speakers who are passing on their language to future generations (as teachers and parents). In this context, L2 pronunciation will likely have a substantial effect on the evolution of a language's sound structures as a whole. It is natural then for speech communities to be particularly concerned about learners acquiring the pronunciation of their elders. Indeed, Bird & Kell (2015; 2017) and King et al. (2009) point out that pronunciation changes in a community can be perceived negatively, particularly by older generations, and the stakes are high to preserve the language as it is spoken by fluent L1 speakers.² In response to these pressures, learners can feel intimidated at the prospect of trying to pronounce words and sentences in ways that are true to the way their elders speak.

In terms of teaching methods, popular approaches to Indigenous language learning such as TPR (Total Physical Response) (Asher 1977), TPR-Storytelling (Cantoni 1999), and Greymorning's (2011) Accelerated Second Language Learning Approach do not explicitly address pronunciation strategies, but implicitly assume that learners' pronunciation will improve over time through listening and modeling of fluent speakers. The "Where Are Your Keys" (WAYK, <https://whereareyourkeys.org>) program acknowledges both the challenges and values associated with correct pronunciation through incorporating techniques such as "Mumble (for now)" and "Accent Adjustment", but like TPR and other immersion-based programs, it does little to provide learners with concrete strategies on how pronunciation skills can be developed.

In terms of research, there are but a few papers that address pronunciation in Indigenous language learning, often based on observations that the Indigenous language is shifting under the influence of a dominant language. For instance, Carpenter (1997) advocates for explicit pronunciation instruction for Indigenous language programs, with a particular focus on learning some basic linguistic principles in order to compare phonetic and phonological aspects of English (the dominant language for these communities) with the language in question. Carpenter's recommendations are not tested experimentally in her work, but she draws on other research in L1 and L2 acquisition to support her claims. Oberly et al. (2015) similarly report on using linguistic terminology and analyses as a way for learners to improve their pronunciation of Southern Ute.

²For a different perspective, see Goodfellow (2003), who documented differences in grammar and pronunciation across three generations of Kwak'wala speakers, and advocates that changes due to language attrition and the influence of English should be embraced, with mixed Kwak'wala-English varieties being accepted in the community.

King et al. (2009) argue that the pronunciation of Māori has been impacted by the dominant language, in this case New Zealand English. Based on their findings for Māori, they hypothesize some patterns of dominant language-influenced sound changes in other Indigenous languages undergoing revitalization, such as the loss of phonemes not found in the dominant language and changes in rhythm based on vowel length changes. King et al. recommend that the oldest generations of speakers act as models for pronunciation, as their pronunciation is less affected by the dominant language. While King et al.'s research focus has been to document changes in Māori pronunciation over time, a practical application of their team's research has been the development of a computer-assisted pronunciation training tool that gives learners access to these older generations of speakers (see Gutla 2006; Rivers 2006). This small body of research supports the need for creative, community-oriented solutions that allow teachers and learners to preserve their languages in an authentic way.³ It motivates the current project, the aim of which is to contribute one tool to the growing toolset for teaching and learning pronunciation.

3. The project

3.1 The collaboration The partners in this project, and co-authors of this paper, are linguists and language revivalists working on three related Salish languages: SENĆO-FEN, Halq'emeylem, and Secwepemc. SENĆO-FEN is the language of the W̱SÁNEĆ people, whose territory includes the Saanich Peninsula on the southern tip of Vancouver Island (BC, Canada) and parts of the adjacent Gulf (BC) and San Juan (Washington State, USA) Islands, as well as the Point Roberts area (USA) across the Salish Sea (Elliott 1990; PENÁĆ 2017); Halq'emeylem is the Upriver dialect of what is sometimes called Halkomelem and is the language of the Stó:lō people, whose territory lies along the south shore of the Fraser River east of Vancouver into the Fraser Valley; Secwepemc is the language of the Splatšin people, in the Interior of British Columbia around the Enderby area (see Figure 1).

All three of the languages involved in the collaboration are classified as critically endangered according to standard language status scales (Moseley 2010; Gessner et al. 2014), ranging between 7 “shifting” to 8b “nearly extinct” according to Lewis & Simons' (2010) language endangerment scale. However, in all three communities, various types of language revitalization projects are underway, including language nests and other immersion programs, language education programming, and language apps.

The Salish language family, including SENĆO-FEN, Halq'emeylem, and Secwepemc, is known for its rich consonant inventories (Table 1). A number of consonants tend to be challenging for learners (most of whom are L1 speakers of English) to perceive and pronounce. Plosives, in particular pre- and post-velars (pronounced at the back of the mouth), come in sets of four, which contrast in voicing (plain vs. ejective,

³Authenticity is a much broader notion than just pronunciation, encompassing other aspects of grammar as well as expressions of traditional values, and in some communities the latter may take precedence over the former (Hinton & Ahlers 1999).

