Southern Michif SoundHunters: A collaborative process of re-purposing an Indigenous language learning technology

by

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Abstract

Many of the Indigenous languages around the world and in Canada are endangered. Furthermore, many of these languages are low-resource and suffer from a lack of language-learning resources and technology that facilitate language revitalization. To help address this problem, we created the language-learning game SoundHunters. SoundHunters is an arcade-inspired game that teaches the sounds of nehiyawewin (Plains Cree). However, creating new learning technology for each Indigenous language in Canada is impractical. A more appropriate allocation of resources would be to repurpose existing language technology for Indigenous languages. Aside from a few sparse instances, this is not typically done. In this thesis, we describe the process of repurposing SoundHunters for Southern Michif, an Indigenous language in Canada. We created this new version in collaboration with Heather Souter and Fineen Davis of Prairies to Woodlands Indigenous Language Revitalization Circle Inc. To investigate the efficacy of Southern Michif SoundHunters, we conducted a participant-based study ($n = 18$) with a pre-test/post-test design. This study measured participant learning using phonemic awareness tests. We also used a questionnaire to solicit feedback. We found participants reported feeling as though they learned with SoundHunters and that they had a measurable change in their knowledge following interaction with Michif SoundHunters. The contributions of this thesis include the reporting of the collaborative process that involved language revitalization activists from an Indigenous language community where Southern Michif revitalization efforts are underway. We detail how we established our collaborative process with our community partners. This process included a language data agreement to ensure data privacy and

sovereignty. The success of SoundHunters as a learning tool for both nehiyawewin and Southern Michif makes the case that it could be repurposed to support the learning of many other Indigenous languages. Further examples of repurposing SoundHunters for other languages are needed to understand the full scope of its applicability.

Preface

This thesis is an original work by Delaney Lothian. No part of this thesis has been previously published. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "E-Learning System and Feature Design", Pro00082188, July 27, 2018. The approval letter is included in Appendix A.2. The current expiration date is April 26, 2023.

"Imagine a trickster on life support, a mythic, transformative being made up of equal parts humanity and the unknown, wired, tired, and waiting . . . on the edge of life. This is the language of Anishinaabemowin today. Because the patient is a trickster, we don't know yet if we are witness to a death or magnificent birth. So we watch the monitors, we try new medicines, we form a network of prayers: Prayers made of wire, glass, and light. Prayers made of digital, full-spectrum sound waves. Prayers of stories recorded in color and contrast that is fed through lenses and transformed into a binary code of bezhig (1), kaa gego (0), bezhig (1), kaa gego (0). Prayers hosted on servers and posted in clouds of computing. Prayers of work and prayers of play. Prayers of convergence, continuance, and collaboration. Prayers that connect the orality of the ancestors to the app-jumping multiplayer community yet to come. Teaching an endangered language today requires extreme measures, and there is no guarantee of success. But the situation is dire and demands adaptive, creative survivance."

-Margaret Noori

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I am eternally grateful to all of my family for all of the support, and to my mom for charting the path as the first one in our family to achieve post-secondary education and a Master's degree.

Thank you to my partner, Peter, for supporting me in my education throughout the years. Thank you to my cats for keeping me company during a COVID-laden degree.

ninanâskomon. ekosi.

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Abbreviations

CALL Computer-Assisted Language Learning.

FNIGC First Nations Information Governance Centre.

IPA International Phonetic Alphabet.

MALL Mobile-Assisted Language Learning.

NRCILT National Research Council Canada Indigenous Languages Technology team.

OCAP Ownership, Control, Access, and Possession.

P2WILRC Prairies to Woodlands Indigenous Language Revitalization Circle Inc.

TRC Truth and Reconciliation Commission of Canada.

Glossary of Terms

Computer-Assisted Language Learning (CALL) The use of computers or other technology in language learning.

Digraph Two characters that map to a single sound.

Diphthong Two vowel sounds that map to a single syllable sound.

First Nations Information Governance Centre (FNIGC) "An independent, apolitical, and technical non-profit organization operating with a special mandate from the Assembly of First Nations' Chiefs-in-Assembly (Resolution #48, December 2009)".

International Phonetic Alphabet (IPA) An alphabet where each symbol represents a sound. It is used to describe sounds in any language.

Learning gain The amount a person learned between two points. This measure balances opportunity to learn with learning by providing the ratio of how much a person's performance improved in comparison to how much it could improve: 1 means they learned everything they could have and 0 means they learned none of what they could have learned.

Loan word A word used in one language that originated in a different language.

Mobile-Assisted Language Learning (MALL) The use of a mobile device (such as a smartphone or tablet) in language learning.

OCAP Principles First Nations data sovereignty principles of Ownership, Control, Access, and Possession created by the First Nations Information Governance Centre.

Phoneme Distinct single sounds within a language that distinguish words from one another.

Semi-vowel Single sound in a language that acts as an intermediate between a consonant sound and vowel sound.

Chapter 1

Introduction

This year marks the beginning of the International Decade of Indigenous Languages. This decade (2022-2032) was declared by the United Nations in a resolution (United Nations General Assembly, 2020) in order to bring attention to the fact that many Indigenous languages across the globe are endangered. Indigenous languages in Canada are no exception. There are over 70 Indigenous languages in Canada stemming from 12 different language families (Statistics Canada, 2016). Almost all of these languages are considered endangered. The most widely spoken languages only have tens of thousands of speakers, and the most endangered have no remaining fluent speakers.

Indigenous languages in Canada are endangered for many reasons, all of which stem from colonization. Aside from typical factors that would threaten a language, such as not being a language of the majority, there were formal government assimilation policies and programs that explicitly targeted Indigenous culture and languages (Ruecker, 2015). The program that was the farthest reaching and most impactful was the Indian Residential Schools system (Fontaine, 2017). These were compulsory boarding schools for Indigenous children in Canada where, among other abuses, children were forbidden from speaking their languages or practicing their cultures. These schools existed for over 100 years with the first school opening in 1879 and the last school closing in 1996 (MacDonald & Hudson, 2012). These schools and their legacy are well within living memory. These schools had a devastating impact on the

intergenerational transmission of Indigenous languages.

The Truth and Reconciliation Commission of Canada (TRC) was created to ensure that the history of Indian Residential Schools and the experiences of those who were forced to attend were a documented and acknowledged part of Canada's history. The commission was conducted over a period of eight years starting in 2007 and ending in 2015 (Government of Canada, 2021). The commission collected stories and accounts from Indian Residential School survivors. From these records, they produced a report and compiled a list of 94 calls to action (Truth And Reconciliation Commission Of Canada, 2015). Many of these calls to actions focus on culture and language revitalization. The TRC specifically calls on governmental organizations and post-secondary institutions to help create opportunities for learning and supporting Indigenous languages.

There are many factors to consider when working to support Indigenous languages. In addition to being endangered, Indigenous languages in Canada are considered to be low-resource; there are very few learning resources and language data available, which hinders revitalization efforts. Furthermore, creating Indigenous language resources requires understanding the unique needs associated with Indigenous languages and the needs of those who are learning them. For example, most Indigenous languages in Canada are traditionally oral. Moreover, Indigenous language learners report prioritizing learning their heritage language(s) for use in familial and cultural contexts (Lothian et al., 2019). That is, Indigenous language learners may prioritize different language skills than the average learner of a majority language, who may wish to learn a language for travel or work contexts (Gao et al., 2022; Gardner & Yung, 2017). The skills targeted by Indigenous language learners are ones that facilitate in-person communication such as listening and speaking. Furthermore, Indigenous language learners may experience additional challenges when learning their heritage language(s) due to personal or intergenerational trauma stemming from experiences such as attending a residential school. Resources for learning Indigenous languages

should be designed to take these factors into account to be supportive and effective.

To create a tool to address these needs, we designed the language-learning game SoundHunters (Lothian et al., 2020). SoundHunters is an arcade-inspired game that teaches the sounds of nehiyawewin[1] (Plains Cree), which is a dialect of the Cree language spoken across the western plains of Canada. In this game, pixel deer descend the screen (Figure 1.1) while a sound is given on repeat. The deer have text attached to them, and it is the player's job to shoot the deer that has the text that corresponds to the repeating sound, while avoiding shooting the other deer or letting the correct deer pass by on the screen. This game supports the development of phonological awareness in learners, a subskill that helps build strong listening and speaking skills.

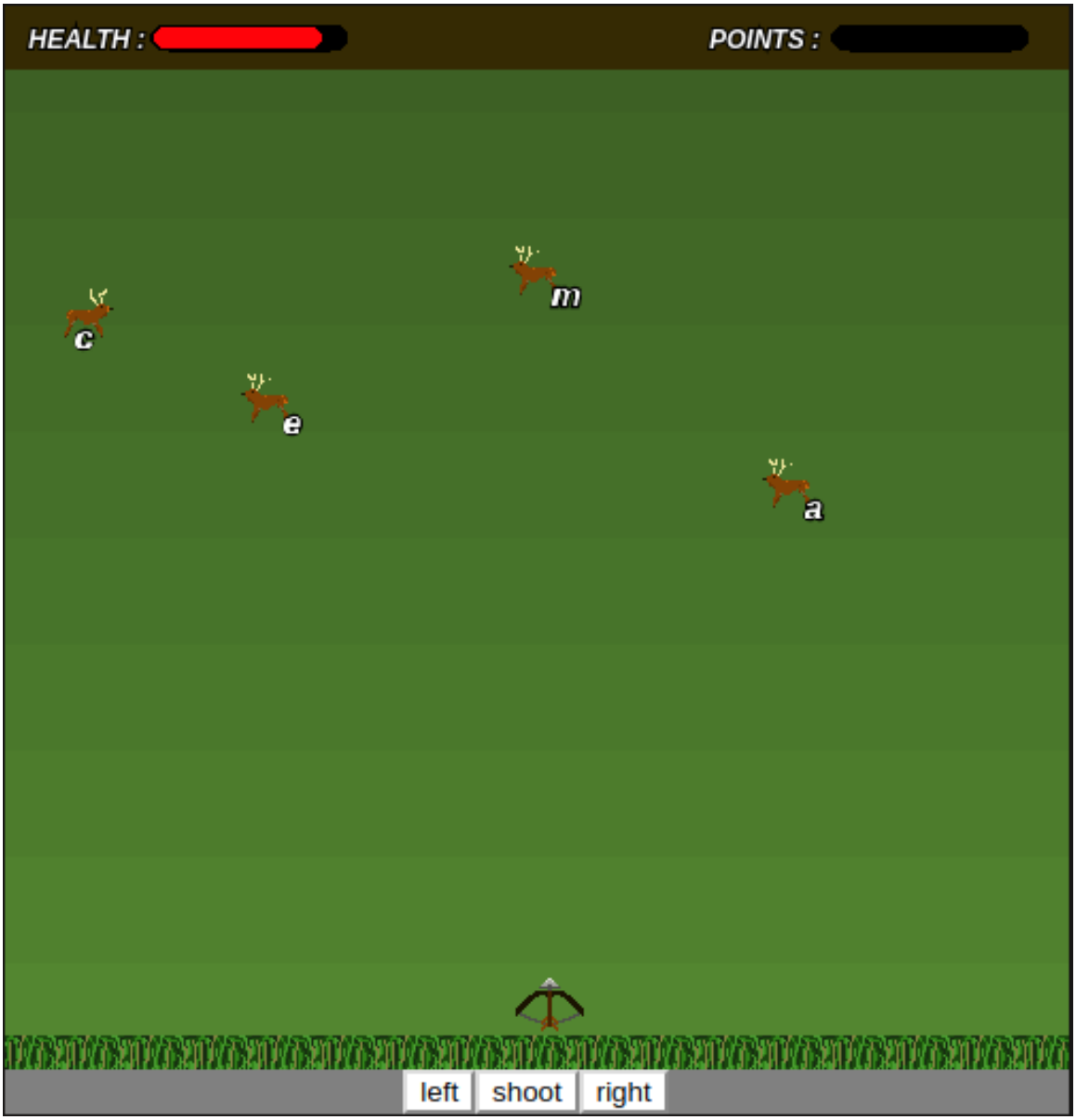
In 2019, we conducted a participant-based study on nehiyawewin SoundHunters to measure learning and player experience. We found that SoundHunters was able to successfully teach participants the sounds of nehiyawewin through pre- and post-tests that were analyzed using a paired-samples t-test ($t(24) = -6.85, p < .001, d = 1.37$). This study also revealed that participants felt they learned language skills from SoundHunters and had an overall positive experience playing the game.

SoundHunters is a relatively simple game that requires little language data or linguistic information. As a learning task, it is also relatively language agnostic. This means that, in theory, the game, its mechanics, and the language skill it teaches should be applicable to other languages. As many Indigenous languages in Canada are endangered and are hindered by lack of language resources, it is likely that other Indigenous language communities may benefit from having access to a game like SoundHunters for their own language. This thesis details the process of repurposing the game SoundHunters for another Indigenous language, Michif.

Michif is an endangered Indigenous language in Canada. It is one of the languages of the Métis people. The Métis are one of three recognized Indigenous peoples in Canada and are descended from the marriages between French fur traders and the

[1]Note words in nehiyawewin are never capitalized, including at the beginning of a sentence.

Figure 1.1: Screenshot of the game play of nehiyawewin SoundHunters.



nehiyaw and Anishnaabe peoples in western and central Canada (Davis et. al, 2019). Michif is a mixed contact language that originated from these unions and stems primarily from French and nehiyawewin. There are different regional varieties of Michif. Southern Michif is the focus variety of this thesis. This variety is spoken in Manitoba, southern Saskatchewan, North Dakota, and Montana (Sammons, O. N., 2019). Southern Michif is a strong candidate for repurposing SoundHunters as it has

cultural and linguistic overlap with nehiyawewin. This increases the likelihood that SoundHunters will effectively teach the sounds of Southern Michif. The success of a Southern Michif SoundHunters will be demonstrated if beginner Southern Michif language learners experience a measurable change in knowledge following game play.

A crucial part of Indigenous language resource creation is collaboration with speakers, learners, and teachers from the associated language community. Community collaboration in Indigenous language and culture projects is mentioned often across the 94 calls to action put out by the TRC (Government of Canada, 2021). In this project, our primary collaborator is Heather Souter. Heather Souter is a Michif[2] (Métis) woman who is a language learner, speaker, and teacher of the Southern dialect of Michif. She is also the co-founder of Prairies to Woodlands Indigenous Language Revitalization Circle Inc., which is a not-for-profit grassroots community organization focused on the revitalization of Michif and other Indigenous languages. The Southern Michif SoundHunters game will be released through this organization. Our second collaborator is Fineen Davis, who is a computational linguist who has worked with Heather on Michif language technology for over three years. There are few reported examples of the collaboration process with Indigenous-community partners for the creation or study of Indigenous language resources. Therefore, the collaboration process followed will be described in this thesis and is a significant part of its contribution.

Note that there are many terms for describing Indigenous peoples in Canada. There are blanket terms that capture all Indigenous peoples in Canada (e.g., "Aboriginal") and terms for specific legal or cultural groups (e.g., "Métis", "First Nations", "Cree"). I use the term "Indigenous" frequently within this thesis. It is important to note that the descriptor "Indigenous" when referring to people can vary depending on the location and context in which it is being used and can have a global meaning. For

[2]Michif is the name of the language but is also interchangeable with the term Métis. This usage is dependent on each individual's preference.

example, the United Nations' Permanent Forum on Indigenous Peoples guidelines (United Nations Permanent Forum on Indigenous Issues, 2006) does not establish a formal definition but instead emphasizes self-identification. In this thesis, I use a working definition that follows these guidelines when referring to Indigenous peoples generally. When specifying Indigenous peoples in Canada, it is synonymous to the term "Aboriginal", which is defined in Section 35 of the Constitution Act 1982 (Canadian Charter of Rights and Freedoms, 1982) and includes First Nations, Inuit, and Métis peoples.

The remainder of the thesis is organized as follows. Chapter 2 reports on the current state of Computer-Assisted Language Learning (CALL) and how it does not adequately support low-resource languages. This chapter also reviews Indigenous language technology in Canada and the most common challenges faced in its development. Finally, Chapter 2 describes two popular examples of repurposing language learning technology for another language (Rosetta Stone and Duolingo) and their history of incorporating Indigenous languages.

As described above, the Southern Michif SoundHunters was made with community collaboration. Chapter 3 introduces our collaborators and describes the collaborative process we defined and followed. This chapter also includes a section on reflexivity; an aspect of some qualitative research methodologies that is often used in participant-based research to help ensure rigor and quality. The reflexivity sub-section of Chapter 3 includes a description of myself as the primary researcher and situates me within the research context. This is particularly important in this project as I have previous connections with our community collaborators.

In Chapter 4, I describe the design and mechanics of the SoundHunters game. This chapter includes a linguistic description of nehiyawewin, the first language the game was designed for, as well as the process and changes needed to repurpose the game for another language.

Chapter 5 details the creation and first version of Southern Michif SoundHunters,

and provides a linguistic description of Southern Michif.

In Chapter 6, I report on the user study I conducted to measure learning and participant experience with new learners of Southern Michif.

Chapter 7 provides further discussion of the study results and of lessons learned. It gives recommendations for possible future collaborations with communities for repurposing SoundHunters for other Indigenous languages.

Finally, Chapter 8 summarizes the work and research conducted in this thesis.

Chapter 2

Background & Related Work

A key way to promote Indigenous language revitalization in Canada is to create Indigenous language-learning technology and tools. There are two ways to create a language technology: building one or repurposing a previously made technology. Given the large number of languages, it is not feasible to create a new technology for each language, and it may be a better use of resources to repurpose an existing technology. In this chapter, I will give the necessary background to understanding the repurposing of learning technology for Indigenous languages.

First, I will define computer assisted language-learning (CALL) and describe its modern day prevalence and scope in order to better understand the current state of language-learning technology. This will illustrate what language skills and target languages are currently the most researched. Following this, I will discuss the needs of Indigenous language learners and the challenges associated with creating Indigenous language technology. Next, I will describe how language-learning technologies have been repurposed for Indigenous languages. This includes a discussion of popular language-learning technologies Rosetta Stone and Duolingo, as well as lesser-known examples. These examples are followed by a description of the challenges that can arise when repurposing existing language technology to support Indigenous languages.

This background motivates my work in further developing and studying the process of repurposing a language-learning technology that had been designed to support one

Indigenous language so that it can be used to support learning for another Indigenous language.

2.1 Computer Assisted Language-Learning (CALL)

The field of computer assisted language-learning (CALL) is over seven decades old and over this time, its definition has evolved. The definition used in this thesis is closest to the one Beatty (2013) provides: "any process in which a learner uses a computer and, as a result, improves his or her language" (p. 7).

Tafazoli et al. (2019) lays out the timeline of CALL development as follows. It emerged in the 1950s in America during the cold war to teach Russian in universities. In the 1970s, with the improvement of computer technology, there were efforts to use computers to teach English. In the 1980s, with increasing interest, larger-scale research was conducted on the impact and use of computers and their programs as language-learning tools. In the 1990s, the introduction of multimedia resources and the Internet allowed for more widespread access to language-learning computer programs outside of government and university institutions. This progressed into the 21st century as internet forums and social media became a novel way of using technology collaboratively for language learning. In the last 15 years, more diverse language-learning technologies have appeared such as mobile applications (often referred to as Mobile Assisted Language-Learning or MALL), video games, virtual reality, and robot assisted language-learning tools, to name a few. The popularity and rise in usage of these technologies is a consequence of access, acceptance, and technical capabilities.

2.1.1 Languages CALL Typically Covers

The popularity, research, and development of CALL tools have continued to grow since their inception. However, the number of languages targeted by these tools has been slower to meaningfully expand beyond European and majority languages. In their review of language-learning technology studies published between 2014 and 2019,

Shadiev and Yang (2020) found that English was the number one language taught. English leads by a substantial margin with 267 reported instances, followed by Chinese as the next most commonly taught language with 24 instances. This is followed by Spanish ($n = 19$) which, along with Chinese, is one of the most commonly spoken languages in the world. The next most common target languages were European languages such as French, German, and Russian, as well as Asian languages such as Japanese and Korean. In a review of Mobile Assisted Language-Learning (MALL) research between 1994-2012, Burston (2014) found that English was the target language for over 60% of the applications reviewed. This was followed by French, Japanese, Chinese, and Spanish. In a commentary piece on the prevalence of English as a target language for CALL tools, Sauro (2016) found that over half of the language-learning technologies researched and published in four major CALL journals had English as their target language, with the percentage of English language technologies having increased each year between 2012 and 2016. Overall, not only does CALL typically focus on majority languages (i.e., majority in a global context), but it is dominated by English as a target language.

2.1.2 Types of sub-skills CALL is used to teach

The skills language learners are taught are productive, such as writing and speaking, and receptive, such as listening and reading. Productive and receptive language skills play different roles in language use and so can determine which contexts a language learner will do well in. However, the kind of language skills targeted by CALL tools can be limited by technical constraints and the complexity of current language and learner models.

Burston (2014) found in his review of MALL research that nearly half of MALL applications studied targeted vocabulary as a language skill. The next most commonly targeted language skill was listening; which was only represented in 14% of the reviewed studies. Moreover, Shadiev and Yang (2020) found that the predomi-

nant language-learning skills that were targeted by the language-learning technologies covered in their review were, in order from most targeted to least, as follows: writing, vocabulary, speaking, reading, listening, grammar, and phrases. Yang & Shadiev highlight that the language skills most targeted focused on language production, such as writing and speaking, with less emphasis on language input skills, such as reading and listening. It is important to note that this review includes technology whose intended use is not language learning. This includes online collaborative-writing tools (e.g., Google Docs), instant messaging, social networking, and voice recording. The inclusion of these tools likely skews the results towards language production skills.

Despite the rise in popularity, the current state of CALL research and target languages and skills has been skewed. The majority of CALL systems have not progressed beyond targeting English language learners and certain skills (e.g., listening) are still neglected. This state makes the creation of language technology for non-majority languages and low-resource languages (such as Indigenous languages) more difficult.

2.2 Creating Indigenous Language Technology

There has been an increase in demand for Indigenous language resources and technologies. As described in the introduction (Chapter 1), there has been a call for efforts made on a global level (e.g., by the United Nations (United Nations General Assembly, 2020)) as well as on a national level here in Canada (e.g., the Truth and Reconciliation Commission of Canada (Government of Canada, 2021)).

2.2.1 Indigenous Language Technology in Canada

In addition to tools that interact directly with learners, tools and frameworks that support more sophisticated Indigenous language technologies are becoming increasingly available. Littell et al. (2018) conducted a review of Indigenous language technologies in Canada that focused on these kinds of supporting technologies. These types of tools include targeting the very first steps of language model and technology

creation, such as data cleaning tools like text/speech alignment, audio segmentation, and Indigenous language orthography recognition. These types of tools are well established for many majority languages such as English, but since Indigenous languages can have significant linguistic differences from majority languages, new methodologies need to be developed. Littell's paper also highlights the next step of language tools that center on language model creation, such as rule-based machine translation, text-to-speech, spell-checking, and verb paradigm generation. These technologies are once again well-established for many majority languages, but are sparse amongst Indigenous and other minority languages.

There have also been a number of Indigenous language-learning technology projects in Canada. In their review, Wagner (2017) collected and analyzed 24 instances of Algonquian language websites. The Algonquian language family is the largest Indigenous language family in Canada ("Aboriginal Languages in Canada", 2018). The researchers found many of these websites to be "facilitative" or resource based. These are websites like online dictionaries or that host an audio recording bank. The next category of websites was collaborative websites, which allow for language learning and sharing via online interaction and collaborative resource sharing. Although instructional tools exist, much of Indigenous language-learning technology currently tends towards providing language resources.

2.2.2 Indigenous Language Learner Needs

Indigenous language learners may have different needs and values than majority language learners. Learners of majority languages, such as English and Chinese, may be motivated by aspects such as travel or work (Gao et al., 2022; Gardner & Yung, 2017) and may be looking to learn about a foreign culture. Conversely, Indigenous language learners are often motivated by trying to reconnect with their own culture, family, or community (Lothian et al., 2019; McIvor, 2020). Furthermore, many Indigenous languages are historically oral languages. Because of this, Indigenous language learners

may value learning oral language skills, such as speaking and listening, over reading and writing (Hermes et al., 2012; Lothian et al., 2019). Oral language skills are also vital for social language use, which could help learners reconnect to their family and community.

2.2.3 Challenges

As established in the previous section, Indigenous language learners have unique needs and considerations. Due to past and on-going histories of colonialism, the creation of Indigenous language technologies also comes with its own set of unique challenges.