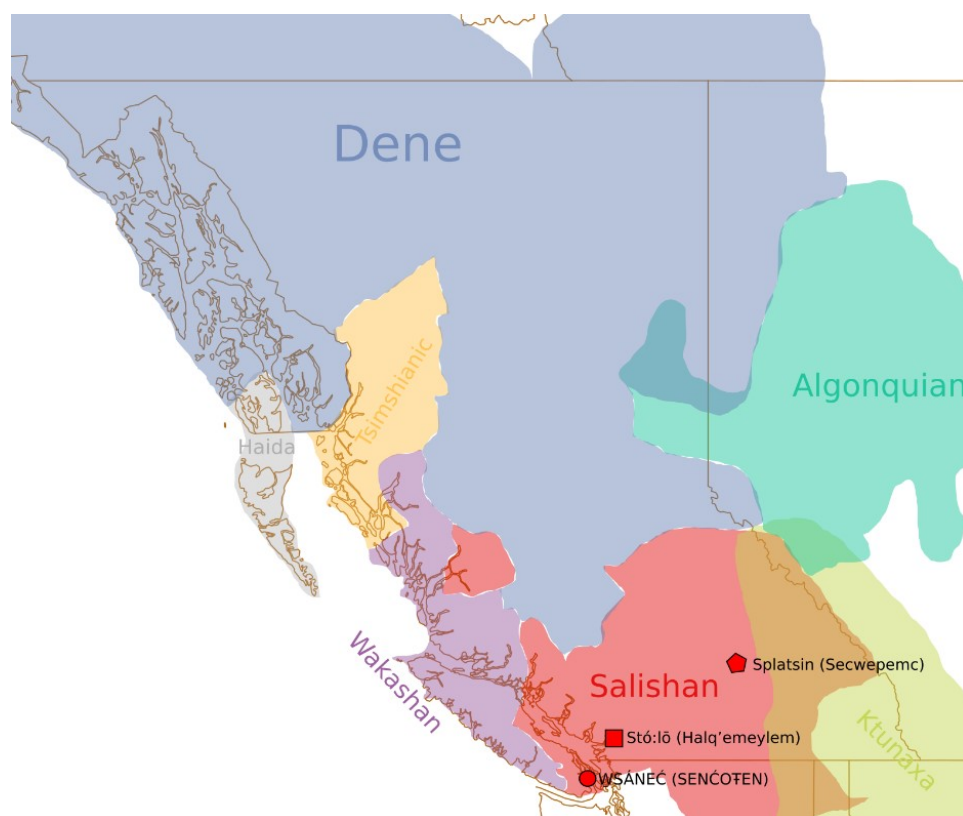


Figure 1. Map showing locations of three Salish community partners (adapted from the FPCC’s language map of BC: <http://maps.fpcc.ca/>)

e.g., /q/ vs. /q̣/) and lip rounding (plain vs. labialized, e.g., /q/ vs. /qʷ/); resonants can be plain or laryngealized (e.g., /m/ vs. /m̥/); and Central Salish languages in particular exhibit a complex set of coronal sounds, including a number of lateral sounds (e.g., /ɬ/ and /ɬ̥/).⁴

This project was initiated by PEPAKIYE Ashley Cooper, a STÁ,SEN TFE SENĆOŦEN Language Apprentice who recently completed the University of Victoria’s Diploma in Indigenous Language Revitalization program, in part as a way of supporting her own language learning. In exploring online resources for pronunciation instruction, PEPAKIYE found the website for the *eNunciate* project, an initiative developed and managed by Dr. Bryan Gick at the Interdisciplinary Speech Research Laboratory (ISRL) at the University of British Columbia (UBC; www.enunciate.arts.ubc.ca). The goal of the *eNunciate* project is to develop and evaluate multimedia pronunciation resources, with a focus on those using ultrasound imaging technology, to give learners a visual aid for learning to perceive and produce unfamiliar and/or challenging sounds. More specifically, the *eNunciate* team’s flagship development is a technique

⁴Symbols used in Table 1 are those of the North American Phonetic Alphabet (NAPA), the standard alphabet used in the Salish literature; c = ts; č = tʃ; š = ʃ; λ = tʰ; ɬ = ɬ; x = χ.

for creating ultrasound overlay videos, which combine ultrasound images of tongue movements during speech with external profile views of a speaker’s head (see Figure 2 below). These allow learners to visualize what their tongues are doing during pronunciation, and help them to achieve the correct articulations in their pronunciation of unfamiliar sounds.

Table 1. Halq’emeylem, Secwepemc, and SENĆOŦEN consonants. /m̥ n̥ ŋ̥ ɺ̥ ʔ̥ w̥ ɣ̥ ʕ̥ ʕ̥w̥/ do not occur in Halq’emeylem;⁵ /c̥ ɕ̥ k̥ x̥ ɣ̥ ʕ̥ ʕ̥w̥/⁶ do not occur in SENĆOŦEN; /t̥ θ̥ ʃ̥ ʃ̥̣ ɲ̥ ɲ̥̣/ do not occur in Secwepemc; /k/ is marginal in Halq’emeylem and SENĆOŦEN, occurring primarily in borrowings.

| | Labial | Dental | Alveolar | Palatal | (Pre-)velar ⁷ | Post-velar | Glottal |
|---------------------|--------|-----------------|----------|---------|--------------------------|--------------------|---------|
| Plosive | p | | t | | k k ^w | q q ^w | |
| | p̥ | | t̥ | | k̥ k̥ ^w | q̥ q̥ ^w | |
| Affricate | | | c | ç | | | ʔ |
| | | t̥ ^θ | ɕ | ç̣ | | | |
| Lateral affricate | | | ʎ | | | | |
| Nasal | m | | n | | | ŋ ɲ | |
| | m̥ | | n̥ | | | | |
| Fricative | | θ | s | ʃ | x x ^w | ɣ ɣ ^w | h |
| | | | | | ɣ̥ ɣ̥ ^w | | |
| Lateral fricative | | | ɬ | | | | |
| Approximant | | | | y | w | ʕ ʕ ^w | |
| | | | | y̥ | w̥ | ʕ̥ ʕ̥ ^w | |
| Lateral approximant | | | l | | | | |
| | | | l̥ | | | | |

At its outset, the *eNunciate* project’s target audience was students of linguistics and university-level learners of Japanese; PEPAŦIYE found videos designed for Japanese learners online, and was motivated to create something similar for SENĆOŦEN. She reached out to Dr. Sonya Bird, a linguist specializing in pronunciation at the University of Victoria who has been working with the SENĆOŦEN-speaking com-

⁵Glottalized resonants and /n/ are found in the other two dialects of Halkomelem – Hulqumínum̥ and hənq̣əmiñəm̥ – but have recently been lost from Halq’emeylem.

⁶SENĆOŦEN /t̥ θ̥/ often sound like [ç s]. Further study of these sounds is required to determine what the extent of the variation is, and whether it is based on systematic factors, like dialect.

⁷In the Salish literature, the “back of the mouth” articulations are commonly referred to as pre- vs. post-velar sounds, as a reflection of the fact that these sounds vary substantially in terms of precise place of articulation.

munity for the past ten years, to see whether something similar could be created for SENĆOTEN. Sonya in turn contacted Dr. Heather Bliss, also a linguist and team member of the *eNunciate* project, and a collaboration was born. This initial collaboration – between the W̱SÁNEĆ School Board, the University of Victoria, and UBC – inspired additional collaborations, with members of two other Salish communities, Stó:lō – via Dr. Strang Burton, also a linguist affiliated with UBC’s ISRL and the *eNunciate* project – and Splaṯsin – via Dr. Christine Schreyer, a linguistic anthropologist at UBC Okanagan, to produce customized pronunciation resources for the Halq’emeylem and Secwepemc languages, respectively. Throughout this paper, we – PEPAḴIYE, Heather, Sonya, Strang, and Bryan – speak with our collective voice. In §6 (Impacts), we use italics to highlight PEPAḴIYE’s voice specifically, as the community-based collaborator on this project.

3.2 The resource As mentioned in §3.1 above, the project involved creating ultrasound overlay videos for three Salish languages, using the technology developed by the *eNunciate* team. A screenshot of what these videos look like is presented in Figure 2.



Figure 2. Screenshot of Japanese ultrasound overlay video

Ultrasound overlay videos are potentially useful for visualizing how to articulate many of the sounds and sound contrasts illustrated in Table 1, as well as sequences of sounds which can be challenging (e.g., /iq/). To explain why this is so, we will first give a brief overview of how ultrasound can be used in pronunciation instruction.

Ultrasound involves emitting a high-frequency sound through a transducer (the “probe”) that can be held under the chin, enabling sound to travel through the tongue and reflect back to the transducer, from which is generated a 2-dimensional image of the tongue. Over the past decade ultrasound has been increasingly used in teaching

and learning pronunciation, usually by giving learners visual biofeedback on their own pronunciation as compared with that of a fluent speaker or teacher (Wilson & Gick 2006; Gick et al. 2008; Tsui 2012; Tateishi & Winters 2013; Ouni 2014; Wilson 2014; Cleland et al. 2015; Pillot-Loiseau et al. 2015; Wu et al. 2015). Certain sounds and sound contrasts are particularly amenable to ultrasound feedback: places of articulation for coronal and dorsal sounds are easily viewed with ultrasound, as are sounds such as laterals and rhotics, which require precise timing of movements of different parts of the tongue (Wilson & Gick 2006).⁸ Specifically regarding Salish sounds, ultrasound can be particularly beneficial for highlighting the contrasts between pre- and post-velar sounds (commonly referred to collectively as the “K sounds”), e.g., /k/ vs. /q/, as well as the contrasts between the many coronal (dental, alveolar, lateral, palatal) sounds in Central Salish languages.

Even for contrasts that are not specifically targeted by ultrasound visualization, such as the glottalized sounds (laryngeal gestures are not easily detectable with ultrasound, although see Moiskis et al. 2013), providing a dynamic audio-visual record of sound contrasts via ultrasound may be beneficial to learners in terms of increasing their general awareness of what their articulators are doing during speech (see Shawker & Sonies 1985 on clinical applications of ultrasound visualization). In addition, preliminary research (Bliss et al. 2017) indicates that ultrasound visualization also benefits perception among language learners; see §5 below for details. This is an important topic to study further, given the perceptual foundation of production in second language acquisition (Flege 1995).