2.2.3.1 Lack of Speakers

One of the primary challenges reported by studies in the creation of Indigenous language technology was lack of speakers (Bliss et al., 2018; Kaleimamoowahinekapu Galla, 2018). A lack of speakers can make it difficult to create new and diverse language data. Furthermore, relying on a small group of speakers for language work can risk overtaxing the speakers who are available. This can be doubly true since many fluent Indigenous language speakers are often older, in the grandparent or great grandparent generation. In extreme cases, there are communities where there are no fluent or first-language speakers. The challenges in these contexts are discussed by Hardy et al. (2016) when detailing their process of collaborating with the Gugu Bahun. The Gugu Bahun is an Indigenous language community in northeastern Australia with no remaining fluent first-language speakers of the Gugu Bahun language. This community has no remaining speakers because colonial powers in Australia previously banned the Gugu Bahun and many Indigenous language communities from speaking their languages. While collaborating with the community to make an application to support their language revitalization efforts, the researchers and community needed to consult and retrieve data from language and culture CDs from the 1970s that had information documented as well as recordings of the few remaining speakers at the

time. This limited the scope of the application they could develop. Another example of this limitation is provided by Moore and MacDonald (2013), who discussed how they were using interactive text-based computer games to support a language program for Halq'eméylem, an Indigenous language in British Columbia, Canada. They reported that all fluent speakers were elders and were no longer able to take an active role in language teaching. This was due to reasons such as health-related issues or the connection between their language and trauma inflicted by residential schools.

2.2.3.2 Lack of Language Teachers

Moore and MacDonald (2013) also discusses the downsides of having language teachers who are not fully fluent. Specifically, they report that language transmission of Halq'eméylem has been affected by the fact that language teachers in this program are not fully fluent. A lack of trained language teachers is a challenge reported by other papers as well. Having few fluent speakers necessarily leads to having few people who are trained and able to teach the language. This means that even if there are technical and monetary resources available, projects may stagnate because they cannot collaborate with Indigenous language teachers for lesson creation and course instruction. For example, Bow (2019) described how there was sufficient interest and other financial resources needed to create Indigenous language courses at post-secondary institutions in Australia. However, the authors attributed the shortage of language teachers as a key challenge to creating these courses.

2.2.3.3 Cost-Related Challenges

Even if a language community has access to the human and language resources needed to create an Indigenous language technology, the next biggest challenge reported is often the monetary cost of the project. This includes the cost of all facets of development, deployment, maintenance, and use. The cost of development includes the initial funding required to plan, recruit, and create the tool. Deployment and maintenance

often requires continuous maintenance of the technical infrastructure (hardware and software). Finally, the cost of use includes the personal or organizational cost of using the technology. This includes the initial cost to access the technological medium itself (e.g., computer, mobile phone) as well as any other contingent technology costs such as electricity, internet service, and phone bills.

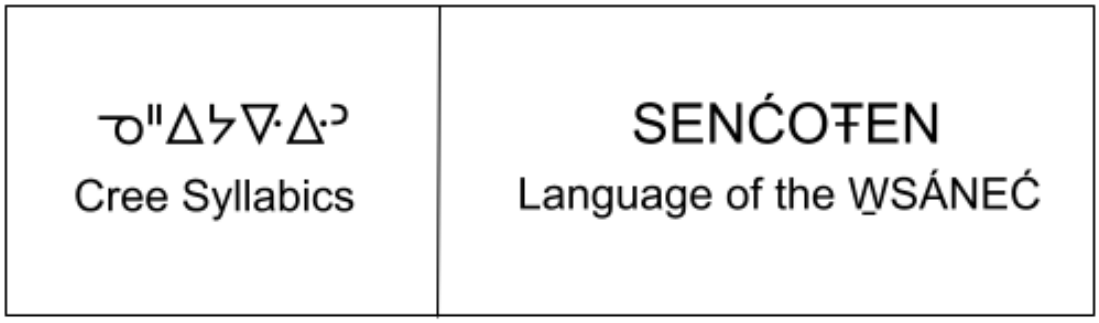
In their master's thesis, Bishop (2019) interviewed local Indigenous elders in Ontario and asked their opinions on using technology for language revitalization. Multiple elders expressed concern over the cost of technology and its maintenance. With respect to the role technology could play in language revitalization, one elder stated that "the biggest problem that we experience and I think the biggest problem that our communities experience is lack of funding, so lack of funding makes everything difficult and it makes things stop and start". Hugo (2016) reported similar issues in their case study on language-learning technology for the Yakama language community in the north-western United States. The authors of this paper discussed how this community's programs were deeply affected by the inconsistency of the language funding they received, resulting in their programs either being reduced or cut entirely.

2.2.3.4 The State of Technology

Once a person or community has come to the point where they have appropriate funding and language resources, they may still be hindered by issues inherent in the state of the technology itself. Many technologies that display text are designed primarily for majority languages, especially those with a Roman alphabet (e.g., English, French, Spanish). Although many languages are becoming more included, Indigenous languages are often still without this support. Elmiligi et al. (2016) proposed a framework for a language-learning mobile application that is general enough that it could be compatible with any Indigenous target language. In their anticipated challenges, they describe how most operating systems do not support some Indigenous orthographies. This includes orthographies that are not in a Roman script or those

that use diacritics that are not used in majority languages. For examples of these orthographies, see Figure 2.1. I have used images since these examples could not be properly displayed using LaTex, the markup language used to format this thesis.

Figure 2.1: Examples of Indigenous orthographies that differ from majority languages. The left is an example of a non-Roman orthography and the example on the right shows an orthography that uses diacritics not used in majority languages.



Overall, there has been a substantial increase in effort and work done on Indigenous language technologies. Despite this, there are still many unique challenges that Indigenous communities face when looking to create language tools for their members and learners. Therefore, an effective Indigenous language technology should consider these challenges in its design.

2.3 Repurposing Language Technology For Other Languages

Repurposing a language-learning tool or technology means, broadly speaking, the use of an existing technology or framework to teach another language. There are over 7,000 languages in the world (Austin & Sallabank, 2011). Therefore, it is pertinent to be able to reuse or repurpose previously-established learning technologies to create language resources for any significant percentage of these languages. Even though many languages differ widely linguistically, certain skills can be taught and learned using the same pedagogy across many languages. Additionally, the increasing acces-

sibility of technology can create more of a demand for remote and individual language learning.

2.3.1 Examples of Repurposed Language-Learning Technologies

This section will detail examples of adapting established technologies to support Indigenous language.

2.3.1.1 Rosetta Stone

2.3.1.1.1 System

The first example we will review is that of Rosetta Stone. Rosetta Stone is a CALL tool that was created some time after the founding of the creator's company in 1992. The initial version of Rosetta Stone was distributed via CD-ROM to teach Russian (Rosetta Stone®, 2022a). In the early 2000s, they expanded to teaching more languages. Their website (Rosetta Stone®, 2022c) describes that they "provide language-learning solutions in 30 different languages", 25 of which are available to language learners whose primary language is English. All of these languages are majority languages and, from our own search of their website, it appears that there are no Indigenous language courses advertised on their website.

Rosetta Stone uses a language learning method called *dynamic immersion* (Lord, 2016). This method assumes that people learn second languages in the same way they learn first languages. Rosetta Stone implements this method by minimizing the amount of explicit instruction in their tool. The reported efficacy of Rosetta Stone for language learners is mixed across studies. This is likely in part due to changing methods across the last decade or so. Lord (2015) found that students learning through Rosetta Stone were able to learn vocabulary but were less likely to be able to use it than students learning in a typical classroom environment. Rosetta Stone may be more effective for supporting receptive language skills; there are at least two other studies that found that Rosetta Stone is efficient at helping language learners

develop their listening proficiency (Ikonta & Ugonna, 2015; Kurniawan et al., 2021).

2.3.1.1.2 Indigenous Collaborative Process & Community Involvement

In 2004, Rosetta Stone released their Endangered Languages Program (ELP) (Rosetta Stone®, 2022b). This program is described as Rosetta Stone partnering with Indigenous language communities to create Indigenous language-learning tools using the existing Rosetta Stone framework and software. The webpage that hosts the ELP description currently cites seven partner communities: Chickasaw Nation, Kahnawake Mohawk Territory, Chitimacha Tribe of Louisiana, Iñupiat Tribe (Kotzebue, AK), Iñupiat Tribe (Barrow, AK), and the Navajo Nation. The earliest project completion date cited for one of these communities is 2007. The current state of this project is unclear. The last project completion date cited in their project was with Chickasaw Nation. It lists 2013, but the project description is for the wrong project: it has the exact same geographical description as the Iñupiat Tribe from Barrow in Alaska, where the Chickasaw Nation is not from. This error creates uncertainty as to whether the cited project completion date is correct. One of their recent blog posts about the endangered language program suggests the program continues to be ongoing (Rosetta Stone®, 2021), but they omitted their Chickasaw project and did not add new projects. This appears to be the only blog post on their site with an ELP tag. Through a search of news articles, it seems that there are still some Indigenous community partnerships either on going or more recent than 2013 (Aanjibimaadizing, n.d.). However, this is not documented on their website. Additionally, any link that advertises joining their endangered languages program redirects to the Rosetta Stone home page [1].

While this process of collaborating and making language-learning technology for these communities is not well documented on their website, there are a few academic

[1]For example: This infographic https://www.rosettastone.com/enterprise/resources/content/endangered-language-preservation-infographic advertises this link: http://corporate.rosettastone.com/Custom with redirects to their main page, accessed April 19, 2022

articles that have been published by outside authors that are related to the process and outcome. This is the case for Rosetta Stone's collaboration with the Navajo Nation. In Papa & Reyhner's paper on language revitalization technology in the Navajo nation (Miller et al., 2016), they describe how it was overall beneficial to collaborate with Rosetta Stone, but the project was not able to maintain sustained support. They stated that "unfortunately, many of the Navajo websites and the office for the Navajo Rosetta Stone are not actively maintained or staffed." Additionally, they also stated that this program is not used in schools as frequently as it was intended. This is potentially indicative that the maintenance requirements or methods for integrating the tool were not made clear to the Navajo nation by Rosetta Stone.

2.3.1.2 Duolingo

2.3.1.2.1 System

The second example we describe is Duolingo. Duolingo is a popular language-learning mobile application that was launched in 2012. On their website (Duolingo, n.d.), it is described as being free of charge, one of the most downloaded education applications in the world, and it is known for using gamification in its lessons. They also report that they have lessons to teach 40 languages, with 38 languages available to learn for English speakers. There are five language courses for English speakers that are described as being in the "beta" stage. Courses in this stage are described as complete enough for distribution. They are not fully complete and continue to be updated.

The language pedagogy that Duolingo employs is largely translation-based (Munday, 2017). Duolingo has the user complete translation tasks such as translating sentences (either through writing with the keyboard or arranging given words) and matching words from their base language to their target language. A systematic literature review looking at all papers investigating Duolingo between 2012 and 2020 found the question of Duolingo's efficacy to be mixed (Shortt et al., 2021). These studies include experiments with a typically small sample size and results ranging

from positive learning outcomes to no changes at all.

2.3.1.2.2 Indigenous Collaborative Process & Community Involvement

They offer courses for three Indigenous languages. As of April 2022, these languages include Navajo, Hawaiian, and Haitian Creole[2]. Navajo and Haitian Creole are both still in the beta stage, and it appears that Navajo has never left the beta stage since the introductory course was first offered in October of 2018 (Schneider, 2018).

The process to make these language courses does not appear to have much public documentation. It seems they may have initially been a part of Duolingo's Contributor program. This program was announced (Duolingo, 2021) to end in spring of 2021, with intentions of replacing it. The contributor program appears to have been a kind of partnership program that was volunteer-run and their goal was to transition from volunteer positions to paid positions. However there have been no blog posts since the announcement so the status of this program is currently unclear. Apart from the above, their website and blog posts do not appear to provide further information or updates on the Indigenous languages or other less commonly taught language courses and their development.

2.3.1.3 Other Examples

A program for repurposing language technologies specifically for Indigenous languages is a not-for-profit called 7000 Languages (Little, 2017). This organization works with Indigenous language communities to create free online language-learning courses. In partnership with communities, they have created courses for 25 different Indigenous or endangered communities. They emphasize data sovereignty by ensuring the communities they partner with have copyright over all language data. To do this work,

[2]Note these languages are not categorized differently than the other languages offered on duolingo.com. In reviewing the 38 languages offered for English speakers, we identified these as the Indigenous languages offered. Haitian Creole is included because one of its source languages is Taino, which is an extinct Haitian Indigenous language. This is similar to Michif which is an Indigenous language.

7000 Languages repurposes a language learning technology for their parent company: Transparent Language (Transparent Language, 2022a). Similar to Duolingo and Rosetta Stone, Transparent Language is a for-profit company that uses a base-template to teach multiple languages. They have an agreement with 7000 Languages to give their services for free to Indigenous and endangered language communities, so long as those communities do not charge users for the final product. Transparent Language reports using a declarative methodology for language learning (Transparent Language, 2022b). Their declarative method focuses on building up a learner's declarative memory for their target language. Declarative memory is a learner's ability to learn and recall information. This is useful for learning things like facts or vocabulary (Ruiz et al., 2021). They are cited as having over 40 learning "activity types", but the descriptions of these types could not be found. As they focus on declarative methodology, they are likely activities that promote memorization.

In addition to the minor work on repurposing technology for Indigenous languages by larger corporations, there are also some additional smaller scale efforts to create or use repurposable language-learning technology that was designed for Indigenous or endangered languages.

Bontogon et al. (2018) created their language-learning tool called "nêhiyawêtân" which was designed to teach Plains Cree (a dialect of the Cree language spoken in the central plains of Canada) at a university level. In this project, they repurposed a language-learning application called "Oahpa!", which was first created in 2008 (Antonsen, 2013) for North Saami which is a language that is both endangered and Indigenous. North Saami is spoken in northern Europe. This program was similarly used and designed for a university-level course. Both programs were created by researchers at university institutions.

Another example is provided by Mirza and Sundaram (2017), who created two applications, as well as frameworks for their design and evaluation. These technologies used crowd-sourcing to gather language data from communities for their Indigenous

and endangered languages. Mirza and Sundaram (2017) worked to ensure that 90% of the application design did not depend on the language. They tested these applications with Te Reo Maori (an Indigenous language in New Zealand), Vietnamese, Arabic, Chinese, and Hindi. These applications are predominantly for storing and sharing language data and media (such as audio, video, and text), and they have some basic language activities such as flashcards and the game "hangman".

2.3.2 Challenges in Repurposing Language Technology for Indigenous Languages

Even with the rise of repurposable language-learning technologies, Indigenous languages are still often underrepresented. In instances where such tools exist, they are often content-sparse and low-level. Moreover, they often lack the financial and human resources to support the created technologies long term.

In addition to a lack of resources, Indigenous language learners may prioritize learning language-skills that are less targeted in the most common CALL tools - as established in Section 2.2.2. This shortage of available tools is especially important since many Indigenous language learners are heritage learners (He, 2010) and are learning their language with the goal of connection to family and culture (Lothian et al., 2019). This goal contrasts with that of many language-learning tools which prioritize other learner goals, such as gaining employment in the target language.

Additionally, many language technologies are unable to be adapted to Indigenous languages in their current state. This can be due to a number of the previously described challenges, such as Indigenous languages being low-resource and lacking the language and linguistic data needed to make use of these technologies. The linguistic differences between Indigenous languages in Canada and majority languages (which are the target languages of the majority of CALL tools, as seen in Section 2.1.2) can exacerbate this issue because it can make the technology inherently incompatible with many Indigenous languages. Many Indigenous languages in Canada are

morphologically complex and polysynthetic (Kuhn et al., 2020). This means that in some Indigenous languages, like Cree, a single word can carry the same amount of meaning as a sentence with multiple words in some European languages, like English. For example, the meaning of the Plains Cree word "kikînohtepewâpamitin" maps to the English sentence "I wanted to come and see you". Technologies designed for less morphologically-complex languages might emphasize memorization. For example, as seen above (Section 2.1.2), the number one language skill taught in MALL tools is vocabulary, which requires memorization. Memorization is less likely to be useful in polysynthetic languages due to the large number of morphemes and the even larger number of possible combinations (Kelly et al., 2014). Overall, there is a lack of research done on the acquisition of polysynthetic languages (Kelly et al., 2014). Therefore, it is likely that many established language-learning tools are insufficient for adequately teaching polysynthetic languages.

Another potential challenge in re-using language technologies for Indigenous languages is the risk of sharing language data with the organization who created and hosts it. This risk depends on the licensing of the tool and is an issue because although majority languages (such as English, Spanish, Chinese, etc.) might have regional dialects, those languages are rarely seen as belonging to a specific community. This is often not the case in Indigenous language communities, which may have a language authority.

Furthermore, many Indigenous communities have experienced the theft or misuse of their language data. A recent example of this is the case of an outsider organization (the Lakota Language Consortium) attempting to sell language data back to the Lakota community of Standing Rock Indian Reservation (USA) after collaborating with them (Brewer, 2022). The Lakota Language Consortium is a not-for-profit organization co-founded by Wilhelm Meya and Jan Ullrich (who are both non-Indigenous). It has received millions of dollars in federal funding since its inception and collaborated with Standing Rock to support language revitalization efforts. The Lakota

Language Consortium holds the un-restricted copyright of all the language data collected from this collaboration. Despite claiming that it is their organizations' number one interest to ensure Standing Rock has access to their own language data, it has yet to be returned and community members cannot share it without paying copyright fees. After this years-long conflict, the Standing Rock tribal council voted to banish the Lakota Language Consortium and its founders from their community. This vote occurred earlier this spring (May, 2022).

Stories such as this one are unfortunately not uncommon in Indigenous language work. In order to help ensure Indigenous language communities maintain sovereignty and control over their language and data, the First Nations Information Governance Centre (FNIGC) created the First Nations Principles of ownership, control, access, and possession (OCAP®)[3] (First Nations Information Governance Centre, 2022). Through these principles, the FNIGC asserts that Indigenous community, cultural, and language data should be controlled by Indigenous communities first and foremost.

Due to the history of theft and poor research practices and Indigenous data sovereignty principles (such as OCAP®), many Indigenous language communities may not want to partner with organizations or groups that create or repurpose language technology. If a language technology organization requires the language data to be in any part owned or kept (e.g., hosted on their servers) by anyone other than the Indigenous language community in question, this could violate almost all of the OCAP®principles.

2.4 Concluding Remarks

The literature and work described in this chapter established the current state of Indigenous language technology. This includes the challenges related to creating Indigenous language technology and the unique needs of Indigenous language learners. Indigenous languages in Canada face many challenges that may impede language revitalization and the creation of Indigenous language technology. The challenges de-

[3]OCAP®is a registered trademark of the First Nations Information Governance Centre (FNIGC)

scribed stem from the low-resource status of Indigenous languages as well as political and cost-based challenges that stem from the historical and on-going treatment and status of Indigenous peoples in Canada. This underscores the value in addressing these considerations in language technologies like SoundHunters. SoundHunters is a sound learning game that may be repurposed for other languages and is the focus project of this thesis. This game has helped people learn sound to character mappings in an Indigenous language, specifically nehiyawewin (Plains Cree). A full description of SoundHunters will be detailed in Chapter 4. SoundHunters aims to address these needs because it is open source and repurposing it will hopefully require little language data, little linguistic knowledge, minimal financial resources, and few human resources. It also targets language skills that are not typically taught by CALL tools. Moreover, it can be made to be more relevant to Indigenous language learners by changing the visual design without altering game mechanics. A tool like SoundHunters could be made more reliable through studying the repurposing process as well as whether it has continued success in helping learners. This work will help address this gap in the literature because it will highlight the process of creating and studying an Indigenous language-learning tool, rather than just focusing on technical development and pedagogical outcomes. In order to reflect this, the following section will detail how I am approaching this thesis as a researcher and Indigenous person.

Chapter 3

Reflexivity & Community Collaboration

The focal research of this thesis is a user-study for an Indigenous language-learning technology that was developed with community collaboration. In order to provide sufficient context for this research, I will describe my own personal background as a researcher as well as that of the community collaborators for this project.

This thesis includes quantitative and qualitative research methodologies. This section describes a qualitative research practice used in participant-based research called reflexivity. Reflexivity can be defined as the researcher reporting aspects about themselves that may contextualize their relationship to the object of study. This can help ensure rigor and quality in research (Dodgson, 2019). In participant-based research, it is important to understand the intersection of experience that the researcher shares with study participants. (Berger, 2015)

Researcher reflexivity is sometimes used in Indigenous research to underscore the power the researcher may have, especially as it relates to Indigenous participant-based research (Nilson, 2017). However, the participant-researcher power imbalance in Indigenous research is often discussed from a non-Indigenous researcher perspective (Bryant, 2015 p.93; Gerlach, 2018). Consequently, this section will contribute to considering this dynamic from the point of view of an Indigenous researcher: myself, the author of this thesis.

3.1 About The Author

In this section, I will introduce myself and information that might be relevant or have overlap with other content in this thesis. My name is Delaney Lothian and my post-secondary academic career began in 2015 when I started my undergraduate degree in the Faculty of Science at the University of Alberta. I graduated with a Bachelor of Science Specialization in Computing Science in 2020. I started my master's degree in Computing Science at the University of Alberta during the fall of the same year. My mother was the first person in my family to complete a university degree after receiving her bachelor's and master's in social work as a mature student. My sister was the next person to receive a university degree, followed by myself.

3.1.1 Cultural Background

I was born and raised in the province of Alberta and have lived in Edmonton, Alberta for the majority of my life. My mother's family is from and lives largely in north-central Alberta, whereas my father's family lives in Ontario[1]. Because of this, I grew up more culturally influenced by my mother's side of the family. I am Cree-Métis and my home community is the historic Métis community of Lac Ste. Anne, Alberta. As with many Métis people in central Alberta, I also have known Kanien'kehá:ka (Mohawk) ancestry. I and many people from my community are descended from Michel First Nation, which was a federally recognized First Nation whose Chief was Michel Calihoo, the son of a fur trader and traveler Kanien'kehá:ka man named Louis Kwarakwante (Calihoo)[2]. However, Michel First Nation was involuntarily enfranchised[3] and all of its members and their descendants lost First Nation's status. My Kanien'kehá:ka ancestry is distant enough that I have no current cultural connections and therefore do not identify with it. However, this heritage and Michel First Nation

[1]Note that in Canada, Ontario is a four-hour flight or a multi-day drive from Alberta.
[2]https://www.metismuseum.ca/resource.php/14479
[3]In this context, enfranchisement refers to the loss of legal Indian status in Canada.

have significantly shaped my community and so it is important and relevant cultural history.

I have multiple relatives who attended residential school. The experience of residential school led many people in my community to be fearful of passing down the language. These fears were connected to threats of having their children taken away or being treated violently in school if they were found to speak the language, or spoke English with an accent. I have living relatives from this era and although they are enthusiastic about language revitalization, this fear still shapes a lot of our community language and culture work.

3.1.2 Language Knowledge & Learning

My primary language is English and it is the primary language of both of my parents. I was enrolled in a French immersion program from Kindergarten through grade 12, where all of my core courses were taught in French. I received my high school diploma in French and lived in France for a year as a nanny. I am currently a learner of nehiyawewin (Plains Cree) which is one of my heritage languages, as well as various regional dialects of Michif, including the one from my own community. The language from Lac. Ste Anne is not well defined but is sometimes called Cree or a Cree-heavy dialect of Michif as it has some French influence. For the sake of this section, I will refer to it as Michif. There are very few first-language Michif speakers at Lac Ste. Anne, and they are all in the generation of my grandparents and great grandparents. I had some basic previous exposure to nehiyawewin and Michif from family and community members, and later took three years of nehiyawewin during my undergraduate degree at the University of Alberta. After progressing to higher level university nehiyawewin courses, I also tutored introductory nehiyawewin for two years.

3.1.3 Experience in Indigenous Language Revitalization & Technology

I have worked in culture and language revitalization since I was a young teen. As part of an initiative within my own community, I worked on an oral history project where we interviewed community Elders about the history of the culture and language at Lac Ste. Anne. In conjunction with my sister, I have also worked on multiple community language revitalization projects such as workshops, culture camps, instructional videos, and a website.

I later began working with Indigenous language technology in an academic setting. While I took nehiyawewin courses, I searched for software applications that would support my learning and act as references for some of the material, and I found that there were very few and even fewer that were robust. In 2018, I joined the Educational Technology, Knowledge, Language, and Learning Analytics (EdTeKLA) research group[4] in the Department of Computing Science at the University of Alberta. This is where I started work on a nehiyawewin language learning system; this work later evolved into the development of SoundHunters. As part of this work, I conducted a set of focus groups to study and collect information on the needs and wants of Indigenous peoples when using or designing an Indigenous language technology.

In addition to these activities, I worked with the National Research Council's Indigenous Languages Technology (NRCILT)[5] team. I first joined them as a Youth Ambassador in 2019 for the team's Indigenous advisory committee. Afterwards, I joined the team as a student intern. I worked with NRCILT as an NRC student intern for all of 2020 and again during the fall of 2021. My supervisor for this internship, Roland Kuhn, is also a co-supervisor for this thesis. During the internship, I worked on the front-end user interface for a verb conjugator web app for the Southern dialect of Michif. It was through this work where I first gained experience of collaboratively

[4]https://spaces.facsci.ualberta.ca/edtekla/

[5]https://nrc.canada.ca/en/research-development/research-collaboration/programs/canadian-indigenous-languages-technology-project

designing an Indigenous language technology. This project is also where I met Heather Souter and Fineen Davis, who are the primary collaborators for this thesis.