3.3 The objectives Incorporating ultrasound into L2 teaching and learning can be challenging. Most studies to date have focused on ultrasound-based pronunciation instruction with small groups or even individual learners, and ultrasound is only just beginning to be explored in the context of large-group settings like classrooms (Bird & Bliss 2017). Furthermore, unedited ultrasound images may be difficult for untrained learners (and/or instructors) to interpret without the aid of an ultrasound technician or expert. These shortcomings of ultrasound-based pronunciation instruction are what led to the development of ultrasound overlay videos. For the three Salish languages in this project, being critically endangered means that one of the challenges for pronunciation (and language learning more generally) is the limited access to L1 speakers. The objective for developing ultrasound overlay videos for these languages was to provide virtual access to speakers by recording their pronunciations using ultrasound. Moreover, these recordings create a new body of language documentation beyond standard audio and video data. Our hope is that these videos will contribute to the relatively sparse resources that exist for pronunciation training, and that they will ease pronunciation challenges for new learners of Indigenous languages by visually illustrating the detailed mechanics of the target sounds.

⁸Ultrasound is not able to visualize bone, which prevents identification of hard structures such as the teeth or the hard palate in the resulting images.

4. Methods In this section, we report on the process of developing the videos. We begin with a description of the recording equipment and set-up; then we discuss the collaboration with each community to complete the ultrasound recordings; finally, we discuss the procedure for editing the videos.

4.1 Recording equipment and set-up To facilitate in-community recording, we designed a recording kit that is portable, easy to set up, has minimal facility requirements, and is as comfortable as possible for the speakers being recorded. Its main components are a CHISON portable ultrasound machine with an EV transducer, a MacBook Pro laptop computer, and a Panasonic camcorder with a tripod. A series of adapters and cables connect the various devices, which collectively fit on an average-sized tabletop and are color-coded to enable easy set-up. A power bar and extension cord are included in the recording kit; only a single power source for the kit is required. A blue cloth functions as a backdrop, and can be taped or pinned to a wall near the table. Finally, a tabletop music stand is included to display any prompts the speaker may want to refer to during the recording (avoiding the sound of rustling papers on the recording). The cost of the entire recording kit was approximately \$25,000 CAD, but it is worth noting that the bulk of the expenses was for the ultrasound machine itself, and ultrasound technology is becoming increasingly portable and affordable.

During the recording, the speaker sits in a comfortable chair; the ultrasound probe is either fixed under their chin using an adjustable arm clamped to the armrest of their chair or an adjacent table (Figure 3), or the speaker holds it him- or herself. The probe must be positioned straight up and down centered under the speaker's chin, and this is monitored and adjusted throughout the recording, so that the image includes the tongue between the shadows of the hyoid bone (at the back) and the mandible (at the front).⁹ A layer of hypo-allergenic gel is applied to the probe to enhance the ultrasound image, and in some cases the speaker may also need to apply gentle pressure between the probe and the skin to ensure a clear image. The speaker wears an adjustable microphone headset that rests behind the ears and back of the head. The exterior video footage (i.e., a profile of the speaker's face) is recorded into the camcorder, and the ultrasound and audio footage is recorded into the laptop running iMovie via a pre-amp and video converter. A photo of the recording set-up is shown in Figure 3.

It is important to note that not all speakers' tongues image equally well with ultrasound. In addition, speakers may have idiosyncratic pronunciation features. For this reason, ultrasound studies ideally include multiple speakers, to accommodate individual differences in both image quality and articulation. However, in this particular context, given how endangered the languages are, this is simply not feasible (see also

⁹While stabilization of both the speaker's head and the probe are optimal for achieving the best possible ultrasound imagery, this is not feasible in all field situations (see Gick et al. 2005). Moreover, because the ultrasound images are being used for pedagogical rather than research purposes, the precision of the image is less important. Following unsuccessful attempts to use the stabilizing arm (which proved too restrictive for some speakers), we opted in most recording sessions to maximize the comfort of the speakers by not using head- or probe-stabilization devices.

Percival et al. 2017). In all cases, we worked with single speakers, well-respected elders whom community members considered to be excellent models.



Figure 3. Recording set-up (with Halq'emeylem speaker Siyamiyateliyot Elizabeth Phillips). Photo credit: Cara McKenna, APTN

There may be minimal discomfort for the speaker wearing these devices and having sticky gel on their chin, but most report having a positive experience during the recording process. The two video streams (exterior face and ultrasound) are recorded in tandem, with a clapperboard¹⁰ being used to synchronize the recordings.

4.2 Halq'emeylem recording The Halq'emeylem recording sessions were conducted by Heather Bliss (then Research Coordinator for the *eNunciate* project at UBC) and Strang Burton (linguist and multimedia developer with the *eNunciate* project), along with Matthew Law (student research assistant with the *eNunciate* project). We were honored to visit Siyamiyateliyot Elizabeth Phillips in her home on the Cheam First Nation in the Fraser Valley, British Columbia to record her as the last remaining L1 speaker of the Upriver dialect of the language. A word list had been prepared in advance by Strang, who has many years of experience working with members of the Stó:lō community on language documentation and revitalization projects, and we recorded multiple takes of the word list. The first recording session took place in April 2016. This was the first time the recording kit had been used outside of the lab, and we faced technical complications in connecting the various components of the kit (which have since been documented and resolved). As a result, we were not able to pay careful enough attention to the positioning of the probe and in the ultrasound recordings, and the back part of the tongue is not visible. We were very

¹⁰Clapperboards (or slates) are commonly used in film production to designate scene beginnings and ends and to synchronize recording streams. Anything that makes a loud single-beat noise could be used towards this end, including someone clapping their hands loudly.

fortunate to have had a second opportunity to record Elizabeth at her home again in December 2016, and this time the recording quality was much better. We took from this experience the valuable lesson to adequately pilot and test all equipment and procedures in advance of working with elders or other speakers.

4.3 SENĆOTEN recording The team for the SENĆOTEN recordings included Heather Bliss, Sonya Bird (linguist at the University of Victoria), Tye Swallow (Director of Language Revitalization with the W̱SÁNEĆ School Board), and four STÁ,SEN TFE SENĆOTEN Language Apprentices: PEPAḴIYE Ashley Cooper, ÍYIXELṮW̱ Nick Henry, Tiffany Śwxeloselwet Joseph, and Katia Olsen. Following an initial team meeting to establish a set of objectives, we convened at the Saanich Adult Education Centre on the TSARTLIP Reserve on Vancouver Island, British Columbia for a two-day recording session in July 2016.

On the first day, we discussed pronunciation challenges, and the types of sounds that would be best suited for ultrasound. Based on these discussions, the apprentices developed a word list for recording, and also set priorities in terms of which speakers to record (including an elder and children in the immersion program). The recording kit was set up, the team was trained on how the recording process would proceed, and team members were assigned individual roles (i.e., one person operated the camcorder, one person monitored the audio and operated the laptop, one person monitored the ultrasound machine to ensure the image was clear, one person directed the start and stop sequences for the recording with the clapper, and one person assisted the speaker with the prompts and the probe, as needed). After everyone was clear on their roles, we were honored to have the opportunity to record one of the few L1 speakers of SENĆOTEN, Lou Claxton, as well as one of the apprentices.

On the second day, we continued with the recording, this time recording two children in the immersion program at the ŁÁU, WEL, NEW̱ Tribal School in the community, as well as all four apprentices. Recording the children involved modifying our set-up somewhat; each child was seated on the lap of an apprentice (the child's mother or aunt), who also held the probe under the child's chin. The decision to record L2 learners (children and apprentices) and an L1 speaker was to facilitate comparisons between different speakers' pronunciations, with a view towards analyzing variation in pronunciation across generations (see also Bird & Kell 2015; 2017). The second day of recording was documented by the Communications Team from UBC; a media story featuring interviews and photographs with team members can be viewed at <http://www.ubc.ca/stories/2016-fall/enunciate.html>.

4.4 Secwepemc recording The Secwepemc recording team consisted of Heather Bliss, Christine Schreyer (linguistic anthropologist from UBC Okanagan), and three people from the Słatsin Tsm7aksaltn Teaching Center: Rosalind Williams (Coordinator of the Słatsin Language Program), Aaron Leon (Researcher and Multimedia Expert), and Phoenix Cardinal (Youth Helper). We were honored to have the opportunity to record Ntlola Emmeline Felix, a very fluent and well-respected L1 speaker of the Słatsin dialect of Secwepemc. A word list had been prepared in advance, but

because Emmeline is vision-impaired, in lieu of a print-out for reading, Rosalind verbally prompted Emmeline to say each word two or three times. We also recorded a short story, which has been archived for potential later research and/or pedagogical purposes.

4.5 Video production Once recorded, the video footage (ultrasound and exterior) was archived with each community and in duplicate on a protected server at UBC. The procedure for transforming the raw footage into ultrasound overlay videos requires a series of steps using software applications in the Adobe Creative Suite. The two video streams (ultrasound and exterior) are time-aligned and then each token of each word or phrase is extracted into two new files (one ultrasound, one exterior). Using a “masking” effect in Adobe Premiere, the tongue is traced on the ultrasound file, then shaded pink to appear more like a natural tongue. Finally, the tongue is overlaid on the face, using the position of the probe as a reference point for positioning (see Figure 3 above). For more specific details on the production methods, see Abel et al. (2015) and Yamane et al. (2015). The *eNunciate* team has also developed a user manual that outlines the procedure.

At the outset of the SENĆOFEN project, the plan had been for the WSÁNEĆ apprentices to do the video production, and one of the apprentices visited the lab at UBC for training. However, it became evident after the recording and training were completed that the apprentices’ skills were more urgently needed on other language projects in the community, particularly those involving developing curricula and materials for the K–4 immersion school in the community. We had discussed a similar plan for Secwepemc videos: we were going to seek external funding for the videos to be produced in the community. In the meantime, opportunities arose for a team of student research assistants in the Interdisciplinary Speech Research Laboratory at UBC to produce a set of videos for all three languages, and with the agreement of everyone involved, we had these students produce the videos. We feel that by being flexible in our plans for the video production, we were able to balance our goals of community capacity-building and completing the videos for use by learners in the communities. As outlined in the preceding sections, community partners were active participants in the design and recording of the videos; they learned new skills in this process that could be used to make more ultrasound overlay videos in the future, or could translate to other projects. However, for completing the video production, we made efficient use of available resources (trained student researchers with ready access to the required software), freeing up the community partners for other language revitalization projects (e.g., Lacho & Leon 2017).