3.2 A Note About Reflexivity In Indigenous Research

Literature on reflexivity will sometimes discuss the idea of the researcher being an "insider" or an "outsider" with respect to the research they are doing. A researcher is considered an insider if they have shared experiences with the study participants and an outsider otherwise (Dodgson, 2019). For example, an allistic (or not autistic) researcher conducting research on autism would be considered an "outsider". In reflexivity, this distinction can underscore the overlap in similarities between a researcher and participant(s).

I am Métis and one of my heritage languages is a dialect of Michif. As will be discussed in the following section (3.3), my primary collaborator for this project is Métis and the target language for the new version of SoundHunters is a dialect of Michif. Being an Indigenous researcher conducting research with Indigenous participants is enough that I would be considered an "insider" under the given definition. Although the insider/outsider notion may be useful in the broader discussion on Indigenous research, to avoid tokenization I would like to look at this under a more detailed and nuanced lens.

I am not from the community where the Michif dialect used in this project is from (nor am I from the same part of Canada; this community is more than a 10 hour drive from where I live). Moreover, I have no experience with the politics of their language or their experience with language documentation, standardization, or revitalization. In addition to these differences, being an "insider" does not negate or remove the researcher-participant dynamic, and I still hold power as the author and lead researcher.

Instead of highlighting differences or distinctions, this section would be better

viewed as similar to a method described by Kovach (2014) in her book "Indigenous Methodologies: Characteristics, Conversations, and Contexts" called the prologue statement. Kovach defines it as a statement that "...introduces the researcher, situates the researcher in relation to the Indigenous community, and functions as a knowledge dissemination protocol for sharing research to a wider audience (notably the Indigenous community)." p.144. It plays a very similar role and overlaps with reflexivity as its goal is "...revealing how one's personal experience, purpose, and preparation influence research choices and interpretations." p.144.

3.3 Community Collaboration

3.3.1 Process of Approaching Collaborators

SoundHunters is a project that I have been working on since May 2018. I conducted a study to measure learning and player experience in 2019 and published and presented the results in 2020 (Lothian et al., 2020). I have also presented it at Continual Workshops in Indigenous Language Technology (CWILTs) in 2019, which were created by Caroline Running Wolf and delivered through the National Research Council Canada. It was shortly after this presentation that I was approached by Heather Souter to create a version of SoundHunters for the Michif language. This was before I had formally started working towards creating a new version for my thesis so I informed her that porting SoundHunters to support new languages was a goal I had and that I would contact her when we started that work. Once we started the process of formally approaching collaborators for this project in late summer of 2021, I contacted her about creating a Michif SoundHunters and we began the collaboration process.

3.3.2 Collaborators

The following information was given to me and reviewed by my collaborators to be shared in this thesis. In this project my primary collaborator is Heather Souter, a

language activist and language revitalization practitioner. She is the co-founder of Prairies to Woodlands Indigenous Language Revitalization Circle Inc. (P2WILRC). Heather is a Michif (Métis) woman who is a language learner, speaker, and teacher of the Southern dialect of Michif. Prairies to Woodlands Indigenous Language Revitalization Circle is a not-for-profit grassroots community organization focused on the revitalization of Michif and other Indigenous languages. Heather was born and raised in Vancouver, British Columbia, and draws cultural heritage from the historic Métis community of Lac Ste. Anne, Alberta. Heather currently lives in Camperville, Manitoba, which she describes as "a small Métis community where an enclave of mother-tongue Michif speakers and cultural knowledge-holders, including [her] own in-laws, also reside". Heather holds a Master of Education in Indigenous Language Revitalization from the University of Victoria and a sessional lecturer position, teaching Michif, at the University of Manitoba.

In addition to Heather, I collaborated with Fineen Davis[6] who is a computational linguist who works with Heather and P2WILRC. Fineen has collaborated with Heather and P2WILRC on Michif language projects for the past three years, first through the NRCILT team and now directly with P2WILRC and Wiichihitotaak Indigenous Language Revitalization. Fineen is a white settler living on the lands of the Algonquin Anishinaabe peoples in Ottawa, Ontario.

Although I never worked directly with Verna Demontigny, I credit her for playing an indirect but fundamental role in this project. Verna is an elder and co-founder of P2WILRC. She is a first-language speaker of Southern Michif and teaches the language and cultural practices in the community and online. She has been a foundational and central member on P2WILRC projects and contributed extensively to the bank of Michif language recordings used in projects, including Michif SoundHunters.

[6]http://findavis.ca/

3.3.3 Collaboration Process

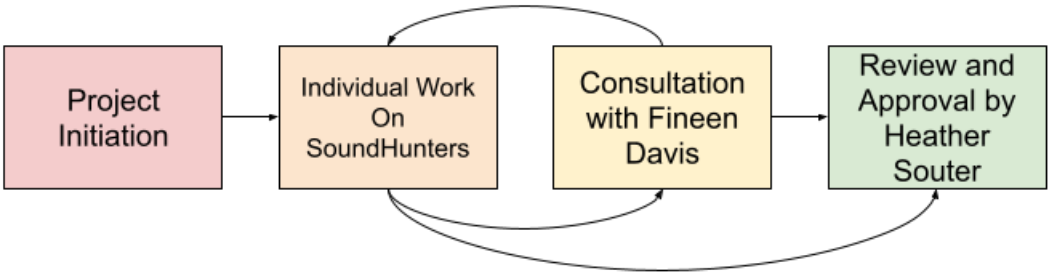
As established in the About the Author section (Section 3.1), I have previous connections with both Heather Souter and Fineen Davis. I met both of them through an internship with the NRCILT team. Through this project and internship, Fineen Davis and I worked together to create a language model and user interface for a verb conjugator of Southern Michif for Heather Souter and P2WILRC. Presently, I continue to work intermittently and as-needed on the Michif verb conjugator project for P2WILRC, and so the conjugator project's timeline and the timeline of this thesis overlapped.

Prior to this, Heather and I served together on the NRCILT Indigenous advisory committee. We have co-authored a paper and a poster together for the UNESCO Language Technologies for All conference. It was through these prior connections that I first told Heather about the SoundHunters project; this was when Heather first showed interest in creating a Southern Michif version. This was before I began my graduate degree and before I had concrete plans to repurpose SoundHunters for another language. Once I began to plan for my thesis work, I reached out to Heather to ask if she was still interested in creating a Southern Michif SoundHunters. She confirmed that she did and we met a handful of times to set expectations for the creation of a Michif SoundHunters.

As Heather is one of the heads of P2WILRC, manages a number of major projects, and teaches Michif at the University of Manitoba, it would be impractical to require frequent meetings with her for this project. In order to mitigate this access limitation, we established a collaborative process (Figure 3.1) where Fineen had time allocated to work with me for smaller and more frequent meetings. Because of Fineen's experience doing linguistic work with Michif language modeling, she is qualified to do initial reviews of my work and answer questions with respect to Michif sounds and orthography. Fineen and I would meet multiple times a month to clear up gaps in

my knowledge and double check my thesis work. With less frequency we would meet with Heather for her to confirm Fineen's knowledge, make decisions, or give needed permissions.

Figure 3.1: The collaborative process for creating Michif SoundHunters.



This protocol was feasible in the context of this specific project because of the years of previous work Fineen and I had done together with Heather. The three of us worked on the Michif verb conjugator project in essentially the same way.

For the development of Michif SoundHunters, I was given access to a database that contained Michif language data from a P2WILRC dictionary project. This database contained basic language data including the Michif and English headwords, as well as information I could use to download recordings of the words, if available. I was given permission to work with this data as needed to extract recordings for SoundHunters. This included full access to all dictionary data, despite only needing a subset. This level of permission would likely be inappropriate to ask for if I was collaborating with a partner I had no previous experience with. Additionally, despite being given overarching permission based on our previous relationship, we ensured that all data usage and storage was agreed upon in writing. This is a vital step in any community collaboration given the historical context.

3.4 Concluding Remarks

In this chapter, I introduced myself as the primary researcher as an exercise in reflexivity. Since it is relevant in this research context, I described my own background which includes my cultural background, my knowledge and experience with natural language learning, and my experience in Indigenous language technology. This background serves to situate myself within this research context. I also introduced the collaborators for this project from Prairies to Woodlands Indigenous Language Revitalization Circle Inc.: Heather Souter and Fineen Davis. Together, we established a development process to create a Michif version of SoundHunters. In the following chapter, I will describe the initial nehiyawewin (Plains Cree) version of SoundHunters, the process of creating and testing this version, and what steps were needed to repurpose it for another language.

Chapter 4

nehiyawewin SoundHunters

In Chapter 2, we discussed how Computer-Assisted Language Learning tools predominantly teach majority languages (and more than half teach English). Chapter 2 also explored how efforts to create Indigenous language technologies can have many speed bumps that slow down progress, such as language communities' lack of access to speakers, funding, language data, and technology related tools and training. To address these gaps, we created the language learning game SoundHunters to teach nehiyawewin (Plains Cree), an Indigenous language spoken across the western plains of Canada. In this chapter, we will describe SoundHunters, the mechanics and details of SoundHunters specific to nehiyawewin, and how its design could be repurposed for teaching the sounds of another language.

4.1 SoundHunters Game Description

SoundHunters is an arcade-inspired game initially designed to teach the sounds of nehiyawewin. The game mechanics are as follows: pixelated deer float down the screen with text attached to them while a sound gets played on repeat. The player controls a bow at the bottom of the screen and can move it side to side using the left and right arrow keys. When the spacebar is pressed, an arrow shoots out of the bow up the screen until it disappears out the top. There is no limit to how many arrows the player can shoot. The player's goal is to shoot the deer that is labeled with the

text that is associated with the given repeating sound (i.e., the "correct" deer). If they shoot the correct deer, the player gains points. If the player shoots a deer with text that is not associated with the given sound or the correct deer escapes off screen, the player loses health. The player wins the game once they achieve enough points to have a full points bar and they lose the game when the health bar becomes empty. The on-screen deer who have text that is not associated with the given sounds are called "distractors". A "question" in this game is defined as the given sound, the correct deer, and a set of distractor deer.

4.2 Cree Language Information & SoundHunters

The first version of SoundHunters was made for the Plains dialect of Cree: nehiyawewin. This language was chosen because it is not only a language local to the land that the University of Alberta sits on but is also taught at the University of Alberta. In order to better understand the description of the Cree version of SoundHunters, we will first cover information about nehiyawewin.

4.2.1 General Cree Language Information

Canada has over 70 Indigenous languages that belong to 12 language families. Cree is part of the Algonquian language family and its use spans across Canada from the western prairies to the east coast. According to the 2016 Canadian census, there are approximately 96,575 Cree speakers in Canada (Statistics Canada, 2016). Cree has 5 major dialects: nehiyawewin (Plains Cree or Y-dialect), nehinawewin (Swampy Cree or N-dialect), nîhithawîwin (Woods Cree or TH-dialect), nehilawewin (Moose Cree or L-dialect), and nehirâmowin (Atikamekw Cree or R-dialect)(Okimasis, 2004). SoundHunters teaches the Plains Cree dialect specifically and so this section focuses on nehiyawewin. nehiyawewin is the western most dialect and is spoken mainly in the provinces of Alberta and Saskatchewan. According to the 2016 Canadian census, there are 3,655 nehiyawewin speakers. It is worth noting that in the census, 69,975

people reported the dialect of Cree they spoke as "not otherwise specified" so 3,655 is likely a lower bound. This gap in reporting may be due to discomfort in reporting such information or because some communities may use their community name or region to indicate dialect.

Like many Indigenous languages in Canada, nehiyawewin is polysynthetic. This means that it is morphologically complex, and sentences can be single words that were composed by combining morphemes (i.e., the smallest meaningful unit of language). It is also agglutinative (Harrigan et al., 2017), which means that morphemes and their sounds do not change much when they are combined.

nehiyawewin has two main orthographies (i.e., writing systems). The first is a syllabary known as nehiyawewin syllabics. A syllabary is a writing system in which each symbol represents a syllable sound. These symbols typically represent a consonant-vowel sound combination (e.g., ᑎ represents the sound "ti"). However, there are other symbols for when the sound of a word cannot be entirely represented by consonant-vowel pairs, such as the word "atim", which starts with a vowel and ends with a consonant. Vowels are represented by different rotations of triangle symbols (e.g., ᐊ represents the "a" sound) and single consonants are represented by much smaller symbols called finals (e.g., ᐟ represents the "m" sound). Combined, "atim" is spelt as ᐊᑎᐟ in syllabics. This results in the nehiyawewin syllabary containing 73 unique symbols. The second orthography is the nehiyawewin standard Roman orthography (SRO). Like English, this orthography pulls its letters from the Roman alphabet. There are some letters in SRO with sounds that map to their English counterparts.

We developed the first version of SoundHunters with SRO to take advantage of this overlap. Using this overlap, nehiyawewin language learners can use previous English knowledge to learn SRO which can help build early confidence and flatten the learning curve. There are downsides to teaching it this way. One occurs when English and nehiyawewin do not overlap. This is where a learner might try to apply English knowledge to letters in SRO whose sounds do not map to their English counterparts.

Additionally, people may prefer learning nehiyawewin with syllabics in order to decolonize the learning of Indigenous languages. For these reasons, we are developing a syllabics version of SoundHunters. The syllabics version was not studied in this thesis research so it will not be explored further in this text.

nehiyawewin SRO has an alphabet of 17 letters, made up of seven vowels, eight consonants, and two semi-vowels. Of the seven vowels, four are long and three are short and can be found in Table 4.1.

Table 4.1: All vowels of nehiyawewin standard Roman orthography, what they sound like, and their IPA equivalents.

Vowel	Sounds Like	IPA
Short Vowel		
i	**i**n	ɪ
a	**a**bout	ə
o	b**oo**k	ʊ
Long Vowel		
â	f**a**ther	ɐ
î	mach**i**ne	i
ô	m**oo**se	u
e	h**ay**	e, eɪ[1]

[1]The pronunciation of the letter "e" varies across context and speaker so it may or may not appear as a diphthong.

The circumflex is the only diacritic in nehiyawewin. It is used to denote a long vowel. Unlike the other long vowels, the letter "e" does not have a circumflex. Since SRO is a fairly recent standard and is not strictly defined, there are some people who write a circumflex with "e", as "ê" and some exclude the circumflex for this character. The argument for including the circumflex is to maintain consistency amongst all long vowels (Okimasis & Wolvengrey, 2008). The argument for omitting the circumflex is that including it might imply that there is a short vowel sound for "e", as there are

short counterparts to the other three long vowels. Since SoundHunters was initially made for the introductory nehiyawewin course at the University of Alberta, we opted to omit the circumflex on the "e" to be consistent with their curriculum.

The consonants in SRO that sound like their English counterparts are: "h", "m", "n", and "s". The letters "p", "t", and "k" all differ from their English counterparts in that they are all pronounced softer and less aspirated. The "p" is closer to a cross between an English "p" and a "b", the "t" is closer to a cross between an English "t" and a "d", and the "k" is closer to a cross between an English "k" and a "g". Note that in nehiyawewin "p", "t", and "k" are not voiced. The eight consonants can be found in Table 4.2.

Table 4.2: Consonants of nehiyawewin standard Roman orthography, what they sound like, and their IPA equivalents.

Consonant	**Sounds Like**	**IPA**[1]
c	ca**ts**	ts
h	**h**ay	h
k	Between s**k**ill and **g**ill	k
m	**m**ake	m
n	**n**ight	n
p	Between s**p**ill and **b**ill	p
s	**s**ay	s
t	Between s**t**ill and **d**ill	t

[1]Note that for all three of letters k, p, and t, their IPA represent unaspirated sounds and not the aspirated sounds made by k^h, p^h, and t^h.

The two semi-vowels in nehiyawewin are "y" and "w". These letters act like consonants when they come before a vowel or consonant sound. In these settings, they sound like their English counterparts. When semi-vowels are preceded by a vowel sound they can change the length and sound of the vowel. For example, "âw" makes an "ow" sound, as in "w**ow**" or aʊ in IPA. The semi-vowels "w" and "y" never make

vowel sounds on their own. This is unlike the semi-vowel "y" in English, which can represent a vowel sound (e.g. part**y** or pɑrt**i** in IPA). The two semi-vowels can be found in Table 4.3.

Table 4.3: Semi-vowels of nehiyawewin standard Roman orthography, what they sound like when they act as consonants, and their IPA equivalents.

Semi-Vowel	**Sounds Like**	**IPA**
w	**w**et	w
y	**y**et	j

Note that for the above tables (4.1, 4.2, and 4.3), I was unable to find any direct nehiyawewin character to IPA mappings. The IPA examples are built in part from the "sounds like" examples from the introductory nehiyawewin textbook for the University of Alberta (Thunder, 2001) and the book "How to Spell It In Cree" (Okimasis & Wolvengrey, 2008).

4.2.2 nehiyawewin SoundHunters

The nehiyawewin SoundHunters has four sub-games: single sound, double sound, minimal pair, and word. Each sub-game has three levels: easy, medium, and hard. Players must play the sub-games in the listed order, starting with the more fundamental single sounds of the language before moving up to more complex combinations. The player starts at the easy level of the single sound sub-game, and must win this level to move on to the medium level of the single sound sub-game. Similarly, they must win the medium level to move onto the hard level, and once they have completed the hard level of the single sound sub-game they can move onto the easy level of the double sound sub-game. The player completes a play-through of SoundHunters when they win the hard level of the word sub-game. The details of these sub-games and their levels are described in the following subsections.

4.2.2.1 The Single Sound Sub-Game

Note that in the following sections, a single sound is defined as any sound represented by a single character, as detailed in the tables above. The sub-game starts by introducing the players to the simplest sounds. In nehiyawewin, these are single letter sounds. In this sub-game, a distractor deer can belong to one of four categories:

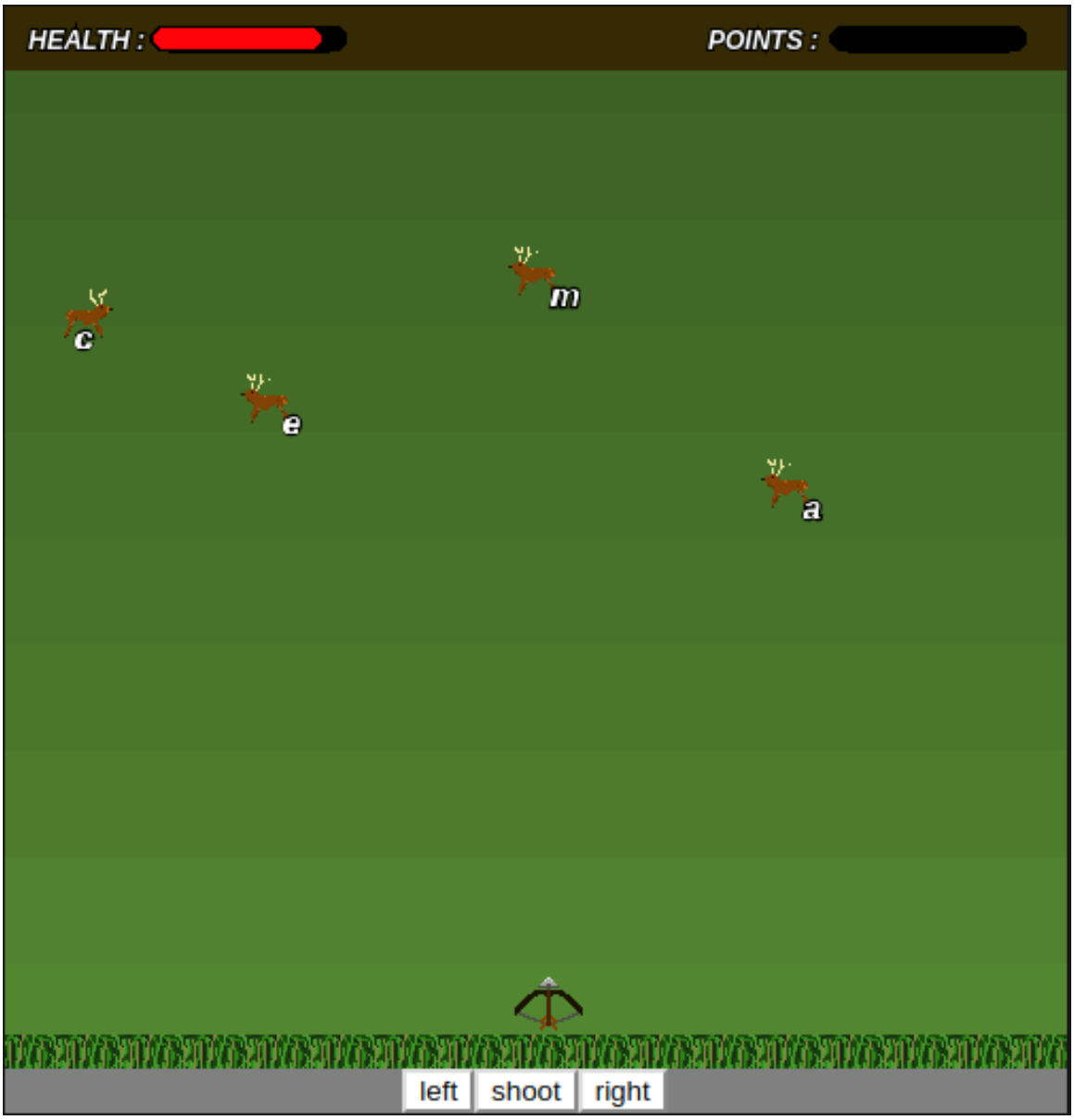
1. Dissimilar
2. Visually similar
3. Audibly similar
4. Both audibly and visually similar

Dissimilar letters are letters that are neither visually nor audibly similar. An example of two letters that are dissimilar in nehiyawewin SRO is "n" and "i". They have no obvious visual similarities and do not sound similar.

Whether two letters are visually similar depends on the font used. For example, if the sub-game displays the letter "a" in the font Arial, it looks like "a". However, if the sub-game were to display the letter "a" in the font of Josefin Sans, it looks like "ɑ". This version of "a" looks more similar to an "o" with a tick so it could be considered visually similar to the letter "o". SoundHunters uses an Arial-like font so "a" and "o" cannot serve as visual distractors for one another.

There are two cases when letters are considered audibly similar. The first case is if two letters sound similar in nehiyawewin. For example, "a" (as in cut or ə in IPA) and "â" (as in far or ɑ in IPA) sound similar in nehiyawewin. The second case is if, for two letters, the sound one letter makes in nehiyawewin maps to the sound the second letter makes in English. For example, the sound the letter "e" makes in nehiyawewin - often, this is pronounced as a diphthong - can be mapped to the diphthong the letter "a" stands for in "acorn" (**eɪ**kɔrn in IPA).

Figure 4.1: A screenshot of the single letter game at the medium level. In this question, the sound given and the correct letter is "e" (as in bet or e in IPA) and the distractors are the letter "a" (as in c**u**t or ə in IPA) which is audibly similar, and "c" which is visually similar, and "m" which is dissimilar.



In the easy level of the single sound sub-game, players are given a question with one correct deer and two distractor deer, for a total of three deer on screen. The two distractor deer are dissimilar to the correct deer. This means the player is mainly being asked to identify the sound being given, rather than to distinguish between the

correct deer and some similar distractor deer. An example question from this level would be a question where the sound given and correct deer is the letter “a” (as in cut or ə in IPA) with the distractors “t” and “m”. At this level, the deer move the slowest of all three levels. Once the player successfully wins a round of the single sound sub-game at the easiest level, they progress to the medium level.

A question at the medium level will have four deer, one correct and three distractors. Since another distractor is added, the speed of descent of the deer remains unchanged. At this level, on-screen distractors will be audibly similar, visually similar, or dissimilar. The number of similar distractors each single sound has varies. Preference is given to distractors that are audibly similar or visually similar but the amount appearing in a question (i.e., 0, 1, or 2) will vary. An example question for this level would be where the sound given and correct answer is the letter “n” with the visually similar distractor letter “h” and the dissimilar distractor letters “a” and “y”. Once the player wins a round of the single sound sub-game at the medium level, they advance to the hard level.

A question at the hard level will have four deer, one correct and three distractors. Since no extra distractor is added, the speed of descent of the deer is increased slightly. At this level, on-screen distractors may be any type of distractor, with a preference given to letters which are both audibly and visually similar to the correct letter. There are no instances where a sound has more than one audibly and visually similar distractor so this results in this level having at most one of this type. An example question of this level could use “a” (as in cut or ə in IPA) for the sound given and correct deer and the distractor letter “â” (as in far or ɑ in IPA) which is both audibly and visually similar. The second distractor could be “e” (as in bet or e in IPA) which is only audibly similar, and the final distractor could be “t”, which is dissimilar. Once a player successfully wins a round of the single sound sub-game at the hard level, they advance to the next sub-game.