5. Outcomes A direct outcome of this project has been the creation of ultrasound overlay video libraries for three Salish languages: SENĆOFEN, Halq’emeylem, and Secwepemc. In this section, we describe these libraries in more detail, with reference to the potential uses and benefits of this work. In §6, we turn to broader community impacts of the project.

The SENĆOŦEN library includes videos of one L1 speaker, four adult L2 learners (apprentices), and two elementary school aged L2 learners (children in the SENĆOŦEN immersion program), as described above. Whereas the word list for the L1 speaker was designed specifically to capture challenging sounds and sound combinations, the word lists for the learners were designed with the intention of making the recording process simple (for the children) and collecting full sets of related lexical items in early vocabulary (e.g., numerals one through ten, words representing the letters of the SENĆOŦEN alphabet). As evidenced in Table 2, even the early vocabulary words recorded by the learners highlight some pronunciation challenges, with sounds and sound combinations not found in the learners' first language (English).

Table 2. Examples of SENĆOŦEN words recorded

| Numeral | Orthography | NAPA |
|---------|-------------|----------------------|
| 1 | NETE | [nət ^h ə] |
| 2 | ĆESE | [čəsə] |
| 3 | ŁIŦ | [łix ^w] |
| 4 | ŦOS | [Ŧos] |
| 5 | ŁKÁĆES | [łqečəs] |

The Halq'emeylem library includes multiple recordings of a single speaker (Siyamiyateliyot Elizabeth Phillips) producing minimal and near-minimal pairs of words that highlight contrasts in the language (e.g., between lateral approximants and fricatives, velar and uvular obstruents, and plain and glottalized stops.¹¹ Examples are given in Table 3 below, with bold type indicating the sounds being contrasted in each pair.

Table 3. Examples of Halq'emeylem words recorded

| | |
|------------------------------------|---|
| lá:lém 'house' | lhà:lomet 'get ashore' |
| kyó 'car' | qó 'water' |
| xá:m 'get canoe stuck on rock' | x á:m 'to cry' |
| pákw'et 'warm it up / smoke it' | p' ákw'et 'repair it / fix it up' |

¹¹Although ultrasound does not provide visual information to distinguish between plain and glottalized consonants, we included words focusing on the contrast because it is one that learners often report to be challenging. Our hypothesis is that having access to a new multimodal resource may be of benefit for learners for *all* contrasts, including this one, simply by virtue of facilitating an increased awareness of articulatory processes during speech (c.f. Shawker & Sonies 1985).

The Secwepemc library consists of recordings of a single speaker (Ntlola Emmeline Felix) producing individual words that exemplify each of the sounds represented in the Secwepemc alphabet. The word list is based on a teaching resource developed by the Splotsin Tsm7aksaltn to teach learners orthography and pronunciation (see Splotsin Tsm7aksaltn 2012, as well as FirstVoices 2000–17). In addition, we took multiple recordings of two words with orthographic <r> (*raplc* ‘to climb’ and *yiri7* ‘that’s it’ or ‘that one’), represented in Figure 2 above as /ɣ/. The phonetic description of this sound is unclear; the “Sounds of Secwepemc” resource describes it as having the same place of articulation as [k] (i.e., velar), and Kuipers & Dixon (1974) describe it as a “velarized postpalatal sonant”, and note that it is similar to a voiced velar fricative. However, there is an impressionistic view in the community that <r> is pronounced even further back in the mouth, and that the existing descriptions are not quite accurate. We recorded these additional tokens with hopes that the ultrasound footage may shed light on how best to describe the place of articulation of this sound.

As the preceding discussion highlights, the lists of words that were recorded for each language – and the processes that went into designing the word lists – differed across languages. The SENĆOTEN word list did not reflect a highly controlled dataset in the linguistic sense, instead reflecting the apprentices’ assessments of community priorities. In contrast, the Halq’emeylem word list was put together by a linguist (Strang Burton), resulting in a thorough, controlled set of phonetic contrasts. While the latter may be more useful from the perspective of capturing the sound system of the language, the former is likely more representative of the common words that learners encounter in their early learning. The Secwepemc word list, meanwhile, is somewhere in the middle; the word list is linguistically informed, representing the sound inventory of the language, but also features words that are taught to early learners (via the alphabet).

In all three cases, the libraries can contribute to both language documentation and conservation. Regarding the former, the videos enrich the documentation record by providing a new level of detail in the production of a variety of Salish words and phrases. While all three communities have large collections of print documentation (e.g., Kuipers 1974; Kuipers & Dixon 1974; Montler 1986; Galloway 2009) and audio file archives (e.g., FirstVoices 2000–17), video materials are less common for the three languages, and, to the best of our knowledge, ultrasound footage of articulatory processes in the three languages has only been previously collected for a small number of SENĆOTEN speakers, for a small subset of the language’s consonants (Bird 2012). Ultrasound footage can be a valuable addition to the documentation record, providing key details about the articulation of different sounds and sound combinations in addition to the corresponding acoustic details (preserved with simultaneous audio recordings).