2.2.1.2 The Double Sound Sub-Game

The next sub-game the user plays is the double sound sub-game. In this sub-game, players are shown text and sounds made up of valid consonant-vowel pairings in nehiyawewin SRO. The mechanics and question selection of this sub-game are identical to those in the single sound sub-game at each level. The four types of distractors (dissimilar, audibly similar, visually similar, and both audibly and visually similar) carry over to this sub-game with a slight adjustment. The similarity between two double sounds is determined by comparing the consonants against each other and the vowels against each other. Whichever of these pairs of single characters has the highest level of similarity is what the distractor type is set as for the double sound pair. For example, in the pair of double sounds "te" and "pa", the consonants "t" and "m" are dissimilar and the vowels "e" and "a" are audibly similar. Then this pair is considered audibly similar to each other. If the consonants or the vowels are identical across a pair of double sounds, then the double sound pair inherits the distractor type of the differing single sounds. For example, in the pair of double sounds "ta" and "pa", both vowel sounds are the character "a" and so this double sound is considered dissimilar.

At the easy level, players are introduced to letter pair sounds where questions consist of the given sound and the correct letter pair with two on-screen distractors that are both dissimilar. At the medium level, a question would contain the correct sound with three distractors that are either audibly similar, visually similar, or dissimilar. The medium level prioritizes selecting distractors that are audibly or visually similar. An example question at the medium level would be the correct double sound "te" with the audibly similar distractor "ce" and the dissimilar distractors "pi" and "ko". At the hard level, a question would contain the correct sound with three distractors of any type with a preference for distractors that are both audibly and visually similar. As with the single sound game, there are no double sounds that have more than one

distractor that is both audibly and visually similar. Therefore, there can be at most one of this type of distractor in a hard-level question. An example question at the hard level would be the correct sound “ma” with the audibly and visually similar distractor “mâ” and the dissimilar distractors “ko” and “sî”.

Figure 4.2: An example question for the medium level of the letter pair game. In this question, the correct letter pair is “ca” and all distractors are audibly similar.

2.2.1.3 The Minimal Pair Sub-Game

Once a player has successfully won the hard level of the double sound sub-game, they advance to the minimal pair sub-game. A minimal pair is two words that differ by only one sound. This sub-game aims to teach players to distinguish between sounds within words. In this sub-game, at all levels, questions consist of two deer on screen: the correct deer and its minimal pair. This sub-game also has three levels of easy, medium, and hard. The main difference in difficulty is created using two factors: the length of the words in a minimal pair set and the speed of descent of the deer. Similarly to the previous two sub-games, the speed of descent increases at the hard level. For example, a question at the easy level could have the correct word be "nîya" with the distractor word being "kîya". An example question from the hard level can be seen below in Figure 4.3, where the correct word is "emetaweyân" and the distractor word is "emataweyan" and the player must successfully distinguish between the "â" and "a" sounds near the end of the word.

2.2.1.4 The Word Sub-Game

The word sub-game is the final sub-game in SoundHunters. A player begins the word sub-game once they have won the hard level of the minimal pairs sub-game. In this sub-game the easy level includes the correct word plus two on-screen distractors. The medium and hard levels have the correct word plus three on-screen distractors. This is similar to the single sound and double sound sub-games.

In this sub-game, a distractor is either a close pair (two words that differ by only two sounds) or is dissimilar. The difficulty of each level is determined not only by the number and type of distractors and speed of descent but also by the length of the word. An example of an easy question can be seen in Figure 4.4. This question has the correct word of "kikot" with the close pair distractor "mikota" and the dissimilar distractor "itwe". Once the player has won each level of the word sub-game, they have completed a playthrough of SoundHunters.

Figure 4.3: Example question of the hard level in the minimal pair game. This question has the correct word of “emetaweyân” and the distractor word of “emetaweyan”.

4.2.3 Cree Recordings Information

The recordings used in the initial nehiyawewin version of SoundHunters are from the lab recordings used in the University of Alberta’s first-year nehiyawewin course. These recordings are of Emily Hunter who helped design and create the course. Since they were recorded specifically for a class, the single letter and letter pair sounds were recorded individually with the intention to teach these sounds, as opposed to

Figure 4.4: An example question of the word game at the easy level. This question has the correct word of "kikot" with the close pair distractor of "mikota" and the dissimilar distractor of "itwe".

clipped from recordings of continuous words or sentences. One important thing to note is that it is difficult to record single consonant sounds without a following vowel sound. Therefore, the only consonants in the single letter recordings that are pronounced without an obvious following vowel sound are "n" and "m". They are both pronounced as they would be at the end of an English word, such as "te**n**" and "hi**m**".

The consonants “c”, “h”, “k”, “p”, “s”, “t”, and “w” are followed by a vowel sound that sounds like œ in the International Phonetic Alphabet (IPA). The consonant “y” is followed by an “i” sound, as in “b**i**g” or like ɪ in IPA. The letter pair recordings are entirely consonant-vowel sounds, and so this issue does not transfer past the single letter sounds. The other letter pair recordings consist of vowel-semivowel sounds to demonstrate how vowel sounds change. There are also four recordings to demonstrate pre-aspirated consonants, with pairings with “h” as the first letter, followed by one of “c”, “k”, “p”, or “t” (e.g., the “hp” sound in the word tepako**hp**) .

4.3 SoundHunters Technical Description

4.3.1 Designing the System

The SoundHunters project started in 2018 as a collaboration between myself and Anaka Sparrow, a Métis high school student. This student was studying in the lab through the Faculty of Science’s summer research program for women in the sciences (i.e., WISEST SRP). I had already started on the idea of making a nehiyawewin tutoring system, and we worked on creating a game for learning nehiyawewin sounds together when she joined our group. She worked on the front-end, made all of the game functionality, and decided on the game engine. I worked on the backend. This work included programming the initial logic and setting up the database. CreeTutor, the tutoring system that SoundHunters was being designed to be a part of, already had a backend framework and database. By the end of the summer, we had created the very first version which only included the single sound sub-game. Afterwards, we prepared the recordings and linguistic information needed for the other sub-games (double sound, minimal pair, and word).

After adding the remaining sub-games, we conducted an initial study to measure whether SoundHunters could promote phonological awareness in players. This study found evidence of positive learning gains in players. Subsequent analyses of player

data additionally revealed that the word sub-game likely did not contribute much to player learning. In the summer of 2021, we started work on another study that would examine a different version of SoundHunters. This version of SoundHunters was designed to personalize learning by adapting the questions asked to the player based on that player's previous game play. This version is not studied in this thesis, and so will not be further discussed.

While preparing for this study, the original version of SoundHunters was refactored by another team member, Nhan Nguyen. This refactored code was used to create the Michif version of SoundHunters, which is described in Chapter 5. Note that at this point, the SoundHunters code is still embedded in the larger CreeTutor project. Nguyen also created all of the code used to host the study online. A slightly modified version of this code was used for the study conducted in this thesis, which is discussed further in Chapter 6.

4.3.2 Technical Details

SoundHunters is a web application. The game was built using PixiJS[1], an HTML5-based game engine. The current version used is 4.1.3, which was released in Fall 2019. The languages used in the front end are CSS, HTML, and javascript. No other frameworks are used in the front end. For the backend, SoundHunters uses a framework called Django[2]. Django is a python web framework, and both the nehiyawewin and Michif versions of SoundHunters used Django version 4.0.4, which is the most up to date version as of April 2022. This Django version requires Python 3.8 or later. Version 12 of PostgreSQL[3] is the current database management system; it was released in Fall 2019.

The database contains all of the necessary language data and references to the recordings. Additionally, the database contains information logged during gameplay.

[1] https://pixijs.com/
[2] https://www.djangoproject.com/
[3] https://www.postgresql.org/

There are currently a number of player actions logged. This data does not inform the progression of the game; it has so far only been used in understanding study results. First, we log basic session information when a user plays a level. Each level played logs a session ID, an associated user ID, when the level began, when the level ended, which sub-game and level they were playing, and whether they won or lost. Note that if the player exits the game page before they finish playing, then there is no game result or end of round time recorded. See 4.4 for an example of the system log data.

Table 4.4: SoundHunters session table (simulated data). This example data shows a player who played and won the easy level of the single sound sub-game, then moved on to play and lose the medium level of the single sound sub-game, and who finally re-played and won the medium level of the single sound sub-game. Note that some column titles have been renamed from their database counterparts for clarity.

Session ID	**User ID**	**Session Start Time**	**Session End Time**	**Sub-Game**	**Level**	**Game Result**
10	3	04/3/2022 1:26:34	04/3/2022 1:29:55	Single	Easy	Win
11	3	04/3/2022 1:30:38	04/3/2022 1:32:29	Single	Medium	Lose
12	3	04/3/2022 1:32:03	04/3/2022 1:35:27	Single	Medium	Win

Additionally, we log game play data as a user plays a level. Logging game play data is triggered by two events: when a player shoots and hits any deer on screen and when any deer leaves the screen. In these events, the system logs each deer that was on screen and their positions. This includes the deer that was hit or left the screen. The system logs its last position before it was removed from the screen. Each deer is also logged with a timestamp, a session ID, the text attached to the deer, and the text of the correct answer. Finally, this table also logs the status of each deer; whether it has been hit, has left the screen, or is still on screen. Table 4.5 contains example output from the event where a deer is hit. In this example, the user saw three deer with the characters: “k”, “i”, and “w”. The sound being played (i.e., correct answer)

is the sound for “w”. When the user shoots and hits the deer with a “w” attached, all three deer and their locations are logged. This includes the location of the deer with a “w” when it was hit. Since the two deer with characters “k” and “î” were on screen when the other deer was hit, their status is logged as “on screen”, and the status of the deer that was hit is logged as “hit”.

Table 4.5: SoundHunters statistics table (simulated data). Note that some column titles have been renamed from their database counterparts for clarity.

ID	Session ID	Time Stamp	Text	Correct Answer	Position On Screen	Item Status
50	10	04/3/2022 1:27:14	k	w	507,262	On Screen
51	10	04/3/2022 1:27:14	î	w	738,232	On Screen
52	10	04/3/2022 1:27:14	w	w	24,192	Hit

4.3.3 Making a New Instance of SoundHunters

We designed SoundHunters to be largely database-driven as well as language and writing-system agnostic. This means that, aside from the language data in the database, there are not many aspects of the code or design that explicitly depend on features of nehiyawewin. The visual and cultural aspects of the design are also informed by the database. This includes references to the backdrop of the game, the deer, the bow, and the arrow that gets shot. The functionality of the game does not depend on the images themselves, and so they can easily be replaced with other items. This could be appropriate for communities where deer are not a significant part of the local geography. It could be changed to anything else that could fit the game mechanics, such as fishing.

In order to make a version of SoundHunters for another language, the primary resources needed are language data and linguistic knowledge. For language data, the

system is designed to receive labeled audio files of sounds for the desired sub-games (i.e., single sounds, double sounds, and individual word recordings). For linguistic information, SoundHunters requires information about the audible and visual similarities between single and double sounds so that appropriate distractors can be selected for each level.

Currently, the database insertions will find minimal pairs and populate the necessary tables given a folder of recordings that are labeled with the spelling of the word. However, the current code assumes that a single sound maps to a single character, as is largely true in nehiyawewin. To create a new instance of SoundHunters for another language, further linguistic information and code modifications might be needed to accommodate insertion of minimal pair information. The need for such modifications will depend on the language that the system aims to support. As will be described in the next chapter, adjustments were needed to support Michif.

4.4 Concluding Remarks

This chapter introduced the learning game called SoundHunters which has been shown to teach the sounds of nehiyawewin. A key aspect of nehiyawewin SoundHunters is that it requires little language data and linguistic knowledge of nehiyawewin. Moreover, it was designed to be largely database driven with the goal of needing little technical skill to implement. These features should make SoundHunters a good candidate for being repurposed for other languages. However, as SoundHunters has only been implemented for nehiyawewin, language-specific challenges are still unknown. To discover some potential challenges, the next chapter will detail the process of repurposing SoundHunters for Southern Michif, another Indigenous language spoken in Canada.

Chapter 5

Michif SoundHunters

In the previous chapter, we looked at the mechanics of SoundHunters, its design, and how it could potentially be repurposed for other languages. We described what language data and linguistic knowledge would be needed for a new version that supports another language. This description includes what aspects of the existing code and database population tools are expected to work with other languages and where there could be conflicts.

In this chapter, we outline the process of creating a new version of SoundHunters for the Michif language. Michif is one of the languages of the Métis people (Davis et al., 2021) and is a good next step for SoundHunters because it is related to nehiyawewin and is spoken in adjacent, even overlapping, regions of North America. Also, the images and design used in the game are relevant to Métis culture. Because we showed positive learning gains following use of the nehiyawewin (Plains Cree) version of SoundHunters, there is reason to expect similar learning for a Michif version.

Michif, like nehiyawewin, is considered an Algonquian language (Davis et al., 2021). As with nehiyawewin and many other Indigenous languages in Canada, Michif is an endangered language. Sammons (2019) stated that Michif "would likely rank at 8b ('Nearly Extinct') of 10 on the Expanded Graded Intergenerational Disruption Scale (EGIDS)" (Sammons, 2019). EGIDS is a 13-point scale that is used to describe how threatened or safe a language is (Simons & Lewis, 2011). EGIDS ranges from rank 0

(international) to rank 10 (extinct). EGIDS was built on a previously established 10-point scale and wanted to preserve the 10-point system, which is why the max value is 10. Heather Souter, the primary collaborator on this project, states that "Michif language activists estimate approximately 50-100 speakers with only a handful presently robust enough to be involved in revitalization work" (Davis et al., 2021).

Métis people are descended from the marriage between French fur traders and nehiyaw and Anishnaabe women in western and central Canada (Davis et al., 2021) and are one of the recognized Aboriginal peoples of Canada (article 35). There are different varieties of Michif. This thesis will be focusing on Southern Michif. Note that whenever the language is henceforth referred to as "Michif" (omitting "Southern"), we are referring to the Southern variety. In Canada, this variety is spoken in Manitoba and Southern Saskatchewan. There are also speakers in the USA, in the states of North Dakota and Montana (Sammons, 2019).

5.1 Michif Orthography & Sounds

Michif is a mixed language which means it is a mix of two (or more) languages and mainly stems from nehiyawewin and French (Davis et al., 2021; Sammons, 2019). Note that a mixed language is distinct from a pidgin language (i.e., a simplified version of a language used for communication between two or more groups) or a creole language (i.e., an established language with mother tongue speakers originating from a pidgin language)(Siegel, 2008). Southern Michif is, in brief, primarily composed of French nouns and nehiyawewin verbs (Sammons, 2019). Southern Michif pulls its sound inventory from both French and nehiyawewin.

Southern Michif currently has two orthographies which both take their characters from the Roman alphabet. The first is the Turtle Mountain Dictionary (TMD) orthography which originated during the creation of the Turtle Mountain Dictionary (Laverdure et al., 1983). As will be discussed further in Section 5.3, the Michif text data used in this thesis originates from this dictionary, but we do not use the TMD

orthography. The second orthography and the one used in this thesis is the Double Vowel (DV) orthography, which is a newer orthography for Southern Michif at Prairies to Woodlands Indigenous Language Revitalization Circle Inc. (P2WILRC). The DV orthography aims to make the sound to character mappings more consistent. Similar to how we chose the nehiyawewin orthography that aligns with the orthography taught in the nehiyawewin class at the University of Alberta for the nehiyawewin SoundHunters, this orthography is the one taught by Heather Souter in the Michif classes she teaches as well as in the online introductory Michif course made by P2WILRC and 7000 Languages.

The Michif DV orthography uses most of the characters found in the Roman alphabet. It only uses "q" and "x" in loan words. Michif has 21 consonant sounds, three of which are digraph consonants. Consonant sounds can be found in Table 5.1.

Table 5.1: Non-digraph consonants, what they sound like in English, and their IPA symbol.

Consonant	**Sounds Like**	**IPA[1]**
b	**b**ook	b
d	**d**inner	d
f	**f**ine	f
g	ji**g**	g
h	**h**ello	h
j	**j**une	dʒ
k	**k**ind	k$^{=}$
l	**l**ake	l
m	**m**any	m
n	**n**ight	n
p	**p**ink	p$^{=}$
r	**r**ed	ɹ
s	**s**ee	s
t	**t**ake	t$^{=}$

v	**v**ery	v
y	**y**ellow	j
z	snoo**z**e	z
w	**w**elcome	w

[1]The consonants p, t, and k are not pronounced exactly the same way in Michif as in English. No explosive "puff of air" is created when they are pronounced (i.e., they are not aspirated).

Digraph consonant sounds can be found in Table 5.2. Note that for the "Sounds Like" column, a French word is sometimes used as an example and is labeled as "fr".

Table 5.2: Michif digraph consonants, how they sound in an English word, and their corresponding IPA.

Digraph Consonant	**Sounds Like**	**IPA**
ch	**ch**ild	tʃ
sh	**sh**ine	ʃ
zh	en: televi**si**on, fr: **j**aune	ʒ

There are 18 vowel sounds in Southern Michif. There are four short vowels and 13 long vowels. As mentioned, the letter "n" with the tilde diacritic (i.e., ñ) makes a vowel sound nasalised. The below table (Table 5.3) displays all of the vowels.

Table 5.3: Vowel sounds in the Double Vowel orthography of Southern Michif.

Vowel	**Sounds Like**	**IPA**
Short Vowel		
a	c**a**t	a
e	**e**lse	ɛ
i	bit	ɪ
o	fr: b**eau**	o
Long Vowel		

aa	f**a**ther	ɑ
aañ	fr: bl**an**c	ɑ̃
ae	c**a**t	æ
aeñ	fr: vois**in**	ɛ̃
ee	fr: **é**t**é**	e
eu	fr: v**eu**x	ø
ii	n**ee**d	i
iiñ	[1]	ĩ
oeu	fr: c**oeu**r	œ
oo	fr: b**eau**	o
ooñ	fr: b**on**	ɔ̃
u	p**u**t	ʊ
uu	b**oo**t	u

These sounds and their IPA mappings come from previous unpublished work related to orthography conversion done by Heather Souter, Fineen Davis, Olivia Sammons, and Christopher Cox. I added the examples in the "sounds like" section; these were confirmed by Fineen Davis and Heather Souter.

5.2 Michif SoundHunters

This section describes the Michif version of SoundHunters. The sub-games, levels, and functionality of this version have many similarities with the nehiyawewin SoundHunters. This section highlights the differences between them. To review the mechanics of SoundHunters and the question selection procedures, see Section 4.2.2. Note that there was no word sub-game created for the Michif version since this sub-game was taken out of SoundHunters, as discussed in Section 4.3.1.

5.2.1 Sub-Games & Levels

5.2.1.1 The Single Sound Sub-Game

The single sounds in this sub-game are all of the vowel and consonant sounds, as described in the Michif Orthography and Sounds section (Section 5.1). Note that although this sub-game is called "single sound", there are two instances included that contain two phonemes. The first is the consonant sound "ch" which is pronounced as the two phonemes "tʃ" in IPA and the second is "j" which is pronounced as the two phonemes "dʒ" in IPA. As with the nehiyawewin SoundHunters single sound sub-game, a question is built by randomly selecting a correct sound from the bank of single sounds. Depending on the level, two to three distractors of varying audiovisual similarity are added to the question. The levels and what determines their difficulties are identical to their counterparts in the nehiyawewin SoundHunters single sound sub-game. A question at the easy level will have a randomly selected single sound and two visually and audibly dissimilar single-sound distractors. A question at the medium level will have a randomly selected single sound and three distractors that are either visually or audibly similar (but not both), or a dissimilar distractor. A question at the hard level will have a randomly selected single sound and three distractors. Distractors that are the most distracting (both audibly and visually similar) are prioritized ahead of selecting ones that are less distracting (only audibly similar or only visually similar, or dissimilar in both respects).

Audio and visual similarity needed to be determined for each unique pair of single sounds in this sub-game. There is overlap between the Michif and nehiyawewin alphabets that are taught by SoundHunters. However, there are characters and diacritics that exist in the Michif alphabet that do not exist in the nehiyawewin alphabet. Therefore, although we were able to use some information to determine visual similarity from the single sounds in the nehiyawewin version, the rest of the similarity information needed to be created from scratch. For a pair of single sounds, if they

are both single letters, are in nehiyawewin orthography, and are labeled as visually similar in the nehiyawewin version, then that pair is considered visually similar in the Michif version. An example of a distractor type that is inherited is between the letters "h" and "n", which are considered visually similar distractors to each other in both the Michif and nehiyawewin versions. Furthermore, if a single sound is a substring of another, and differs in length by only one character, then it also was considered visually similar. For example, the sound "s" (s in IPA) is a substring of the sound "sh" (ʃ in IPA), and so would be considered visually distracting. Audio similarity information for single sounds could not be inherited from the nehiyawewin SoundHunters and was determined first by myself before being double checked by one of our collaborators.

The primary difference between the nehiyawewin and Michif versions of the single sound sub-games is that all single sounds in nehiyawewin are represented by a single character whereas with Michif a single sound can be represented using up to three characters. Therefore, the correct answer and a distractor may vary by up to two characters in length for the Michif single sound sub-game.

5.2.1.2 The Double Sound Sub-Game

The double sounds in this sub-game are valid sound pairs where the first sound is a single consonant sound and the second is a single vowel sound, as established in Section 5.1. Not all of the possible consonant-vowel pairs appear in Michif, and so the questions in this sub-game only use the subset of pairs that exist in Southern Michif from the cross product of the set of all consonants and all vowels. The mechanics of this sub-game and its question selection are like those of the single sound sub-game. The levels and difficulty for the double sound sub-game are the same as they are for both the single sound sub-game in Michif and the nehiyawewin double sound sub-game. Specifically, the Michif double sound sub-game also will have two to three distractors accompanying a correct sound and the choice of distractors depends on

the difficulty level. The on-screen distractors will also be more or less audibly and visually distracting depending on the level, just as in the nehiyawewin SoundHunters double sound sub-game.

Whether a pair of double sounds is considered audibly or visually similar is inherited from the single sounds within each double sound. Specifically, the initial sounds are compared against each other and the final sounds are compared against each other. For example, if we want to determine the distractor type between the pair of double sounds "ba" and "loo", we look at the distractor type for the initial sounds (i.e. the consonants) "b" and "l" and the distractor type for the final sounds (i.e. the vowels) "a" and "oo". If the initial sounds in the pair are the same, then the double sound pair inherits the audio and visual similarity labels from the final sounds. Conversely, if the final sounds are the same, the pair inherits the similarity label from the initial sound. This is because when there are identical sounds within a pair, the player is only working to distinguish between the differing sounds. If there are no identical sounds between the pair, then the pair inherits the highest difficulty type between two single sounds across the pair.

5.2.1.3 The Minimal Pair Sub-Game

The Michif minimal pair sub-game is very similar to its nehiyawewin counterpart. Each question contains a pair of words in Michif that differ by a single sound. Note that since single sounds in Michif can vary in number of characters, two words in a minimal pair may have different lengths. As with the nehiyawewin version, questions in the minimal pair sub-game only ever include the correct answer and one distractor, as a minimal pair is by definition only two words.

Recall that for the nehiyawewin minimal pair sub-game, the difficulty of each level was primarily determined by the length of the words within the minimal pair: specifically, by how many syllables words have. The nehiyawewin version would show minimal pairs with one to two syllables in the easy level, three to four syllables in

the medium level, and five to six syllables in the hard level. However, the set of Michif minimal pairs that we had access to for this sub-game did not vary greatly in length and were mostly short words with one to two syllables. Because of this, the Michif minimal pair sub-game levels showed minimal pairs with one syllable for the easy level, two syllables for the medium level, and two to three syllables for the hard level. There were not enough three syllable minimal pairs for the hard level to not become overly repetitive, and so some minimal pairs from the medium level would also appear in the hard level.

5.3 Michif Language Data

To create the sub-games described in Section 5.2, we needed Southern Michif language and linguistic data. For the Michif SoundHunters, unlike with the nehiyawewin SoundHunters, we did not have access to individually recorded sounds. Since the nehiyawewin sounds were recorded for a learning context, the instructors purposefully recorded the single and double sounds. In our collaboration process, we had to discuss whether it was feasible to create new recordings specifically for this project or whether there was a way to utilize previously recorded samples. To make this project less work for our collaborators, we asked for any recordings of Michif they had so that we could clip the individual sounds from those. This section discusses the recordings used and the cleaning process that prepared them for use in Michif SoundHunters.

5.3.1 Recordings & Dictionary Information

The previous recordings P2WILRC had created were recordings for a talking dictionary project. P2WILRC gave us permission to use any of these recordings and this is where all of the recordings used in the Michif SoundHunters came from. The talking dictionary project had a couple of female speakers who contributed to the set of recordings. However, the recordings were not annotated with who recorded each one, and so we do not know the distribution of speakers for the recordings used

in this project. Additionally, I was given a comma-separated values (CSV) file that contained the dictionary headwords in the original TMD orthography as well as the DV orthography and the paths to the associated recordings. Note that the dictionary project is on-going and so not all headwords had associated recordings. I was given full access to this CSV file and access to all linked recordings in part due to my previous relationship and work with Heather Souter and P2WILRC. However, it was still under the agreement that these texts and recordings would not be spread or shared with anyone without explicit permission from Heather Souter.

P2WILRC is currently in the midst of converting the dictionary data from the original TMD orthography to the new DV orthography. This is being done by an automated process which is not yet finalized, and so the resulting DV headwords may have errors and could affect my use of the data. I kept this in mind in the subsequent work and got feedback on sounds or recordings from Fineen Davis or Heather Souter when I was unsure.

The dictionary data given to me is from a bilingual English to Michif dictionary. It is important to note that there are words in English that do not exist in Michif, and this results in the Michif headword being a description of the English word rather than a matching single Michif headword. Additionally, even if a word or concept in English does technically exist in Michif, it still might not map to a single word. For example, Michif will often include a word analogous to the English word "the" as a part of the headword. It is considered as a part of the word, even though in English or French it would not be. For example, the Michif word that is analogous to "arm" is "li braw" (French: le bras) which directly translates to "the arm". In summary, although a headword typically denotes a single word, a Michif headword in this dictionary may contain multiple words.

5.3.2 Data Cleaning & Recording Clipping

Initially, I met with Fineen Davis multiple times to get information on the sound system and DV orthography of Southern Michif. This included information on which characters and diacritics are included in the alphabet and orthography. It also included information on how many single sounds (as defined in tables 5.1, 5.2, and 5.3) there are in Southern Michif. However, there was no documentation of double sounds (specifically consonant and vowel pairings as used in the double sounds sub-game) that exist in the language or minimal pairs. This subsection describes the processes used for cleaning the dictionary data, how it was used to find necessary language data for the sub-games, and details of clipping sounds out of longer recordings.

5.3.2.1 Cleaning & Pre-processing the Dictionary Data

As described, Michif headwords can have multiple words in them. Therefore, we initially split all headwords on whitespace. All items resulting from this split will be referred to as tokens. As mentioned, there were a few instances of English words in the Michif headwords and these were ignored in the data cleaning stage. If an English word appeared in a recording while searching for a specific sound, this would be set aside and the search would be repeated. No sounds in this game were clipped from English or English loan words. After the data was split by whitespace, the language data was pre-processed so that each single sound was represented by a single character. For example, take the vowel sound "aañ", which has three characters and maps to a single sound (ɑ̃ in IPA). All tokens containing "aañ" had these characters replaced by a different single character (e.g., #) that represents the ɑ̃ sound. For example, the token "vaañtr" would become "v#tr".

5.3.2.2 Single Sounds

There was no further preprocessing to the data required to find single sounds. The greatest difficulty that arose during the single sound clipping stage was in clipping

voiced consonants (e.g., “b”, “d”, “z”). It was not possible to clip clear and recognizable voiced consonants from these recordings without including a following or preceding vowel sound. Therefore, to ensure consistency, we decided to clip these voiced consonants from recordings that had a following short “i” vowel sound. All single sounds defined in Section 5.1 have recordings included in the single sound sub-game.

5.3.2.3 Double Sounds

As with any language, not all combinations of single sounds exist in Michif. Michif inherits its sound inventory from both French and nehiyawewin, and so there could be sound combinations inherited from one language that do not exist in words pulled from the other. As mentioned, I did not have information on valid consonant and vowel combinations in Michif, which is necessary for the double sound sub-game. To minimize the manual work needed from my collaborators, I used the clean dictionary data to find instances of all valid pairings. Recall that this cleaned data was pre-processed so that all tokens had single sound to character mappings. We collected bigram counts of consonant and vowel pairs and created a set of valid pairs based on bigrams that had non-zero counts (Table 5.4).

There are a few double sound pairs within this valid set that were uncommon. Since they were less common, there were fewer recordings that contained these sounds. If there were no recordings with headwords that contained an uncommon double sound, or if the recordings were too-poor quality to be clipped, then this double sound was excluded from the sub-game. For example, the consonant “n” and vowel “uu” pair “nuu” only appears in the word “nuuvel” (“new” in Michif). Of the instances where this word appeared in a headword, there were only instances without a recording and instances with a recording that was too poor-quality to clip. Table 5.4 shows the number of double sounds that were excluded at this stage ($n = 61$) and how many were included in the final version ($n = 273$). It also includes the potential number

of double sounds, which is the number of double sounds in the cross product of all consonants and vowels. Note that almost one third of these sounds were excluded. In addition to cases where sounds could not be included due to lack of a high quality or existing recording, some sounds are rare in Michif. For example, the "uu" vowel only appears after the consonants "r" and "n", and specifically only in the words "nuuvel" ("new" in Michif) and "ruuzh" ("red" in Michif).

Table 5.4: This table shows the number of double sounds that were included in the double sound sub-game of Southern Michif SoundHunters. It also includes the number of potential double sounds, which is the cross product of all the consonants and vowels (in that order), the number of double sounds within that set that had counts of zero, and the number of double sounds excluded due to missing or poor recordings.

Potential Number of Double Sounds	378
Double Sounds With Zero Counts	44
Number of Double Sounds Excluded	61
Final Count	273

5.3.2.4 Minimal Pairs

Recall that we did not have a previously established list of minimal pairs. We discovered minimal pairs by using the pre-processed data that had the single sound to character mapping. All tokens were compared against each other, and the ones that differed by exactly one character were considered a minimal pair. These minimal pairs were categorized by the pair of single sounds that differed between them. This pair of single sounds that differentiate a minimal pair will be referred to as a pair of distinguishing sounds. This was imperfect because there were occasionally English words included in the headwords. Any minimal pairs that included an English word were removed from the set using manual inspection. There were well over 1,000 unique minimal pairs that resulted from the initial search. To minimize the manual inspection required to validate this set, the set of minimal pairs was reduced so that there was only one minimal pair per pair of distinguishing sounds. For example, the

minimal pair “vaañ” (vã in IPA) and “veu” (vø in IPA) and the minimal pair “zhaañ” (ʒã in IPA) and “zheu” (ʒø in IPA) both share the same pair of distinguishing sounds: “aañ” and “eu”. So as to reduce the number of minimal pairs, only one of these pairs would be chosen. This reduced the number of pairs to 267 pairs, which were reviewed by Fineen Davis and Heather Souter.

Using the dictionary data, we were able to look through all recordings associated with a sound or word in order to clip it out. There was one pair of distinguishing sounds: the vowel pair “ee” (e in IPA) and “e” (ɛ in IPA), from the approved set where no recordings could be found such that both recordings were clear enough for a player to be able to distinguish between them. For a full breakdown of the counts of each of these stages, see Table 5.5.

Table 5.5: The counts of the set of minimal pairs for the minimal pair sub-game at each stage of the selection process.

Number of Minimal Pairs Found Programmatically	1259
Number of Unique Pairs Per Distinguishing Sounds	283
Number of Unique Pairs After Removing English Words	267
Final Count	266

5.4 Technical Changes

To make this new version of Michif SoundHunters, there were two small technical changes that needed to be made. As briefly mentioned in the previous chapter (Section 4.3.1), the database insertion code creates a list of minimal pairs based on a set of words already in the database. It would do this for the nehiyawewin version by comparing words and pairing words together that differed by one character. Since single sounds in Michif can have more than a single character, I could not use this code to find minimal pairs. Additionally, there are words in Michif that looked as though they differed by one sound, but actually differed by multiple sounds or were the same word but spelt differently due to the changing orthographies. For example,

this system flagged the pair of words "framaezh"and "framazh" as a minimal pair. However, they are both the same word (meaning "cheese" in Michif). This error is due to the dictionary not being completely transitioned from the TMD orthography to the DV orthography. This resulted in changing the database insertion code to take in a predetermined list instead of automatically finding minimal pairs.

Additionally, there was one place in the game logic code that needed to be updated. As described in the previous section (Section 5.2), the nehiyawewin minimal pair sub-game determined difficulty based on the number of syllables of the words in the pair. This number of syllables per level was hard-coded into the sub-game. Therefore, as there were no Michif minimal pairs with more than three syllables, the sub-game would fail to select minimal pairs for the hard level. Since there was little variation in the number of syllables in the minimal pairs, this resulted in little expected difference between levels.

5.5 Concluding Remarks

In this chapter, we described the process of repurposing SoundHunters for Southern Michif. The first step was to decide which sounds to include in each sub-game; this was followed by associating the included sounds with relevant linguistic information. This linguistic information, along with input from collaborators, allowed us to determine the difficulty of the sound combinations needed for the levels of each sub-game. Afterwards, we clipped and labeled necessary sounds, excluding those that did not have a recording available or whose recording quality was too low.

The development process highlighted important aspects to consider when creating a version of SoundHunters for another language. This includes aspects of the recordings that will be used such as where they will come from, how many speakers there are across recordings, and the quality of the recordings used. This process also highlighted that there were language-based considerations, despite nehiyawewin being a source language for Michif. Lessons learned from this will be discussed further in the

Discussion and Future Work chapter (Chapter 7).

At the end of this process, we had a working version of a Southern Michif SoundHunters. After creating this version, we could not yet say whether this version would be able to help Southern Michif language learners. Although SoundHunters is demonstrably able to teach learners the sounds of nehiyawewin, this is not sufficient to claim it will be similarly effective at teaching Southern Michif. In the following chapter, we detail the design and results of the study we conducted to measure learning and learner experience following use of Michif SoundHunters.

Chapter 6

Study

In the previous chapter, we reviewed the process of creating and implementing the Michif version of SoundHunters. In this chapter, I will report on the study I conducted using a pre/post-test design to investigate whether this new Michif version of SoundHunters promotes learning and phonological awareness among beginner Michif language learners. We also investigated whether our target user group had a positive player experience. The study protocol was approved by the University of Alberta's institutional research ethics board (REB). For the REB approval letter, see Appendix A.2.

6.1 Study Design

All participants are first brought to a consent form page. Through this page they have access to a downloadable pdf of the consent form. The participant is prompted to press a radio button to either accept and consent or not accept (withhold their consent). If they do not accept, they are redirected to a page that finishes the study. If they consent, they are redirected to the next portion of the study. The full consent form for this study can be found in Appendix A.1.

The next page the participant is brought to ensures they have the appropriate technology and browser to play the game (Figure 6.1). The participant is given an audio clip of a piano to play to test whether their browser and system can play audio.

They are also shown a one-question version of SoundHunters that walks them through the simple mechanics of playing the game; specifically, which keys to press. The one question that is asked uses a sound and character mapping that exists in English so that it is only training the game mechanics and not testing knowledge of Michif. These steps ensure that the participant has everything needed to complete the study before beginning.

After completing this check, the participant is directed to a phonemic awareness test. For this test, participants listen to recordings in Michif and write what they hear to the best of their ability. After this, the participant plays Michif SoundHunters. They play it in the order described in the game description subsection (see Section 4.2.2). This includes playing the single sound, double sound, and minimal pair sub-games in that order. The participant plays each level of each sub-game in order (easy, then medium, then hard) and only moves from one level to the next once they have won the current level. They only progress to the next sub-game once they have won the hard level of the current sub-game. With three sub-games and three levels per sub-game, this results in playing a minimum of nine sub-games if the participant wins every single level. The participant proceeds from the game-play section once they have won the hard level of the minimal pair sub-game or 30 minutes have passed, whichever is shortest.

After completing game play, the participant is brought to a post-test which is another phonemic awareness test. This test uses an identical process to the pre-test where they are asked to write three Michif recordings. The recordings in the post-test are different from those in the pretest to avoid artificially inflating learning scores due to test familiarity. See Section 6.3 for details on the tests.

The final section is a questionnaire that collects demographic and player experience information. Upon completion, participants are directed to a thank you page.

Participation in the entire study took approximately 40 minutes. See Figure 6.5 for the distribution of game play time.

Figure 6.1: A screenshot of the requirement check page that is displayed prior to starting the study.

Figure 6.2: A flow chart that shows the progression of a participant through the study.

6.1.1 Study Data Agreement

Before conducting the study, I came to an explicit agreement with Heather Souter about what Michif language data would be stored and where, how long it would be stored there, when it would be removed, and which data would need to be kept in order to follow REB protocols. This agreement prioritized having as little language data as needed on a University of Alberta server for the minimum time needed to conduct the study. The data that was required to be kept is text data from participant tests and game logs that are saved on a password-protected machine for at least 5 years, as required by the REB.

6.1.2 Target Sample Size

We did not estimate the sample size needed to attain statistical significance for this study. As our target participant group is beginner Michif language learners, the recruitment pool is small and so it would be irresponsible to use potential participant's time and our resources on a pilot study. The study design used here is the design used in the previously mentioned pre-registered (https://osf.io/xjy4v) study on nehiyawewin SoundHunters, with two changes. We omitted the use of the TOWRE test (as cited in the pre-registration) and we did not estimate an effect size a priori. We did not use the effect size from the previous study because, even though there is overlap between Michif and nehiyawewin, there is also overlap between Michif and French. Since we are recruiting participants from Canada, previous exposure to French could

affect their phonemic awareness test scores. Therefore, using the previous study's effect size could result in an underpowered study.

With all this in mind, we decided our target sample size for this study would use 25 participants as an approximate lower bound. This is an estimation based on the previous nehiyawewin SoundHunters study under the assumption that we would require more participants due to people's possible previous exposure to French in this context.

6.2 Participants

6.2.1 Participant Recruitment

Since our target population is beginner Michif language learners, this limited our recruitment pool. Participants were initially recruited through Heather Souter, the primary collaborator with this project.

Heather Souter gathered email addresses from her circle of university and community-based learners of Michif and distributed them to me. Everyone in this list was asked and gave written consent to have their email address given to me for purposes of distributing this study. As I was the one who was directly contacting people for recruitment, I included a brief description of who I am, that I am Métis, and my relation to Heather Souter. For a full copy of the recruitment email, see Appendix A.3.

6.2.2 Participant Demographics

There were a total of 18 participants and participants were offered a $15 gift card as remuneration for completing the study. Participants' ages ranged from 23 to 77 ($M = 46.65$, $SD = 13.89$). Note that disclosing age was not obligatory, and one participant did not disclose their age (PID 8). Most participants (12 total) reported their first language to be English. Of those remaining, two participants reported Cree as their first language, three participants reported their first language as Michif,

French, and Polish respectively. One participant reported two first languages, English and French. For a full breakdown of participant demographics, see Table 6.1.

Table 6.1: Full participant demographic information. Note L1 represents first language, language spoken and language use are directly quoted, and "M" represents male and "F" represents female in the Gender column.

ID	Age	Gender	Digital Game Play Frequency	L1	Languages Known	Language Usage
1	45	F	Rarely	English	*English. Learning Michif*	*English 100%*
2	26	F	Rarely	English	*English, a bit of French, learning Michif, Spanish, and German*	*English 95%, French 4%, Michif 1%*
3	50	M	Rarely	English	*English, Learning Michif*	*About or more than 95% English, Michif 5% or less*
4	23	F	Rarely	English	*English, French, learning Michif*	*95% English, 5% French*
5	28	F	Weekly	Cree	*English, I am also a learner of French, Cree, and Michif*	*English 90%, Michif 10%*
6	60	F	Rarely	Michif	*Some Michif, Saulteaux and English*	*90% English, 5% Michif, 5% Saulteaux*
7	42	F	Rarely	English	*English, some French, very little Michif*	*English 98%, French 1 %, Michif 1%*
8	NA	F	Weekly	English	*English, some Southern Michif*	*English 95%, Michif 5%*
9	54	M	Rarely	English	*English*	*English 100%*
10	77	F	Daily	English	*English*	*English 95%, Michif 5%*
11	47	M	Weekly	French	*English, French*	*English 80%, French 20%*
12	56	F	Daily	English	*English and Southern Michif*	*English 95%, Michif 5%*

13	64	F	Rarely	Cree	*Cree and Northern Michif*	*English 80%, Michif-Cree 20%*
14	49	F	Monthly	English	*English, French and learning Anishinaabemowin and Michif*	*English 75%, Anishinaabemowin 25%*
15	46	F	Weekly	English	*English, some Mandarin, some Michif*	*English 98%, Michif 2%*
16	34	F	Rarely	English	*English, Spanish, a tiny bit of Michif*	*English 90%, Spanish 10%*
17	48	F	Weekly	Polish	*Polish and English*	*English 50%, Polish 50%*
18	44	F	Rarely	Both French and English	*English, French*	*99.5% English, 0.5% Michif (greetings, occasional words)*

Participants were asked to give a self-reported rating of their proficiency in English and Michif, and this can be found in Figure 6.3 and Figure 6.4 respectively.

Figure 6.3: A Heat map of the participants' self-reported proficiency in English reading, writing, speaking, and listening. Participants selected from the option of low, medium, or high. Note that one participant (participant 12) did not report their proficiency in English speaking, and this is shown using the white square.

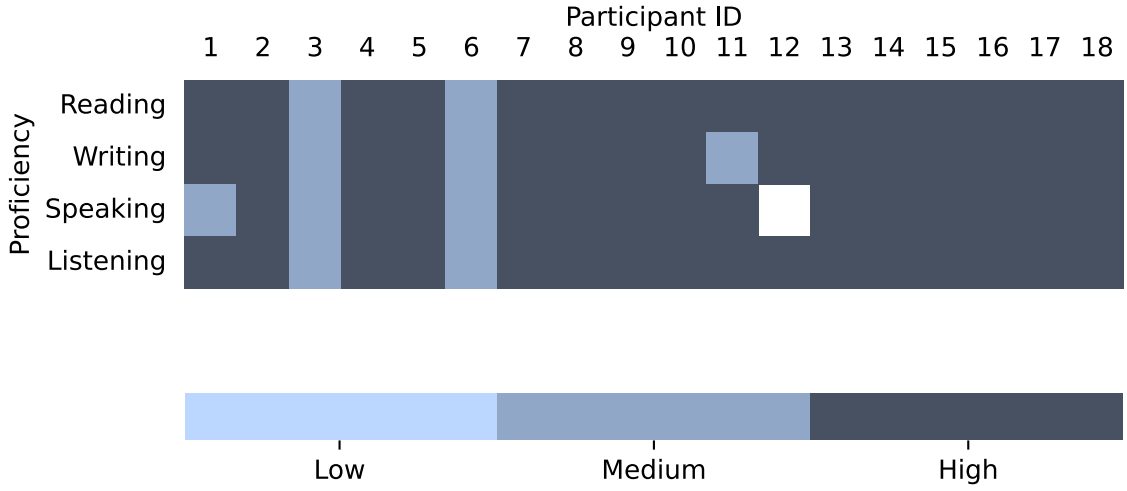
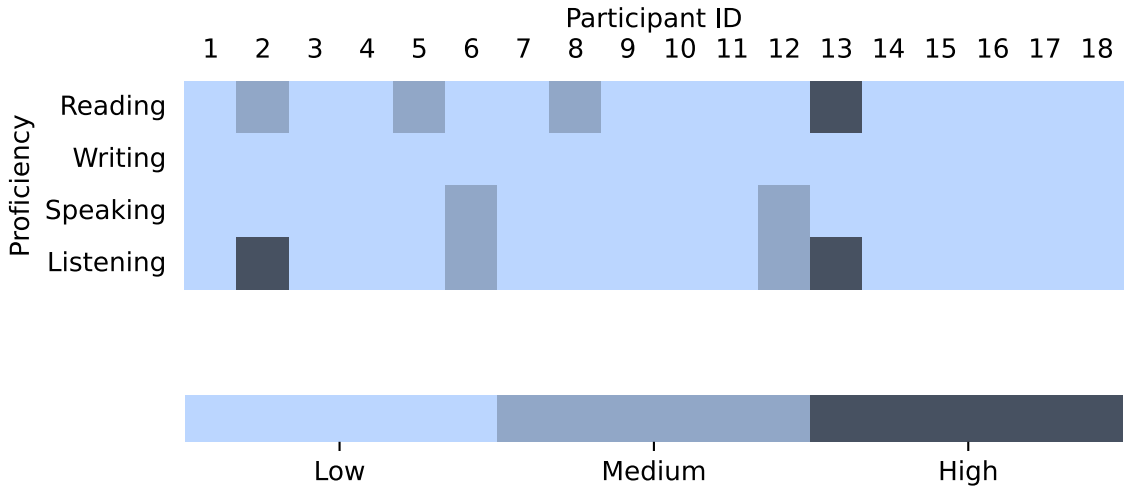


Figure 6.4: A Heat map of the participants' self-reported proficiency in Michif reading, writing, speaking, and listening. Participants selected from the option of low, medium, or high.



From this set of participants, one participant (PID 13) misunderstood the test

instructions and translated the recordings instead. Additionally, one participant (PID 9) did not complete the gameplay required (30 minutes or an entire play through) and only played approximately two levels. They completed the rest of the study (post-test and questionnaire) the following day so this is likely due to the game timing out after 30 minutes. Another participant (PID 18) stopped the study for approximately one hour after 21 minutes of gameplay. When participant 18 returned, the system did not allow her to continue to play the game because the 30 minute threshold had passed; she did complete the rest of the study.

6.3 Instruments

6.3.1 Phonemic Awareness Tests

Participants were asked to complete two sets of dictation tests on their phonemic awareness where they were asked to write recordings. Each set of tests contained three recordings of a full sentence. Recordings ranged from 2-5 seconds each. Participants were asked to listen to each recording and write down what they heard to the best of their ability. They were asked to listen to each recording up to three times, without pausing during playback. The three recordings that participants were asked to write in the pretest are different from the three recordings given in the posttest. Recordings were selected to be similar in length, overall difficulty, and sound distribution across tests.

These phonemic awareness knowledge tests are comparable to dictation tests frequently conducted in language learning environments around the world (Wong & Leeming, 2014). Dictation tests typically entail a teacher or examiner reading a sequence of words out loud as students write down what they hear. These tests are often scored on correctness; each word spelt correctly receives a point and the total number of possible points is the number of words read aloud during the test (Lee, 2006).

Similarly, the grading scheme for the phonemic awareness knowledge tests used in this study is based on correctness at a character-level. Participants receive one point for each character correctly written and zero otherwise. Character insertions are not penalized. For each dictation test, the participant can receive a maximum score of the total number of characters in the recording. Since SoundHunters is designed only to teach sound to character mappings, white spaces in participant tests are ignored. All phonemic awareness tests are graded manually by the thesis author. An example of a scored single word can be found in Table 6.2. We did not include a full Michif sentence example because of the language data agreement we made with our collaborators.

Table 6.2: Example of a graded portion of a phonemic awareness test. The bolded characters indicate the correct characters that received points.

Correct Answer	eemiyo**m**a**sch**ihoya**an**	Total possible points:	18
Participant Response	**m**u**sh****ch** ew **an**	Points received:	6

Note that the purpose of the phonemic awareness tests in this study is to evaluate an educational intervention. Therefore, the pairwise sequence alignment and scoring methods often used in natural language processing (NLP) (e.g., edit distances) are not appropriate for this setting.

The scores on these tests were used to measure learning for participants after playing Michif SoundHunters. As there are a different number of characters across the pretest and the posttest, these scores will be reported as percentages.

During recording selection, we calibrated recordings across the pretest and posttest to ensure the difficulty of the tasks was evenly distributed. Initially, Fineen Davis (one of the main collaborators on this project) provided us with recordings in Michif that were balanced in nehiyawewin and French influence, as well as access to other full sentence recordings used in the online Michif course. From these, we selected a set of 12 recordings. These recordings were distributed to lab members who did not have previous experience with Michif and afterwards these tests were graded using the

grading scheme described above. Based on these grades, we selected two recordings that were easier, two recordings that were medium difficulty, and two recordings that were more difficult. From these six recordings, each test set used one from each difficulty.

6.3.2 System logging

During gameplay, we logged a number of system or game events. The details are given in the technical description of SoundHunters (Section 4.3.2). At a macro level, for each sub-game played, we logged which level and which sub-game the participant played, their start and end time, and the result of the sub-game played (win/loss). At a micro level, game play data logging is triggered by two different events: when a participant shoots a deer and when a deer goes past the participant on the screen. The data logged during these events include: the positions of all deer on screen, the correct answer to the sound currently being played, and the deer that triggered the event. All data logged is associated with a user ID. This information allows us to determine, among other things, how far the participant progressed, their success per round, and the distribution of sounds and questions they were shown.

6.3.3 Questionnaire

The questionnaire collected data on player experience and participant demographic information. Screenshots of the questionnaire can be found in Appendix A.4.

Demographic information included the participants' history of playing digital games, their primary language, any other languages they know and their daily use, and their self-rated knowledge of English and Michif.