From a conservation standpoint, the video libraries function as a pedagogical tool to help learners acquire correct pronunciation. A key advantage of the videos is that they allow learners direct access to the articulatory shapes and movements that are involved in pronouncing challenging words or sounds; learners are able to see how

speech is produced rather than just hearing and trying to mimic it. They are also engaging; learners tend to be excited to be able to see “inside” a speaker’s mouth. Although we are only in the preliminary stages of evaluating whether these videos indeed help learners of SENĆOTEN, Halq’emeylem, and Secwepemc improve their pronunciation, there is evidence from studies of other languages that ultrasound overlay videos have a positive impact both on learners’ pronunciation and perception. For instance, Bliss et al. (2017) conducted a pedagogical experiment investigating the use of ultrasound overlay videos as a pronunciation learning tool in Cantonese language classes at UBC. Using a blended learning paradigm, half of the students interacted with the videos online, while half interacted with audio-only media under otherwise identical conditions. Results show that students who received the ultrasound-based training performed better than ones who received only audio-based training in both perception and production tasks. These findings are consistent with Tsuda et al.’s (2015) qualitative study in which 57 students were surveyed about their experiences with ultrasound overlay videos in their Japanese language class at UBC. Of the 57 students surveyed, 81% reported that the ultrasound video helped them to understand how to pronounce the Japanese sounds, and 82% reported that it helped them to achieve the correct pronunciation. In sum, ultrasound overlay videos are evidenced to improve learners’ pronunciation of Cantonese and Japanese sounds, and by analogy, we predict that they will also be of benefit to learners of SENĆOTEN, Halq’emeylem, and Secwepemc. In collaboration with Halq’emeylem teachers, we are developing evaluation strategies in the form of a language game (“Auntie Says”) that will measure primary and secondary school learners’ improvements in pronunciation through interaction with the videos, and we predict a positive result. In fact, as an anonymous reviewer points out, ultrasound overlay videos may have the potential to be particularly useful to learners of Salish languages, as many of the phonemic distinctions in these languages are produced at the back of the mouth with few visible cues, unless ultrasound is used. Anecdotally, the ultrasound overlay videos do indeed seem to be helping learners with their pronunciation of the “back of the mouth” sounds; adult learners in Secwepemc language classes have reported improvements in their ability to pronounce the velar/post-velar contrast.

6. Impacts Beyond any quantifiable improvements in learners’ pronunciation, the videos – as well as the process of creating them – have broader impacts for those involved in their creation, and for their communities. In this section, we reflect on the broader community impacts of this work. We begin with a discussion of how the three communities are using or intend to use the resources in pronunciation teaching, and then we turn to some testimonial statements from community partners to highlight the various ways in which the project has benefitted them and their communities.

The Halq’emeylem videos will be distributed to language teachers and learners through various digital media sources. A community-run language blog and two local intranets will host the videos for community members to access directly. The videos will also be shared in an ePublication format through a locally-distributed eBook, designed for teachers and learners at the secondary and post-secondary levels.

The plan for the SENĆOTEN videos is to host them in an app that can be accessed by language learners who want extra practice with pronunciation outside of any formal classroom instruction. The apprentices involved in the project identified parents whose children are in the immersion school as a key demographic to target for this resource, as many want to speak SENĆOTEN in their homes, but do not have the same grasp of the language as their children do. An easily accessible app may give them flexible opportunities to practice their pronunciation. As for the Secwepemc videos, these will be uploaded to the Splotsin FirstVoices page, allowing learners to access them on the web or via the associated language apps. Select videos have already been used in adult language classes both in the community and at the Nicola Valley Institute of Technology, and according to Rosalind Williams, the Coordinator of the Splotsin Language Program, they will become standard curriculum material for all language classes at the Splotsin Tsm7aksaltn Teaching Center.

Community members who were involved in creating the videos share a common sentiment that providing learners with dynamic visual information about the articulation of challenging sounds will help them better understand their languages.

As a L2 SENĆOTEN learner it was extremely challenging to understand how to produce certain sounds in the language; my mentors tried showing me with diagrams or explained the area in the mouth, but it wasn't something that I could quite understand. I think the ultrasound overlay videos will be extremely beneficial to my community and language learners. I am a visual learner so I know that these videos will help other visual learners as well. This will be an amazing resource that will preserve and encourage language growth within my community.

PEPAKIYE Ashley Cooper

Our own sentiments are echoed by our community-based partners (see §4 above). Rosalind William remembers her own language learning process:

“Because I know, when I was learning to make certain sounds in our language, it was so frustrating, because I just couldn't get it. I didn't know what was going on down there. And I would re-read the instructions, and I couldn't get it.”

In discussing the Secwepemc recordings, Rosalind comments:

“...for the sounds, all we have is textual information for us to create those sounds, but there is no way for us to look inside the fluent speaker's mouth or in their throat to see what they're actually doing to make those sounds. So this process was so interesting to us, to be able to actually see what she's doing down here in her throat. That's amazing.”