Player experience information was collected using rating scales and open-ended response items. The first set of Likert items (five points between strongly agree to strongly disagree) collected information about their enjoyment of the game and whether they felt as if they were able to learn from the game. Participants were

prompted to give open text feedback for what they liked about the game. They were specifically asked with the following prompts:

1. Please list three strengths of the game.
2. Please give three suggestions to improve the game.
3. Is there anything else you would like to tell us about your experience with this game?

6.4 Data Analysis

Visual inspection of histograms of the phonemic awareness test results did not allow us to determine whether the data was normally distributed. Consequently, data are described using the median (Mdn) and interquartile range (IQR).

We used a one-tailed Wilcoxon signed-rank test (Taheri & Hesamian, 2012) to analyze the phonemic awareness test scores to determine if there was any improvement between the pre-test and post-test. Because the study design is within-subject and the data were not normally distributed, we met the assumptions of the Wilcoxon signed-rank test, which is non-parametric. A post-hoc power analysis is reported and was conducted using G*Power version 3.1.9.2.

We also used the pre- and post-test results to calculate learning gain. Learning gain measures whether there has been any positive or negative change in someone's knowledge. Specifically, we used normalized learning gain, which represents how much a person learned given the amount they could learn (Hake, 1998). This learning gain is normalized by looking at the difference between percentage scores, as opposed to raw scores.

Additionally, we triangulate the types of errors in the graded phonemic awareness tests across participants and across tests and recordings. This is similar to thematic analysis, where we are looking for commonalities in the nature of the errors. From

this, we can see if there are any types of errors that are reduced or introduced after game play. The types of errors made by participants were grouped into the following categories: *French spelling*, *English or other spelling*, *characters added*, *characters replaced*, *characters removed*, and *vowel changes*. An error would be counted as *French spelling* if the participant spelt a French-origin Michif word as it would be spelt in French. Recall that in Southern Michif, an n with a tilde (i.e., ñ) indicates that it is a nasalised sound. Note that although in French, the letter "n" can sometimes indicate a nasalised sound, this was not included in the *French Spelling* count as it could not be definitively determined to be an error influenced by previous exposure to French. Similarly, an error would be counted in *English or other spelling* if the participant spelt a Michif word like its cognate in English or misheard the word as a different Michif word. The remaining error types focus on the errors made at the character-level where participants made addition, deletion, and replacement errors. Finally, an error would be counted in the *vowel changes* category if the vowel written is relatively clearly in place of another. Note that this category has overlap with other categories. For examples of each category, see Table 6.3.

Table 6.3: Descriptions and examples of the error categories for errors made by participants in the knowledge tests.

Error Category	**Description**	**Example Correct**	**Example Incorrect**
French Spelling	Using French spelling French-origin Michif word.	meusik (IPA: møsɪk)	musique
English or other spelling	Using English spelling for Michif cognate or Michif spelling for another word.	meusik (IPA: møsɪk) or oshaam (IPA: oʃɑm)	music or Michif: oschi (IPA: ostʃɪ)

Characters Added	Incorrect character added and not clearly in place of another character.	oshaam (IPA: oʃɑm)	os**c**haam
Characters Removed	Character incorrectly removed.	oshaam (IPA: oʃɑm)	osha**a**m
Characters Replaced	Character incorrectly replaced with another character.	d**i** (IPA: dɪ)	d**e**
Vowel Changes	Vowel sound incorrectly replaced with another vowel sound.	anih**iñ**	anih**i**

The player experience data from the Likert-scale items is reported using divergent stacked bar charts. The open feedback data is analyzed using thematic analysis (Braun & Clarke, 2012). Thematic analysis is a qualitative method and will be used to find overarching themes across participant feedback. To begin, I inserted all of the open response data into a spreadsheet. For my first round of review, I read all of the responses and summarized their key points in my own words. For the second round, I split all the responses from each of the three prompts into a separate spreadsheet. In each sheet, I grouped together all the main points into subthemes (e.g., "fun", "perceived learning") and counted all the instances across all responses. In my third round of review, I grouped these sub-themes from each prompt type into greater themes, which are reported in the results.

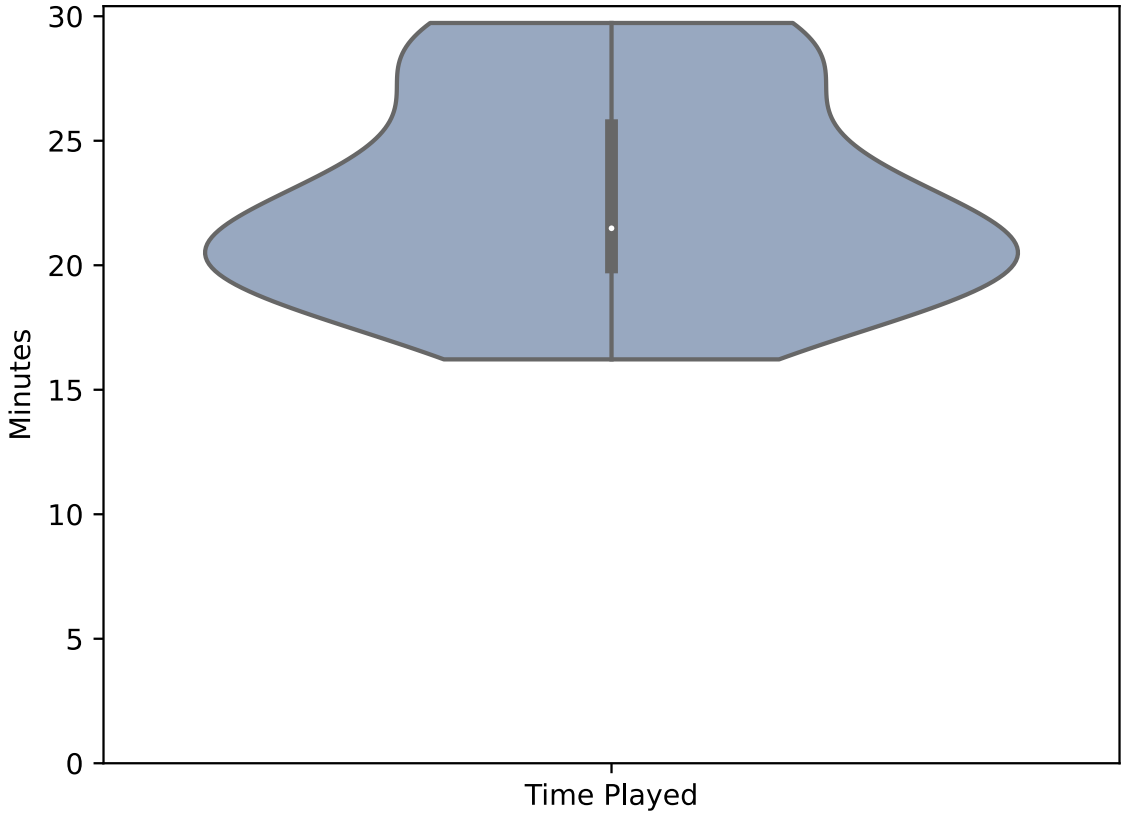
Note that we did not include the data from participants 9, 13, and 18 - who were not able to complete the study - in the analyses of the test results. However, since all three did have exposure to the game, we included their data in the analysis of player experience and feedback.

6.5 Results

6.5.1 Statistical Testing & Descriptive Statistics

Participants interacted with the game for approximately 22 minutes ($Mdn = 21$ min. 30 s, $IQR = 5$ min. 41 s). Figure 6.5 shows the full distribution of play times.

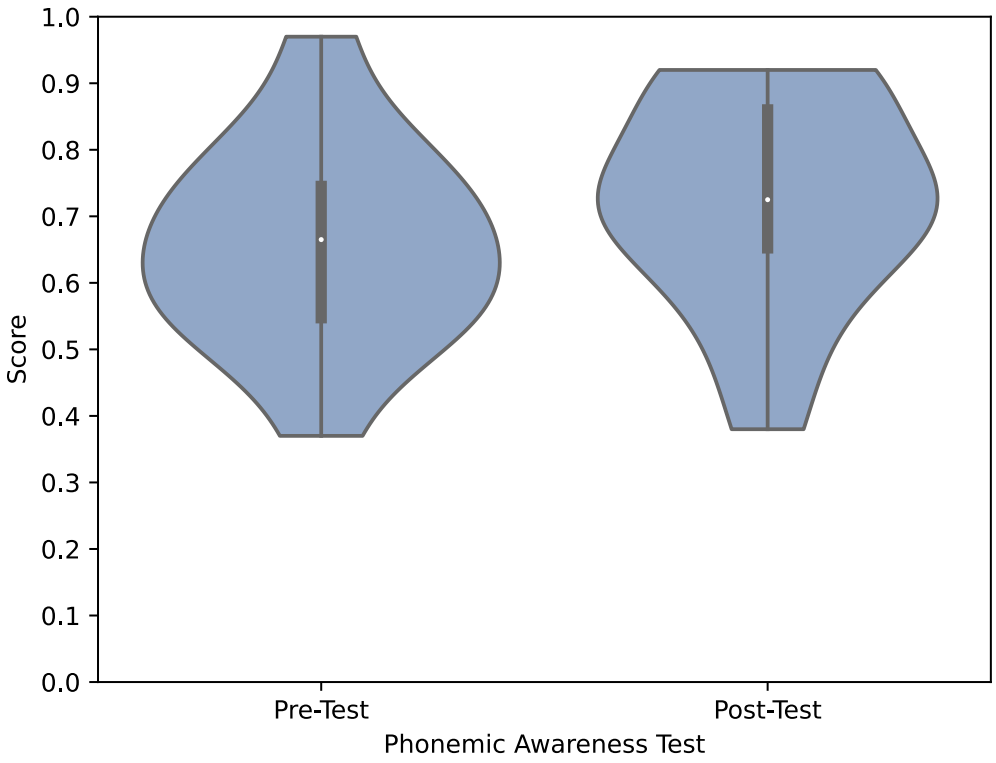
Figure 6.5: Violin plot of time spent in the game play portion by participants.



The median of the pre-test scores was 0.66 ($IQR = 0.19$) and the median of the post-test scores was 0.73 ($IQR = 0.21$). Score distributions can be seen in Figure 6.6.

We found a statistically significant change in knowledge amongst participants based on a one-tailed Wilcoxon Signed-Rank Test ($W = 21.50, Z = -1.96, p = .025$, *post-hoc power* = .87). This difference is characterized by a large effect size ($r = 0.50$). The median for participants' normalized learning gain was 0.11 ($IQR = 0.37$). For a

Figure 6.6: Violin plots of the phonemic awareness test (pre-test and post-test) scores.

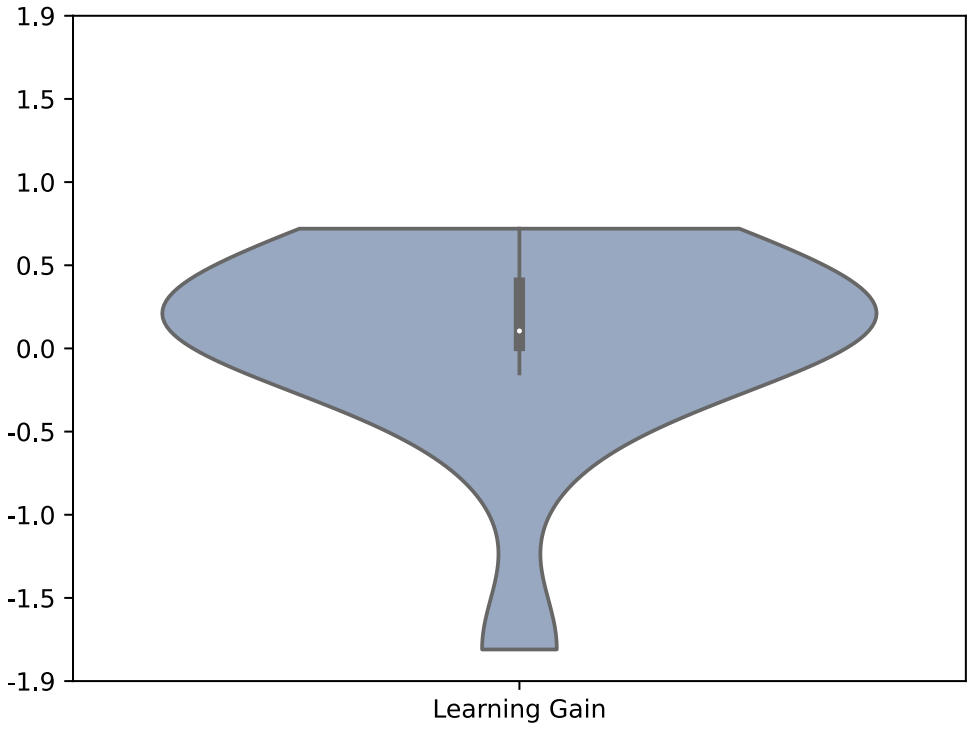


violin plot of the learning gain, see Figure 6.7.

6.5.2 Knowledge Test Error Analysis

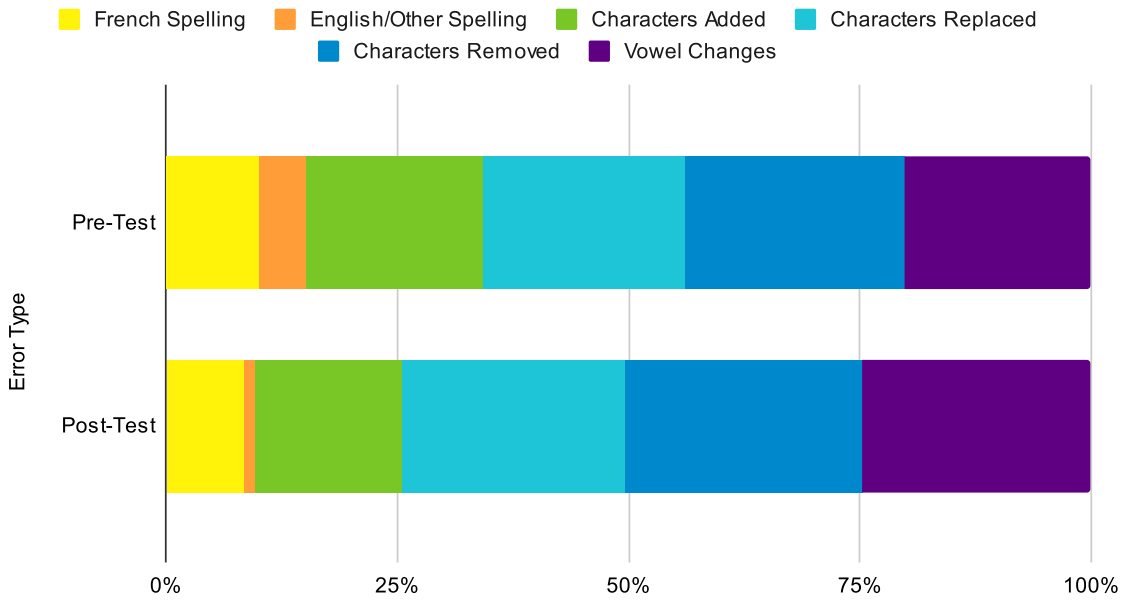
Figure 6.8 shows the distribution of the error types across phonemic awareness tests, as described in the data analysis subsection. Note that some of these error types have overlapping elements, and so this chart does not express the total number of errors made per phonemic awareness test. Additionally, the overall number of points participants could score in the pretest is higher than what could be scored in the posttest, as the recordings used for each test varied in length slightly. Therefore, the overall percentage and change in percentage of an error type across phonemic awareness tests is a more relevant indicator. Raw counts can be found in Appendix A.7.

Figure 6.7: Violin plot of the normalized learning gain scores. Recall that this is the ratio between the difference between a participant's actual scores (post-test% - pre-test%) and the maximum possible gain (100% - pre-test%).



As described, for an error to be considered a French spelling error, the word that was misspelled should have French origin and map to a real French word. In the pretest, the French origin words that were commonly misspelled were the Michif words: "di" ("de" in French), "vyaloñ" ("violon" in French), "meusik" ("musique" in French), and "boolet" ("boulette" in French). Some instances would be counted as a French spelling error despite not being the exact French spelling if it could reasonably be assumed to be influenced by French, or a variation on the French word. For example: "boulette", "bouletts", "boulette", and "boulettes" are all instances that were included towards the French spelling error count. In the posttest, the most common instances were with the Michif words "vyaañd" ("viande" in French), "wii"

Figure 6.8: Proportion of error types across the phonemic awareness tests.



("oui" in French), and "marsii" ("merci" in French). See Table 6.4 for a breakdown of the most common French spelling errors.

Table 6.4: The most common *French spelling* errors made in the Pre-Test and Post-Test, in descending order of most common to least common. This is not an exhaustive list of all *French spelling* errors made by participants.

Michif Word	**French Spelling Error**
Pre-Test	
di (IPA: dɪ)	de
vyaloñ (IPA: vjalɔ̃)	violon
meusik (IPA: møsɪk)	musique
boolet (IPA: bolɛt)	boulette
Post-Test	
vyaañd (IPA: vjɑ̃d)	viande
wii (IPA: wi)	oui
marsii (IPA: maɹsi)	merci

The most common English (or other) spelling errors (Table 6.5) made in the pretest were misspelling the Michif words "vyaloñ" ("violin" in English) and "meusik" ("music" in English). The word "vyaloñ" was misspelled once as "violin" and twice as "viola", which is the spelling of a similar word in English. There were two instances in the pretest where Michif words were written as different Michif words. Specifically, the Michif word "oschi" was written in place of the correct Michif word "oshaam". Additionally, "eeniki" was written in place of "anihiñ" and this was also considered a plausible other spelling error. Note that "eeniki" is not a correctly spelled word in Michif; the correct spelling is "aaniki" and both are two different ways to say the word "those"; context affects which one is used. Since I do not have very high proficiency in Southern Michif, I confirmed that this could be a possibility with my collaborator, Heather Souter. The most common English spelling error in the posttest was the Michif word "krii" ("Cree" in English).

Table 6.5: The most common *English or other spelling* errors made in the Pre-Test and Post-Test, in descending order of most common to least common. This is not an exhaustive list of all *English or other spelling* errors made by participants.

Michif Word	**English or Other Spelling Error**
Pre-Test	
vyaloñ (IPA: vjalɔ̃)	English: Violin, viola
oshaam (IPA: oʃɑm)	Michif: oschi (IPA: ostʃɪ)
Post-Test	
krii (IPA: kɹi)	Cree

The most common errors from the characters replaced category in the pretest were incorrectly replacing "i" with "e", "e" with "a", and "a" with "e". The "e" sound in Michif can sometimes sound similar to the English sound of "a". The sounds these characters make can be found in Table 6.6. Recall that this error classification does

not account for vowel lengths longer than a single character, and errors of swapping one vowel sound for another will be discussed further on. The next most common error of this type in the pretest is incorrectly writing the consonant "n" in place of "ñ" (n with a tilde accent). These four most common instances of character replacement errors are also the four most common instances in the posttest. However, as opposed to the pretest, incorrectly replacing "e" with an "a" was more common than incorrectly replacing "i" with an "e". It is worth noting that there were no instances in the pretest of incorrectly writing an "n" in place of "ñ" (n with a tilde accent) but there were two instances of this in the posttest.

Table 6.6: The most common *characters replaced* errors made in the Pre-Test and Post-Test and how they sound. This table is in descending order of most common to least common. This is not an exhaustive list of all *characters replaced* errors made by participants.

Correct Character	**Sounds Like**	**Character Replacement Error**	**Sounds Like**
Pre-Test			
i	b**i**t or ɪ in IPA	e	**e**lse or ɛ in IPA
e	**e**lse or ɛ in IPA	a	c**a**t or a in IPA
a	c**a**t or a in IPA	e	**e**lse or ɛ in IPA
n	**n**ight or n in IPA	ñ	Indicates nasalization
Post-Test			
e	**e**lse or ɛ in IPA	a	c**a**t or a in IPA
i	b**i**t or ɪ in IPA	e	**e**lse or ɛ in IPA
a	c**a**t or a in IPA	e	**e**lse or ɛ in IPA
n	**n**ight or n in IPA	ñ	Indicates nasalization

In the pretest, the most common character addition errors were, in order, "e", "h", and "o". Similar errors were seen in the posttest, as the most common character

addition errors were in the following order: “a”, “e”, and “h”. See Table 6.7 for sound descriptions of the most common character additions.

Table 6.7: The most common *characters added* errors made in the Pre-Test and Post-Test and how they sound. This table is in descending order of most common to least common. This is not an exhaustive list of all *characters added* errors made by participants.

Character Addition Error	**Sounds Like**
Pre-Test	
e	**e**lse or ɛ in IPA
h	**h**ello or h in in IPA
o	French: b**eau** or o in IPA
Post-Test	
a	c**a**t or a in IPA
e	**e**lse or ɛ in IPA
h	**h**ello or h in in IPA

The two most common character removal errors in both the pretest and the posttest were “i” and “a”, with reversed order of frequency (“a” was the most common in the pretest and “i” was most common in the posttest). The next two most common character removal errors in the pretest were the two vowel letters “e” and “o”, whereas the second two most common in the posttest were the two consonant letters “ñ” and “h”. See Table 6.8 for sound descriptions of the most common character removals.

Table 6.8: The most common *characters removed* errors made in the Pre-Test and Post-Test and how they sound. This table is in descending order of most common to least common. This is not an exhaustive list of all *characters removed* errors made by participants.

Character Removal Error	**Sounds Like**
Pre-Test	
i	b**i**t or ɪ in IPA
a	c**a**t or a in IPA

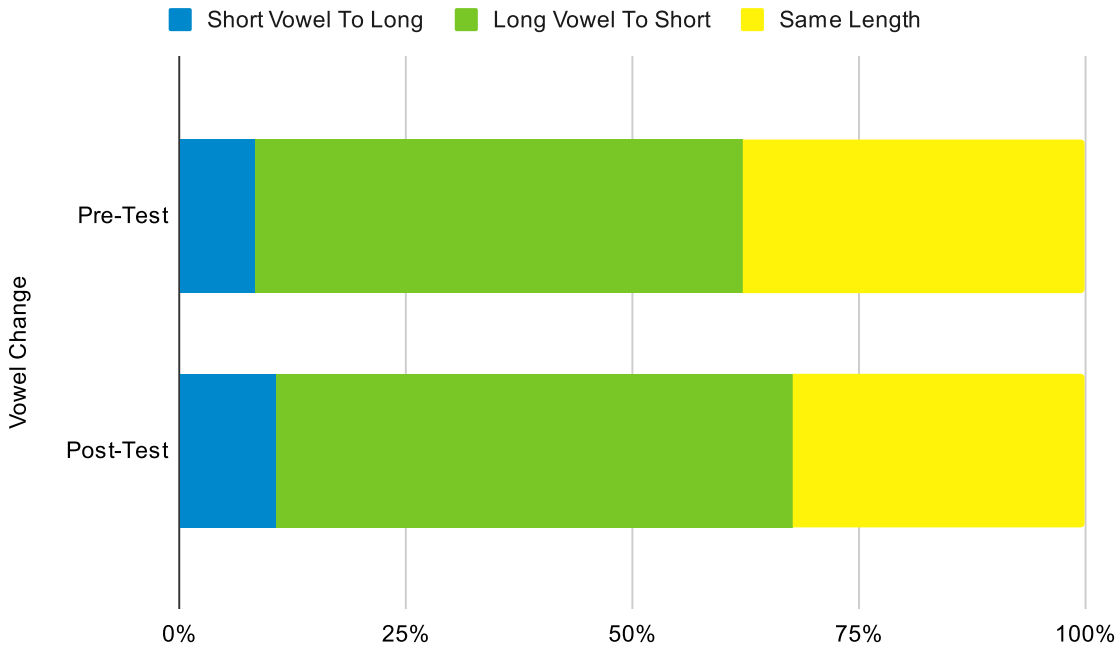
	e	**e**lse or ɛ in IPA
	o	French: b**eau** or o in IPA
Post-Test		
	a	c**a**t or a in IPA
	i	b**i**t or ɪ in IPA
	ñ	Indicates nasalization
	h	**h**ello or h in in IPA

Note that the letter "h" appears as both the most common added character and the most common removed character. Consulting with Heather Souter, who teaches introductory Southern Michif, revealed that these errors followed a pattern that was consistent with her experience with Michif learners. Heather identified that when the "h" is removed, it is often when a learner does not hear the pre-aspirated sound in the word (e.g., the word "daweeyi**h**ten" being spelt as "tawiitaeñ"). Conversely, participants often added an "h" for short vowel sounds (e.g., "omaamaawa" spelt as "o**h** wawa") or when a single "s" sound was misheard for a "sh" (pronounced as it is in English).

As shown in Figure 6.8, there was also an increase in errors made where participants used the wrong vowel in the posttest. Figure 6.9 shows the types of *vowel changes* errors with respect to the length of the vowel. Note that in this instance, the length of a vowel is referring to the perceived length of the vowel sound, and not the number of characters in the vowel sound. This graph demonstrates that after game play, there was a higher proportion of errors made where participants would mishear the length of the correct vowel.

In the pretest, the most common instance of the *vowel changes* error was mishearing the long "aa" sound as the short "a" sound. The next most common *vowel changes* error made is a tie between two pairwise vowel confusions, where both vowel sounds are short in length. Specifically, incorrectly writing the short "e" in place of "i" and

Figure 6.9: Total percentage of the types of vowel length error changes across the phonemic awareness tests. For full counts, see Appendix A.7



incorrectly writing the short "e" in place of the short "a". In the posttest, the most common instance of vowel change was mishearing the long and nasalised "aañ" sound as the short "a" sound. The next most common instance was mishearing the long "ii" sound as the short "i" sound, and the third most common instance was mishearing the long "ee" sound as the short "e" sound. Note how in the posttest, it is more common for participants to correctly identify the core vowel sound, but incorrectly identify its length.

Table 6.9: The most common *vowel changes* errors made in the Pre-Test and Post-Test and how they sound. This table is in descending order of most common to least common. This is not an exhaustive list of all *vowel changes* errors made by participants.

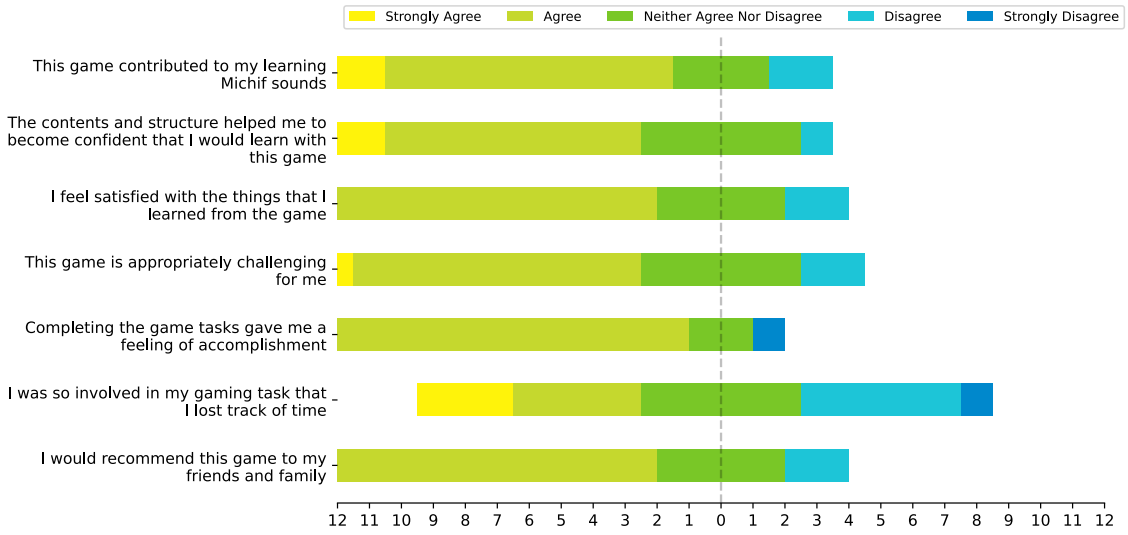
Correct Vowel	**Sounds Like**	**Vowel Change Error**	**Sounds Like**
Pre-Test			
aa	f**a**ther or ɑ in IPA	a	c**a**t or a in IPA
i	b**i**t or ɪ in IPA	e	**e**lse or ɛ in IPA
a	c**a**t or a in IPA	e	**e**lse or ɛ in IPA
Post-Test			
aañ	French: bl**an**c or ɑ̃ in IPA	a	c**a**t or a in IPA
ii	n**ee**d or i in IPA	i	b**i**t or ɪ in IPA
ee	French: **é**t**é** or e in IPA	e	**e**lse or ɛ in IPA

6.5.3 Player Experience

As described above, we solicited feedback on player experience through a questionnaire. Figure 6.10 shows the distribution of participant responses to Likert items on player experience such as: perceived learning, feelings of accomplishment, and whether the game is sufficiently challenging. This figure shows that most participants felt they learned from the game or could learn given further game play. This is consistent with the positive learning gain observed in the subsection on learner test performance (Section 6.5.1). This figure underscores that participants reported having positive experiences of interacting with the game.

In addition to the Likert feedback items on player experience, participants were asked to provide open feedback. As described in the data analysis subsection, participants were prompted to provide strengths of the game, suggestions for improvement, and if there was anything additional they wanted to share about their experience with Michif SoundHunters. Themes were identified in this open feedback. Please note re-

Figure 6.10: Participant responses to the game play and learning experience items.



sponses from across all three prompts may be included within the same theme.

6.5.3.1 Perceived Learning & Effective Teaching

A few participants reported that they felt themselves learning or that they could see how they would learn, given extended or repeated use. For example, P12 reported "I felt myself improving as I played" and P2 said that "If I were to play it more I can see my spelling improving the more that I practice!" Some participants explained that they thought the game and its methods were an effective teaching strategy for the targeted language skills. This feedback primarily focused on how the game encouraged participants to listen closely to the sounds they were hearing. Generally, participants reported that they thought SoundHunters was a good learning resource for Michif and had potential for being useful in different learning settings. For use in a formal learning environment, P3 stated they thought that "this could be a great tool for development of skill levels and can help assess a students comprehension of course materials, etc." This feedback on SoundHunters as a useful learning resource is consistent with the overall positive reports on learning as shown through participant ratings in Figure 6.10.

In addition to the positive feedback on SoundHunters as a good learning resource, participants provided suggestions for additions to enhance the learning experience. A few participants suggested that they would find it beneficial to have more opportunity during and between gameplay to hear or understand the sounds they encountered. This included providing example sentences that included the sounds they learned or pairing words (i.e., from the minimal pair game) with their meanings. P4 suggested:

> "stopping the game when you select a wrong answer, and having that wrong answer say their own respective sound so people can hear the difference between the sound they're trying to find, and the wrong sound they selected [...] Before each section, having a list of audio recordings for people to go through and hear all the sounds they'll be looking for in the section."

These suggestions indicate that participants are looking to target sound combinations, such as those found in longer words or sentences. This is indicative that learners are looking for more scaffolding and overall support in learning the individual sounds and how they are used in context.

6.5.3.2 Appropriately Challenging

On the whole, participants reported that SoundHunters was an easy game to pick up without a steep learning curve. Participants specifically described it as an "easy and usable format" (P5) and "not too complicated to play" (P6). In addition to the game structure being accessible, many participants found the game mechanics and questions asked were appropriately challenging. As P2 described, "the speed of the game was not too fast or too slow - it was challenging enough, but not too challenging." Similarly, P3 said that the "difficulty level was right for an early to mid level player." Participants reporting that overall the game was appropriately challenging is consistent with the reports on challenge level in Figure 6.10.

However, a few participants indicated that, even if the game at its core was appropriately challenging, there were aspects of the game that were not challenging enough and could be improved. P3 suggested that SoundHunters could have "game levels with increasing speed and sound challenges." P2 described what they felt was not challenging as well, reporting that "the health bar was a bit too slow to decline - I was not worried about losing at all". The suggestions to make gameplay more challenging could be indicative of why when asked if they were so involved in the game they lost track of time, more participants responded negatively than they did for any other question ($n = 6$). From these six participants, three reported that they rarely played digital games, two reported they played digital games weekly, and one reported that they played monthly. Note however that this question was also the most balanced across all possible responses (SA to SD). Therefore, whether the game mechanics provide enough challenge appears to vary widely across participants.

6.5.3.3 Game Content & Visual Design

Several participants remarked that they valued or liked the types of sounds included in the game, as well as aspects of the recordings included. P2 said that "the longer sounds were really helpful in recognizing the spelling (which I struggle with) and with time it may improve my Michif." The positive aspects of the recordings that participants reported underscore that there is a value to having the language content in the game come from actual Michif language speakers. Participants' reports indicate that some responded positively to listening to different speakers and thought that the recordings used provided authentic Michif pronunciation. Additionally, P7 described the benefit of the sounds being clipped from larger recordings, stating that "hearing Michif speakers use the sounds in a mostly casual way was helpful [because] it was challenging." Many participants also had suggestions that targeted adding or modifying the learning content. These suggestions often included suggestions for longer recordings, such as "short phrases in addition to sounds" (P18) and "more words, less

sound fragments" (P15). With respect to the design and concept of SoundHunters, a couple of participants appreciated that it is a hunting game. P12 said that "I love that [it] is a hunting game." and P2 expressed "I really loved the concept of hunting and incorporating that into the game! It really added to the game!" Conversely, one participant did not like that it was a hunting game, and suggested different potential concepts such as "maybe shooting the bottles, pin wheels, etc. would feel "safer" or more age-friendly." (P1)

6.5.3.4 Game Mechanics & Game-Based Learning

In the open feedback, a number of participants state that one of the key strengths of SoundHunters is that it is game-based learning. These responses highlighted specific aspects of game-based learning that they enjoyed, such as the game feeling competitive. P6 reported that "learners may grasp sounds better over shorter periods of time."

In their suggestions, a portion of participants targeted the game mechanics or design and visuals. Some of these suggestions were slight changes that aim to add to the existing system. P3 suggested that the game could be multiplayer or "online interactive", and P16 suggested that the visuals could be changed between levels. Other suggestions target issues the participant found and aim to improve the current system. After having difficulty hitting the right target despite knowing the answer, P13 expressed that "I would just use the mouse but then It wouldn't be a shooting game so not sure. hit the letter and it would say the sound?" P4 had a suggestion that targeted the issue of slow game play, and suggested that "once a correct answer has been selected, removing the other deer from the screen in that round (so that you can move onto the next round more quickly)".

For the participants who made notes specifically on the game-based aspect of the learning activity, the response was overall positive. Some participants liked the concept as a whole, whereas others specifically reported that the game would target

youth Michif language learners. P10 expressed "I think it is such a good idea to create games to learn languages." However, there was at least one participant who reported that they did not enjoy playing the game as a learning activity, stating that "the game was stressful for me. Shooting the right deer was difficult. I'm not sure if I learned anything. [sic] I was so focused on shooting the right deer. Maybe I did though I don't know." (P7) This participant did have a mild learning gain of 0.09 (recall that the median learning gain is 0.11). This means they learned 9% of what they could have learned, which is small and potentially unnoticeable. This underscores the difference between perceived learning and measured learning.

6.5.3.5 Technical & Game-Based Difficulties

The most commonly reported issues were ones with the recordings used in the games. Recall that the single sounds, double sounds, and minimal pair words were all cut out of larger recordings from a bank of recordings for a Southern Michif dictionary (Section 6.3). These recordings were done over time with varying equipment and speakers. Many participants noted that these clipped sounds were too short, unclear, or overall poor quality. P5 said that "sometimes the audio was so short it was difficult to figure out what the beginning or ending sound was." and P10 described that "the sounds are not standardized/normalized in audio terms, but rather sound like they are clips from multiple different people and sometimes hard to hear the difference in sounds starting with a few of the consonants."

The next most common issue described by participants was difficulty with game play. As opposed to a technical difficulty like a bug, difficulty with game play included aspects of the game mechanics that were there by design and that hindered the participants' ability to play the game. These difficulties were almost exclusively around there being too many items on screen at a time, which obstructed their shooting of the correct target. P2 described it in more detail: "mechanically, there were some points where I could not shoot the right answer because previous answers consistently

blocked the correct answer until it was almost too close to the bottom."

Finally, the third most common issue reported by participants was instances of technical difficulties that included real or perceived bugs in the game. These reports vary in the kind of issues but underscore instances where it seems some aspect of input or output was not received or transmitted correctly. P7 reported that they saw the arrow hit the deer without it disappearing, P10 said that "when there were too many deer on the screen, the arrows did not fire when the space button was pressed", and P12 said that sometimes sounds were not repeated. As of the time of writing, the bugs reported have not been investigated in the system so it is not clear which bugs were real or perceived. At least one participant reported that they struggled overall with the game, stating that "I couldn't get the hang of it and would keep missing the target. My space bar was too slow." (P13)

6.5.3.6 Overall Enjoyment

Although participants had constructive criticism to provide, the overall participant response to the game was positive. Descriptors that were repeated across participant feedback were the terms: interesting, enjoyable, and fun. In addition to general positive remarks, many participants also described enthusiasm for the project as a whole. P15 said that "It's a great start!" and P2 expressed "Great job on the game! [...] The game was also fun! I quite enjoyed it [...] I am so glad that you are doing this project! It is such a wonderful idea!"

For an extended report of participant open response feedback with additional quotations, see Appendix A.5.

6.6 Discussion

6.6.1 Study Design & Error Analysis

The results of this study highlight that learning gain is not always an appropriate measure for participants who begin with higher proficiency, and therefore may not

have much room for improvement or gain on the phonemic awareness tests. For example, the participant with the lowest learning gain (-1.81) showed high proficiency on the phonemic awareness tests. This participant scored 97% on the pretest and a 91% on the posttest. Similarly, the participant with the second lowest learning gain (-0.58) showed intermediate proficiency with a score of 82% on the pretest and a score of 72% on the posttest. Although changes in test performance across all participants were significantly positive, the scores from the proficient participants likely affected the final results. On the other hand, the final results could have also been skewed if a proficient participant scored higher on the posttest than on the pretest. For example, if the recordings in the pretest and posttest were swapped and the participant with the lowest learning gain had instead gotten 91% on the pretest and 97% on the posttest, then they would have received one of the highest learning gains (0.64). Typically, knowing the measurement error of a test or instrument would be useful in acknowledging and understanding the scope of the error originating from the method used. However, because of the size and context of this study, it is not within our ability to calculate it. Learning gain also is not sufficient for measuring a change in learning when a participant receives a perfect score on the pretest. For example, one participant received a perfect score on both the pretest and posttest. A learning gain cannot be calculated for a perfect knowledge test score, in part because there is clearly no potential for gain. The formula reflects this because a perfect pretest score results in division by zero when calculating learning gain and so must be excluded from calculating the learning gain.

These issues with learning gain may also be indicative of other flaws within the study design. As there were multiple participants who scored high on the pretest (six participants scored above 70%), some participants recruited may have had too high proficiency in Michif to be appropriate for inclusion in this study. Another possibility could be that the phonemic awareness tests selected were too easy. The phonemic awareness tests were calibrated on members of our research group, none of whom had

familiarity with Michif. As our target recruitment pool was beginner Michif language learners, this calibration might have brought the difficulty levels of the recordings chosen to a point that was unsuitable.

The case where a participant received the same score on the pretest as well as the posttest does not affect the outcome of the statistical testing. Any instance where a participant receives the same score on the pretest and posttest does not affect the result of the Wilcoxon signed-rank test. To calculate this test, the difference between the two knowledge tests for each participant are calculated. These differences are ranked, and the sign of the difference (positive or negative) is what factors into the final W statistic. Since the difference of the pretest and posttest for this participant is zero and therefore unsigned, it does not become ranked or factored into the final result.

The instance where a participant received a perfect score on both tests also highlighted a flaw with the grading scheme. This participant made two errors in the pretest, but they were both instances of an added character. For example, they spelt the word "boolet" as "booklet". Recall that in the description of the phonemic awareness test grading scheme (Section 6.3.1), added characters are not penalized. The current process only penalizes the characters that are missing, and the denominator of the score for a recording is the number of characters in the recording. Another potential weakness with the grading scheme is that it does not appropriately capture which sounds the participant did or did not hear, only the characters they wrote correctly. This is because in Michif, multiple characters may map to a single sound, as described in Section 5.1. A solution to this may include shifting to grading by sound instead of by character. This switch was considered during the grading process. However, I did not feel that my knowledge and intuition of Michif was high enough to be able to create the answer key (how each recording's transcription broke down by sound) or to grade it myself. As described previously in the collaborators chapter (Chapter 3), it was a goal to ensure that we required as few person hours from

our collaborators as possible, and so it was not reasonable to draw on their limited resources for more input from proficient Michif speakers for designing and grading the phonemic awareness tests. These issues in the knowledge test portion of the study demonstrate the value of doing research collaboratively and closely with a fluent or relatively proficient speaker who has the intuition to better design and make use of the results.

The error analysis of the phonemic awareness tests is another portion of the study that would have been improved if it had been conducted primarily by a proficient Michif speaker. The categorization and reporting of the errors made is relatively straightforward. However, due to my lack of proficiency in Michif, I was not able to provide insight on the patterns and kinds of errors made. I also was unable to review all of the errors with Heather Souter, and so some are still unexplained. For example, one error pattern found was that when participants wrote the wrong vowel and that vowel was of a different length in the posttest, the participant was likely to have written the correct core vowel. In my future work on this project with Heather Souter outside the timeline constraints of a thesis, I intend to work closely with her to gain all the benefits of having this kind of learner data.

6.6.2 Participant Response

This study resulted in valuable and diverse feedback from participants. The response to using game-based learning was overall positive, although there were some responses that indicated that the game medium was too stressful or confusing to pick up. Mixed responses to game-based learning are reasonable and expected, and they underscore the importance of a diversity of language resources in order to support all learners.

There was also one participant who recommended changing aspects of the game and how it is hosted so that it could be more competitive and multiplayer. This concept was investigated in a study on a similar game called "Tone Wars" by Head et al. (2014). They created a mobile game to help teach the tones of Chinese to

learners of Chinese as a foreign language. The authors of this study incorporated a competitive and multiplayer aspect to their game where language learners competed in the game against native Chinese speakers or against an agent. In their study, they found that participants reacted positively to the incorporation of competition and reported that it improved their motivation to focus on the game. This implies that participants from this study who enjoyed playing SoundHunters against the clock, may enjoy a version where they play against other players or an agent. However, it is important to underscore that this could harm the motivation of players who already struggled with this style of game-based learning. It could also harm the motivation of others who may have their learning negatively impacted by having their performance directly compared to that of others. If this were implemented, it would benefit from either a detailed understanding of the target user group or the ability to opt out of competing directly against another person or agent.

Additionally, participants' feedback on technical difficulties offers valuable insight into current and anticipated challenges on the backend and indicates more work needs to be done on the technical aspects of SoundHunters before a full release. When giving suggestions on content, participants asked for more complex content such as longer recordings with words and phrases. As discussed in Section 4.3.1, there was previously a fourth subgame in the nehiyawewin SoundHunters that asked players to distinguish between words, similar to the single and double sound subgames. However, in reviewing the logged game play data after the first study was conducted, we found that this subgame had the fewest errors made by players. This is likely because all of the words and their distractors on screen have at least two different characters/sounds, and many had few similarities. This meant that ruling out the distractors for a question in the word subgame was too easy, and did not require players to use much knowledge of nehiyawewin sounds to play. It thus proved to not be a very effective learning activity. Because of this previous research, we do not think that SoundHunters is the appropriate medium for building phonological awareness beyond

identifying and distinguishing between small units of sound in a language. However, this insight does help better define the boundary between where SoundHunters could be useful in a learner's journey and where they might need to transition to a different resource.

Overall, the positive feedback reported by participants and the statistically significant positive learning gains are encouraging indicators that SoundHunters is an effective language-learning resource and could likely see success when implemented with other languages.

6.7 Concluding Remarks

In this chapter, we described and reviewed the study we conducted to determine measured and perceived learning following use of Michif SoundHunters, as well as overall player experience. The administration of phonemic awareness tests for Michif before and after game play, indicated that learning occurred ($W = 21.50, Z = -1.96, p = 0.025, r = 0.50$).

The errors made by participants on the phonemic awareness tests were analyzed and categorized. In the pretest, participants' most common mistake was adding a character (as opposed to removing it or replacing it), whereas in the posttest the most common mistake was excluding a character. Review of the error types with our primary project collaborator and Michif teacher, Heather Souther, revealed a common error that looked contradictory (i.e., "h" being one of the characters mistakenly added as well as removed) was not contradictory because of where the character was being removed and where it was being added. This confirmed Heather's experience with common learner mistakes where they exclude the h when they do not hear pre-aspirated sounds.

We gathered information on participant experiences through prompted open-responses as well as five-point Likert-scale (SA to SD) items related to participant experience. This participant feedback demonstrated that participants felt as though they learned

with SoundHunters, which aligns with measures of their learning. Although participant feedback skewed mostly positive, we also received many useful suggestions or reported issues that will be considered before releasing a full version of Michif SoundHunters and a general version for other language communities to adapt.

Overall, the positive feedback reported by participants and the statistically significant change in participant performance on a phonological awareness task are encouraging indicators that SoundHunters is an effective language learning resource and could likely see success when implemented with other languages. Thorough recommendations, cautions, and reflections on the technical details of repurposing SoundHunters for another language as well as reflections on the entire collaborative process will be detailed in the following discussion and future work chapter.

Chapter 7

Discussion & Future Work

In the previous chapter, we conducted a study to measure learning gain and player experience following game play of Southern Michif SoundHunters. Through this study, we found that players did show significant positive learning gain and that they reported having an overall enjoyable experience interacting with the system. Before that, we described the development of the first version of Southern Michif SoundHunters (Chapter 5). The development process and subsequent study revealed aspects of SoundHunters and the development process of repurposing it for another language that require further inspection.

In this chapter, we describe the further work needed before SoundHunters is available to be repurposed by other language communities. This includes discussing technical difficulty feedback we received from study participants, as well as issues or gaps faced during the development process. We also report on the current state of Southern Michif SoundHunters, the lessons learned from developing it, and plans we have made with our collaborators to release it. Finally, we discuss recommendations and tips for those looking to potentially create an instance of SoundHunters for a new language, including discussion on collaboration with Indigenous language communities.

7.1 Releasing SoundHunters

When SoundHunters was first developed, it was created as a game in a larger language-learning system called CreeTutor. This means that, although it is currently technically publicly available and open-source, it is also embedded in a more extensive web application and requires further work to extract it so that it works as a stand-alone tool. This section describes the remaining work needed to do this and it describes the intended accompanying documentation.

7.1.1 Technical Work Remaining

As described, our goal is to extract SoundHunters from the more extensive system it is currently embedded in and release it in a way that will make it easy for others to create their own instances. An aspect that currently needs to be updated is the code for inserting the language data and any linguistic knowledge used for determining difficulty within sub-games into the database. The primary area that needs revising is the insertion code for the minimal pair recordings. Recall that the nehiyawewin SoundHunters had a fourth sub-game that asked players to distinguish between words, and so this version of the game had a bank of word recordings. The minimal pairs used were a subset of this word bank. Because of this, the initial insertion code would create the list of minimal pairs based on the words in the word table. The insertion code from the nehiyawewin version would systematically create a list of minimal pairs based on the words already in the database. This is problematic for other versions because the word sub-game was removed from SoundHunters, as it was not found to be an effective sound learning task. Therefore the insertion code needs to be updated to receive a predetermined list of minimal pairs, independent from recordings already within the database.

The creation of the Southern Michif SoundHunters revealed another reason why it is beneficial to create the list of minimal pairs before the data insertion step. The code

that would find minimal pairs based on words in the bank of word recordings would compare all words against each other and flag words that differed by only one character. This worked because nehiyawewin mostly has single sound-to-character mappings in its orthography. However, as discussed in Chapter 5, Southern Michif often has one-to-many sound-to-character mappings. In order to address this, I needed to create a single character to single sound mapping and write additional code to update the language text data with these mappings. For example, the digraph "sh" has two characters and maps to a single sound (as in **sh**are or ʃ in IPA). So all instances of "sh" were replaced by a question mark (i.e., ?) that would map to the ʃ sound. For example, the Michif word "shakaha" would be updated as "?akaha". From this point, the same code to find minimal pairs was used. The SoundHunters repository will include this code template for finding minimal pairs given updated sound-to-character mappings. This should make the creation process easier for anyone else interested in creating an instance of SoundHunters for another language and not require them to insert word recordings that will not be used.

The Southern Michif SoundHunters creation process highlighted a portion of the game mechanics that is inflexible or not useful for other languages. As described in the nehiyawewin minimal pair sub-game description, the difficulty between levels is determined by the length of the words in the pair, specifically the number of syllables. In this code, the number of syllables as a selection criteria for each level is hard coded. Specifically, it selects words with one to two syllables for the easy level, three to four for the medium level, and five to six for the hard level. This worked for the nehiyawewin version because the bank of minimal pairs we have varied enough in length. However this did not work for the Michif SoundHunters, where words were no longer than three syllables and were mostly one or two syllables long. The solution in the Michif case was to keep it hard coded, but to have the easy level map to single-syllable words, the medium level map to two-syllable words, and the hard level map to two- and three-syllable words, as there were not enough three-syllable words

for avoiding excessive repetition in the hard level. This is not an elegant solution, and it is cumbersome for anyone creating their own SoundHunters to need to adjust the code at this level. A solution to this would be to pre-determine the difficulty of each minimal pair and have labeled difficulties in the database. This would be similar to how all pairs of single and double sounds have prelabeled distractor types in the database: this information is what is used during distractor selection for each level. In repurposing SoundHunters, this would allow for more flexibility and complexity in determining the difficulty of a minimal pair.