Similarly, Aaron Leon commented on the connection that learners may make between visual and auditory information, noting that “so far the reaction has been that everybody is pretty impressed with them. Yeah, it’s really given a lot more interest into those sounds, and it has helped them train their ear towards recognizing those sounds”.

While from the perspective of mainstream L2 pedagogy, digital media and other technologies are sometimes thought to detract from face-to-face teaching methods (e.g., Lee et al. 2015; Neri et al. 2002), videos can fill an important niche in endangered language learning situations: one of the challenges that many learners face is the fact that they have such limited opportunities to work with their elders. In the case of Halq’emeylem, for example, there is only one L1 speaker of the dialect; regular face-to-face contact between her and all learners is simply not possible. The ultrasound overlay videos were developed in response to a number of requests by Stó:l learners and teachers who, unable to access native speakers, had requested help with pronunciation of the sounds in the language. As Rosalind points out, “The fluent speakers get tired. When you ask them to repeat a word or repeat a sound, they get tired out.” In the face of this challenge, Rosalind says of the overlay videos that “It will be a really good practice tool. Back and forth, back and forth – without making the speaker do it”. She also notes that younger learners are often comfortable engaging with technologies and will employ a variety of different strategies and tools in their language learning; ultrasound is yet another technology they can make use of.

Creating the overlay videos themselves also gives younger language revivalists – many of whom are technologically savvy – the opportunity to spend time with their elders.

The ultrasound overlay workshop was the first time I got to work with a L1 SENĆOŦEN elder. I feel very fortunate to have been able to work on such cutting edge work with a L1 speaker to collaborate and create extremely useful resources for our language learners.

PEPAŦIYE Ashley Cooper

Aaron (Secwepemc) speaks of the process of recoding his elder as well:

“Really, just working with Emmeline, making sure she was comfortable. It was a fairly lengthy process that we went through, because we wanted to document as much as we could while we had the time, but at the same time we needed to make sure she wasn’t getting fatigued ...”

Aaron’s words reflect the care and thought that learners take in working with their elders; beyond the potential impacts that the videos themselves may have on communities and community members, the process of recording the videos created new opportunities for Aaron and others to connect with their elders.

Finally, beyond providing visual information about articulation, the videos also contribute towards language learners’ metalinguistic awareness, which can potentially help with language learning and pronunciation more broadly.

I find that learning the linguistic terminology makes learning a new language a bit easier to understand, and it led me to some amazing visuals to help me process the information better.

PEPAKIYE Ashley Cooper

Developing the video libraries has sparked the interest of some of the community partners, and plans are being made for future collaborations using ultrasound to advance pronunciation.

I am hoping to start an ultrasound one on one project with a LI SENĆOTEN [speaker] to study their recordings and videos on sounds that I'm struggling with. I plan on having a pre-assessment to document my level of proficiency that will be used to compare the mid and post assessments. I will also journal my experience to reflect on my learning experience.

PEPAKIYE Ashley Cooper

For the Halq'emeylem videos, linguist Strang Burton is collaborating with professional animators to combine ultrasound overlay technology with animations that provide additional layers of detail on pronunciation. The Splantsin team, meanwhile, is planning to make ultrasound recordings of singers singing Secwepemc language songs.

In sum, the process and results of creating ultrasound overlay videos have had broad impacts on the communities involved; they are being made available to learners in a variety of ways, and are providing dynamic visual representations of how to pronounce challenging sounds, increased metalinguistic awareness, opportunities for practice without burdening fluent speakers, and inspiration for new projects. By documenting this project, we hope to inspire other communities and allies to explore creative ways to collaborate to develop resources for pronunciation.

The impact of the eNunciate Ultrasound workshop that took place at the Saanich Adult Education Centre in the summer of 2016 has been extremely meaningful to me. It's very exciting to think back on my days of linguistic studies, and to know that such a project sprouted from sharing a couple of ultrasound overlay videos with my classmates ...I feel extremely honored to be participating in such a creative and ground-breaking work that is taking place in my community. My hands are raised to the ones who have helped document the SENĆOTEN language, the ones who have helped create more resources that will help preserve the language, and for our future language speakers.

PEPAKIYE Ashley Cooper

7. Conclusions In this paper we detail the methods, outcomes, and impacts of collaborative projects with three Salish communities in British Columbia to develop ultrasound overlay videos to help language learners improve their pronunciation of challenging sounds. Although an understudied area in L2 pedagogy and language revitalization, many language teachers and learners see pronunciation as an important aspect of language learning. For Salish languages, pronunciation is particularly challenging, given the complex consonant inventory that includes many sounds not found in English, the first language of most L2 learners. Moreover, for each of the languages discussed here, learners may not have access to or do not want to fatigue the few fluent L1 speakers in their communities. They need resources that allow them to observe and model the pronunciation of challenging sounds.

Ultrasound overlay videos can help address that need, and working together with community partners, we have developed video libraries that are specific to each community's needs. Within these collaborations, we were able to combine our skills to the best advantage; community partners initiated, participated in, and gave input on all aspects of the project. In the end, most of the technical tasks such as video production were handled by linguists, so as not to direct resources away from other community-based language projects. We hope this project has shown that it is feasible and valuable to develop multi-media pronunciation teaching tools through community-university collaborations.

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