As described in Section 6.5.3, some participants reported on what could potentially be bugs within the code. The potential bugs reported include the arrows not always firing when the spacebar is pressed, the audio not always repeating, and the deer occasionally appearing to not be hit by an arrow that passes through it. Before SoundHunters is released on its own, these bugs will be reviewed and addressed. In the same section, participants also described issues with the game that are not technically bugs, but which inhibit proper game play. The most common complaint was that there were instances where a distractor deer on screen would be blocking the participant's shooter from being able to hit the correct answer until it was too late, and they would lose the point despite knowing the correct answer. This means that how many deer are allowed on screen and where they are positioned needs to be revisited, to avoid this type of difficulty.

7.1.2 Setting Up The Repository & Documentation

Currently, an older version of the SoundHunters code (still embedded in a more extensive project) is available on GitHub[1]. The current version and the future updated version will be made available for free to anyone looking to repurpose SoundHunters for their language. To support repurposing, the game SoundHunters will be extracted and put into its own repository; this version will function on its own. Because of

[1]https://github.com/EdTeKLA/Cree-Tutor

SoundHunters' integration in a larger website, it currently has a user account / login system that prevents anyone from using the site without having an account and being logged in. Since it is a simple game, this functionality might not be very useful in all cases. However, Indigenous language communities may be inclined to keep access to their language resources and data restricted. Therefore, this functionality will be kept and we will include instructions to remove or deactivate the login restriction.

For SoundHunters to be a suitable game for repurposing, it should require minimal technical or language work. To keep these requirements low, the SoundHunters repository will include comprehensive documentation. This documentation will include minimal linguistic or technical jargon: it will have only as much as is strictly necessary. This will help ensure a lower barrier to entry for being able to create a new version. This documentation will also include clear and detailed step-by-step instructions for how to create a new version. As SoundHunters has only been made for nehiyawewin and Southern Michif, two languages with very similar orthographies, these instructions will likely be insufficient for languages that have unanticipated differences that could affect development. In order to deal with these instances, the instructions will point to lower-level details about the code so that the information needed to find or create a solution is available. The SoundHunters public repository will ideally be populated with example data to illustrate where data files should be placed and how they should be named. This example data will be using copyright-free language data, likely in English or French.

7.2 Michif SoundHunters & Next Steps With Collaborators

The Southern Michif SoundHunters is relatively complete. However, the development process and the study feedback revealed that there are a number of aspects that should be updated or inspected for quality. This section will detail these aspects as well as the lessons learned in repurposing SoundHunters. I will also discuss how these

considerations should be factored into making future instances of SoundHunters for other languages.

7.2.1 Lessons Learned

The technical changes that need to be addressed were described in Section 7.1.1. This section will focus on the lessons for language-related aspects of SoundHunters, as well as lessons from conducting a study of participant learning and participant game-play experience. These lessons provide insight into potential studies that could be done with future versions.

7.2.1.1 Language & Recording Related

For both the nehiyawewin and Southern Michif SoundHunters, we used previously recorded sounds. This has the benefit of minimizing the burden of work on speakers of those languages who, as with many Indigenous communities in Canada, are few and far between (if there are any at all). Recall that for the nehiyawewin SoundHunters, we were able to pull recordings from a bank of sounds that was recorded for a nehiyawewin course. Thus, the smaller sound recordings were recorded with the intention of using these sounds in a learning context, and so are clearly and slowly pronounced. However, for the Southern Michif SoundHunters, the previously recorded bank of sounds we had access to were recorded headwords and example sentences from a Southern Michif talking dictionary project. These recordings were then clipped in order to have recordings of smaller sounds to use in the game. Although the words and sentences in these recordings are spoken relatively clearly and slowly, the focus was on pronouncing the words correctly and not on each individual sound. This resulted in some of the clipped recordings of sounds being too fast and inconsistent in speed across recordings. This was noted as a potential issue during development, and was also brought up by many participants in the open feedback portion of the study, as discussed in Section 6.5.3. Therefore, we conclude that it is

better to collect high quality new recordings, where possible, since the goal is to teach sounds at a phonemic level. Discussion and recommendations on how to mitigate the amount of work needed to make new recordings and document them will be given in a later section (Section 7.3).

Another aspect of SoundHunters that was brought under the microscope was how difficulty was determined in the sub-games, primarily the minimal pair sub-game. In the nehiyawewin minimal pair sub-game, one of the primary differences between levels that dictates difficulty (other than speed) is the number of syllables for the answer in a pair. We were able to exploit this because the set of minimal pairs we had access to for nehiyawewin varied in length (one to six syllables). Although we had a relatively large set of minimal pairs to choose from for the Southern Michif minimal pair sub-game, they did not vary greatly in length. Most were either one or two syllables, with a handful having three syllables. Since there is less variability in the length, there might be less challenge between difficulty levels in the Michif version than the nehiyawewin version. Therefore, it would be beneficial to review what determines which minimal pairs will appear in each difficulty level. Suggestions for how to determine the difficulty of a minimal pair can be found in Section 7.3.

7.2.1.2 Study Transcription Knowledge Test

As examined in the study discussion (Section 6.6), there were aspects of the grading scheme that were insufficient for Michif. This is in part due to this grading scheme being initially designed for nehiyawewin standard Roman orthography (SRO), as this is what was used for the initial SoundHunters study (for more information on nehiyawewin SoundHunters, see Chapter 4). In short, the grading scheme would award a single point for each correctly written character within a test question. The final score would be a ratio of the sum of these points and the maximum number of points that could be awarded (i.e., the number of characters in the correct transcription). This grading scheme was more appropriate for nehiyawewin because single

sounds mostly map to single characters. However, there are many instances where single sounds map to multiple characters in Michif . For example, Michif signifies vowel length using single and double characters (e.g. “a” is short and “aa” is long), whereas nehiyawewin signifies vowel length using a diacritic (e.g., “a” is short and “â” is long). Additionally, there are some single consonant sounds that are represented by multiple characters in Michif (e.g., “sh” and “ch”, pronounced like “**sh**oot” and “**ch**urn” respectively). Therefore, this grading scheme likely did not entirely capture what Michif sounds the participants did or did not successfully transcribe. We considered an alternative grading scheme of grading by sound rather than by character. However, as I do not have high proficiency in Southern Michif, I did not believe I had the capacity to grade based on this criterion. This challenge underscores the importance and benefit of conducting Indigenous language work closely with a fluent or proficient speaker. In collaborating closely with a proficient speaker, a more language-appropriate grading scheme could be created. Furthermore, the grading could be more confidently done by a proficient speaker.

7.2.1.3 Participant Feedback

In the study, we received feedback from participants that they would like to see longer sound combinations included in SoundHunters, such as words. As discussed in the nehiyawewin SoundHunters chapter (Chapter 4), we previously had a fourth sub-game that asked players to identify entire words. In the initial nehiyawewin SoundHunters study, we found that this sub-game was not effective at teaching sounds due to its low difficulty level, as there were rarely enough similarities across words in a question to make distinguishing between them challenging. This prior finding suggests the need for other types of activities that could better support this more complex learner need. Typically, phonological awareness tasks that incorporate larger sound combinations, such as words, involve more complex activities such as rhyming tasks (e.g., identifying rhyming words) (Gillon, 2005), or initial, final, or other phoneme

isolation tasks (e.g., what is the first sound in the word "fun"?) (de Graaff et al., 2011). Another phonological awareness task is a method called shadowing. Shadowing is a learning activity that promotes listening skills where language learners read or hear continuous input in their target language and repeat the oral language accurately while trying to match the pace of the recording; the goal is to achieve simultaneous production (Kadota, 2019). These tasks are more complex than the simple identifying and distinguishing sound tasks in SoundHunters and so are beyond the scope of the game.

7.2.2 Planned Future Work

After the study had come to a close, I met with Heather Souter to discuss the results of the study and the state of the current version of Southern Michif SoundHunters. This discussion included a brief overview of my recommendations for changes and considerations for the final version. These recommendations are largely captured in the previous section (Section 7.2.1). I also described the technical changes and review that SoundHunters would be undergoing (as described in Section 7.1) to make it easier to adapt to other languages, and I explained that this would specifically benefit the Southern Michif SoundHunters.

As with many academic projects, this thesis was constrained by time and did not allow for the completion of Southern Michif SoundHunters beyond a working prototype. This meant it was a necessary part of the collaborative process to ensure there was a plan for finishing and releasing the game. Because I have another ongoing project with Heather outside of my thesis work, this wrap-up procedure was not more formal than this review meeting. We determined that this was appropriate because our working relationship would not be ending upon completion of this thesis. Had I partnered with an Indigenous language community that I had no previous or ongoing experience of working with, I would have set out a more formal plan and timeline for project completion.

7.3 Repurposing SoundHunters For Other Indigenous Languages

The previous sections established the updates and review that is needed for SoundHunters as a technical project generally. These sections also described the lessons learned from creating and studying the version of SoundHunters that was repurposed for Southern Michif. With this information as a foundation, this section will review recommendations for repurposing SoundHunters for other languages, including the development process, investigating whether it promotes learning for the new language, and collaborating with Indigenous language communities.

7.3.1 Technical Considerations

7.3.1.1 Font Encoding

A major consideration for learning the sound-to-character mappings in a language is the orthography. However, some Indigenous languages have orthographies that may not be supported with a font encoding. In this case, the game mechanics may need to be modified: images of text could be included instead of using regular text when orthography support is not available. Although this image over text-based approach is possible, it would require someone with front and back end web experience to change many aspects of the code. This includes changing the database to receive image file paths, and parts of the front-end code that handles displaying game elements. Therefore, it is not recommended.

7.3.1.2 Language Recordings

As discussed in Section 7.2.1, the sounds used in the Southern Michif SoundHunters were clipped from larger recordings of spoken Southern Michif words or sentences. This was done to avoid taking time from Southern Michif speakers. However, it resulted in a set of sounds that were not normalized and also took many hours because I had to sort through recordings of sufficiently high quality from which the target

sounds could be clipped. My recommendation is to, where possible, record at least the single and double sounds that will be used in a new instance of SoundHunters, if they have not been recorded already.

In order to find a balance between having high quality recordings and minimizing the amount of time taken from speakers, I recommend finding ways to work with text language data first. This includes determining the single and double sounds that exist in the language, as well as desired minimal pairs. If a language has consistent and unique sound-to-character mappings, the amount of time needed to find minimal pairs can be reduced using a text-based list of words in the language and the minimal pair code included in the existing insertion code. Once these are determined, agreed upon in advance, and presented in an ordered list, a speaker can read the given list in that order. From this point, the recorded audio and ordered text can be passed to existing software packages[2] in order to partially or fully automate recording annotation. This could reduce the amount of time needed to record and label the recordings to a few hours, depending on the sound inventory of a language.

It is important to note that participants still demonstrated significant learning following Southern Michif SoundHunters game play despite not having a set of consistent or high-quality recordings. Therefore, if a language community is interested in repurposing SoundHunters for their language but only has access to older or lower quality recordings, these recordings could be sufficient.

7.3.2 Language-Related Game Mechanic Considerations

Based on the significant positive learning gain seen in both the nehiyawewin SoundHunters study and the Southern Michif SoundHunters study, new SoundHunters instances would likely benefit from sticking to the current game play outline of single sounds, double sounds, and minimal pairs with difficulties set to easy, medium, and hard levels. However, these two studies investigated linguistically similar languages,

[2]Such as the audio annotation tool ELAN - https://archive.mpi.nl/tla/elan

and so it may be that this combination of sub-games and levels are not appropriate for another language. I recommend that future versions consider whether it is valuable and feasible to use the current system design, or whether it would be more useful to alter it. Large deviations from the current version would require changing the code, but some changes may be made at the level of the included linguistic knowledge or language data.

For example, the granularity of single or double sounds might be too complex or too simple for a learner at a given difficulty level. A concrete example based on the lessons learned from developing the Southern Michif SoundHunters (Section 7.2.1) involves determining which difficulty level a minimal pair should be in. For example, the position of the differing sounds in each word could be considered. Differing sounds that occur at the beginning of the word (e.g., "fun" and "sun") may be more easy to distinguish than different sounds in the middle of a word (e.g., "desk" versus "disk"). The game could also utilize how difficulty is determined in the single and double sound sub-games by using audiovisual similarities between paired sounds. For example, in the nehiyawewin single sound sub-game, the character "a" (as in about or ə in IPA) would only be paired with the character "â" (as in f**a**ther or ɐ in IPA) in the hard level, since they are both audibly and visually similar to each other. This could translate to the minimal pair sub-game with the minimal pair "metawey**a**n" and "metawey**â**n", where this pair is shown at the hard level for the same reason. These changes should be decided on a case by case basis. This should only affect the linguistic knowledge given to the insertion code during development, and not require any changes to the code itself.

7.3.3 Investigating the Efficacy of Future Versions

The study design described in this thesis is likely to be sufficiently language agnostic. However, as discussed in the lessons learned from the development of the Southern Michif SoundHunters (Section 7.2.1), the grading scheme used to grade participant

transcription knowledge tests was likely insufficient for Southern Michif. The grading system used was nearly identical to the one used in the nehiyawewin SoundHunters study. However, nehiyawewin standard Roman orthography has mappings of single characters to sounds. Therefore, evaluating which sounds participants correctly or incorrectly identified based on individual characters was sufficient for nehiyawewin. This is not the case for the mapping of multiple characters to sounds in Southern Michif[3], and so there are probably errors that were not appropriately captured by this grading scheme. Therefore, unless the language has an orthography that reliably has mappings of single characters to single sounds, the grading scheme for the transcription knowledge tests will need to be individualized for each language. This individualization should be created with a proficient language speaker. This process would also strongly benefit from having input from someone who has experience teaching the language. Such a teacher will be valuable in the error analysis process. For example, in the error analysis section of the study in this thesis (Section 6.5.2), the letter "h" was amongst the most common characters both wrongly added and wrongly removed. Heather Souter, who is both a proficient Southern Michif language speaker and a teacher of introductory Southern Michif, was able to identify the pattern of where "h" was being removed and added without seeing the participant tests. She was able to do this because of her understanding of Southern Michif as well as her experience with common learner errors.

Another important consideration for future versions of SoundHunters that may differ from this thesis is the identity of the researcher(s) involved. Recalling the "insider"/"outsider" discussion on researcher reflexivity in Chapter 3, there are ways in which this may have affected the outcomes of the study. For example, as shown in the study recruitment email in Appendix A.3, I self-identified as Cree-Métis and named my home community. I did this, in part, because it is a cultural expectation in introducing yourself to say who you are and where you are from. As participants

[3]See Section 5.1 for full list of sound-to-character mapping.

may have viewed me as an "insider", this could have positively affected both participant recruitment numbers and participant perceptions of the project as a whole. Given the identity of a researcher(s) involved, the creation and subsequent study of SoundHunters repurposed for another language could be anticipated to have different outcomes.

7.3.4 Collaborating With Indigenous Language Communities

In Chapter 3, I described the collaboration process that was established with our partners, Heather Souter and Fineen Davis. In this process, we aimed to meet as frequently as necessary and to ensure that any major or sensitive decisions were made together and documented in writing that everyone could access. However, there were aspects of this process that were heavily informed by my previous connection with both Heather and Fineen. While interning for the National Research Council Canada's Indigenous Languages Technology Team, Fineen and I had a similar collaborative process for creating another Southern Michif language tool with Heather. Therefore, not only was this process informed by previously established trust, but it had also been tried and tested on another project. If I had done this project with an Indigenous language community and a partner that I was not familiar with, I would suggest a different protocol than the one followed in this project.

A different protocol could include more frequent meetings with a greater focus on mutual understanding and what was being done with the collaborators' data and what their needs and expectations were. However, even with the familiarity and previous experience I had with Heather, I still ensured that during the meetings we had together, we continued to be on the same page and, where more sensitive decisions needed to be made, I had those decisions confirmed in writing. For example, in running the study I had to move the language data off my local machine and onto a University of Alberta server. Since this went beyond our initial agreements for only

storing and using the Michif language data on my local machine during development, I ensured that we had a written agreement along with a full understanding of where the language data would be stored for the study, for how long, who would have access to the server, and what data would need to be kept after the study ended.

As with the collaborative process, I also felt comfortable with asking for language data in contexts where I would have felt somewhat uncomfortable if we did not have an established relationship. Recall that I was given access to language data from a dictionary project to create the recordings used in Southern Michif SoundHunters. In this instance, I felt comfortable asking for permission to download the Michif recordings directly from the dictionary project and skip additional data requests that would have wasted Heather's time. This was only possible because of our previous connection. Even with our existing relationship, it was still necessary to ask. I highlight this instance because my experiences have shown me that academics and software developers sometimes think that making data available is granting anyone permission to use that data. Since there is a history of theft and miscrediting of Indigenous language data and research, those involved in the work should prioritize clear and ongoing agreements for any access and use of Indigenous language data, and not make assumptions based on work in related fields.

In conclusion, the collaboration processes between academic and Indigenous language community partners should be decided on a case by case basis by the individuals involved. These protocols will be most reliable if they are ongoing discussions that are welcoming of changes.

7.4 Concluding Remarks

In conclusion, SoundHunters has been shown to be effective at teaching two languages and is designed to be easily repurposed. However, the repurposing process for Southern Michif required making some system changes. In addition to the changes that were needed to make the game work, others will need to be made to enable

the game's release as a stand-alone system. The lessons learned throughout this process will hopefully make additional SoundHunters instances easier to create. These lessons include the importance of the collaboration process, which must be understood as a vital part of every aspect of the design, study, and release of each version of SoundHunters.

Chapter 8

Conclusion

Many Indigenous languages in Canada and around the world are endangered with the risk of becoming extinct. In order to help reverse this process, the United Nations declared 2022 the beginning of the International Decade of Indigenous Languages. There are many ongoing efforts to revitalize Indigenous languages, and many challenges to revitalizing Indigenous languages. A major source of these challenges is a lack of access to resources such as funding, language data, and technology. Moreover, many Indigenous communities are left with few fluent speakers due to government policies and practices, such as residential schools.

To help address this shortage in Indigenous language-learning resources, we created the arcade-style language learning game SoundHunters. This is a simple game that teaches learners to identify and distinguish between sounds in nehiyawewin (Plains Cree), an Indigenous language in Canada. SoundHunters is a simple game and its design is not strictly tied to nehiyawewin. It requires little language data, linguistic knowledge, and human resources. It was also shown to support learning for nehiyawewin (Lothian et al., 2020). These aspects make it a good candidate for being repurposed to support other Indigenous languages. It was thought that repurposing SoundHunters would only require changing the language data in the backend. However, this was not the case when we tried to repurpose the game to support Southern Michif.

Southern Michif is an endangered language in Canada and one of the languages of the Métis people. It is a mixed language whose sound inventory pulls from nehiyawewin and French. In order to create a Southern Michif SoundHunters, we collaborated with Heather Souter and Fineen Davis from Prairies to Woodlands Indigenous Language Revitalization Circle Inc. Heather, Fineen, and I established a collaborative process for the development of Southern Michif SoundHunters. This process ensured we were on the same page throughout the project and that all necessary changes will be implemented before its release. This collaborative process was informed by my previous connection with both Heather and Fineen working on other Southern Michif language-technology projects.

For the development of the Southern Michif version of SoundHunters, we used recordings from an existing Southern Michif dictionary project. This required us to cut larger recordings into smaller sound sections for use in the game. This resulted in the length, quality, and clarity of the target sound being variable across recordings. After we had a complete version of Southern Michif SoundHunters, we conducted a study with 18 learners of Southern Michif to investigate whether SoundHunters would help them learn the sounds of this language. This study used a pre/post-test design where participants completed Michif transcription knowledge tests before and after game play. This was followed by a questionnaire that elicited participant feedback and information about their experience. A one-tailed Wilcoxon Signed-Rank test showed that participants learned by playing Southern Michif SoundHunters ($W = 21.50, Z = -1.96, p = 0.025, r = 0.50$). Furthermore, their feedback indicated that they enjoyed playing SoundHunters and that their experience was positive overall.

The study revealed that there are further changes and decisions that need to be made to the current version of Southern Michif SoundHunters so it has not been released at the time of writing. Additionally, further work needs to be done on SoundHunters before it is fully released as a template game for other languages. In addition to the instructions and specifications for creating a new instance of SoundHunters,

the documentation will include tips and recommendations for languages that differ from nehiyawewin and Southern Michif in their orthography or sounds.

This thesis established that the SoundHunters language-learning game can be used to learn the sounds of two Indigenous languages: nehiyawewin and Southern Michif. This is a positive indicator of the potential for repurposing SoundHunters for other Indigenous languages. However, additional examples using increasingly diverse languages are needed to understand the boundaries of where SoundHunters might be helpful. A key part of the success of this work was due to the collaboration with the community of the language that was being studied. This is an integral part of the creation of any Indigenous language technology that has rarely been documented. A contribution of this thesis is describing the collaborative process followed as well as providing recommendations for future collaborations.

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Appendix A: Study Documents

A.1 Consent Form

Figure A.1: Southern Michif SoundHunters study consent form.

DEPARTMENT OF COMPUTING SCIENCE

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Study Title: Southern Michif SoundHunters

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The purpose of this project is to improve existing educational technologies and build new learning technologies. To do this, you will be asked to use a technology, complete some questionnaires**,** and do some tests.

Specific study activities include:

- Playing a game
- Doing a few brief tests
- Completing a questionnaire about your experience playing the game

You must meet the following criteria to participate in this study:

- be an adult

Your participation should take around 40-60 minutes.

The data collected from this study will be used in articles for publication in journals and conference proceedings. Any write-ups of the data will not include information that can be linked directly to you.

Benefits
Other than the receipt of a small honorarium, you will not directly benefit from your participation. Information gathered in this research will help us improve existing educational technologies and develop new ones that could benefit future students.

Risk
While it is always possible that someone can figure out who participated in a study, we will remove all identifying information from your data before analyzing it in order to make it harder for people to tell who has participated.

There are no other foreseeable risks.

Remuneration/Compensation
To thank you for your time, we will be pleased to make a summary of the results available to you once they have been compiled. This summary will outline the research and discuss our findings and recommendations. It will be made available through our lab website:
https://spaces.facsci.ualberta.ca/edtekla/

We expect this summary to be available by the end of 2022.

You are also eligible to receive a gift card for $15 per completed study session. You will be given a code at the end of the study which you must email to dlothian@ualberta.ca in order to receive compensation for your participation. You will only receive compensation if you complete the task. You will be given an

A.2 Research Ethics Board Approval Letter

Figure A.2: Research and ethics approval for the Southern Michif SoundHunters study.

Notification of Approval

Date:	July 27,2018		
Study ID:	Pro00082188		
Principal Investigator:	Carrie Demmans Epp		
Study Title:	E-learning System and Feature Design		
Approval Expiry Date:	Friday, July 26, 2019		
Approved Consent Form:	Approval Date 7/27/2018	Approved Document consent.docx	
Sponsor/Funding Agency:	NSERC - Natural Sciences And Engineering Research Council		NSERC
Sponsor/Funding Agency:	Faculty of Science Startup Funds		

RSO-Managed Funding:

Project ID	Project Title	Speed Code	Other Information
RES0038658	NSERC RGPIN-2018-03834 Demmans		Demmans Evidence-based adaptation of Learning: Supporting informed decision making
RES0039792	OFAB SF Demmans Epp		

Thank you for submitting the above study to the Research Ethics Board 2. Your application has received a delegated review and has been approved on behalf of the committee.

A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Research Ethics Board does not encompass authorization to access the staff, students, facilities or resources of local institutions for the purposes of the research.

Sincerely,

Stanley Varnhagen, PhD.
Chair, Research Ethics Board 2

Note: This correspondence includes an electronic signature (validation and approval via an online system).

A.3 Participant Recruitment Email

Taanshi,

My name is Delaney Lothian, I am Cree-Métis from mânitow sâkahikan (Lac Ste. Anne, AB), and I am a graduate student in the Department of Computing Science at the University of Alberta. I study technology's role in Indigenous language revitalization. The last few months I have been working with Heather Souter on a game that teaches the sounds of Michif, and now I am running a study on it.

If you are interested in participating, you will be asked to play a Michif language game and complete a questionnaire and a couple small tests. Participating in this study will take approximately 40-60 minutes to complete. It's entirely asynchronous, so you may begin whenever you like, but please ensure you are able to complete the study without interruption. Specific study activities include:

- Playing a game
- Doing a few brief tests
- Completing a questionnaire about your experience playing the game.

You must meet the following criteria to participate in this study:

- be at least 18 years of age.

If you choose to participate, you will receive a $15 e-gift card as a small thank you.

If you are interested in participating, please click here to start the study.

If you have any questions or concerns, please email me at dlothian@ualberta.ca or my supervisor Dr. Carrie Demmans Epp at demmanse@ualberta.ca.

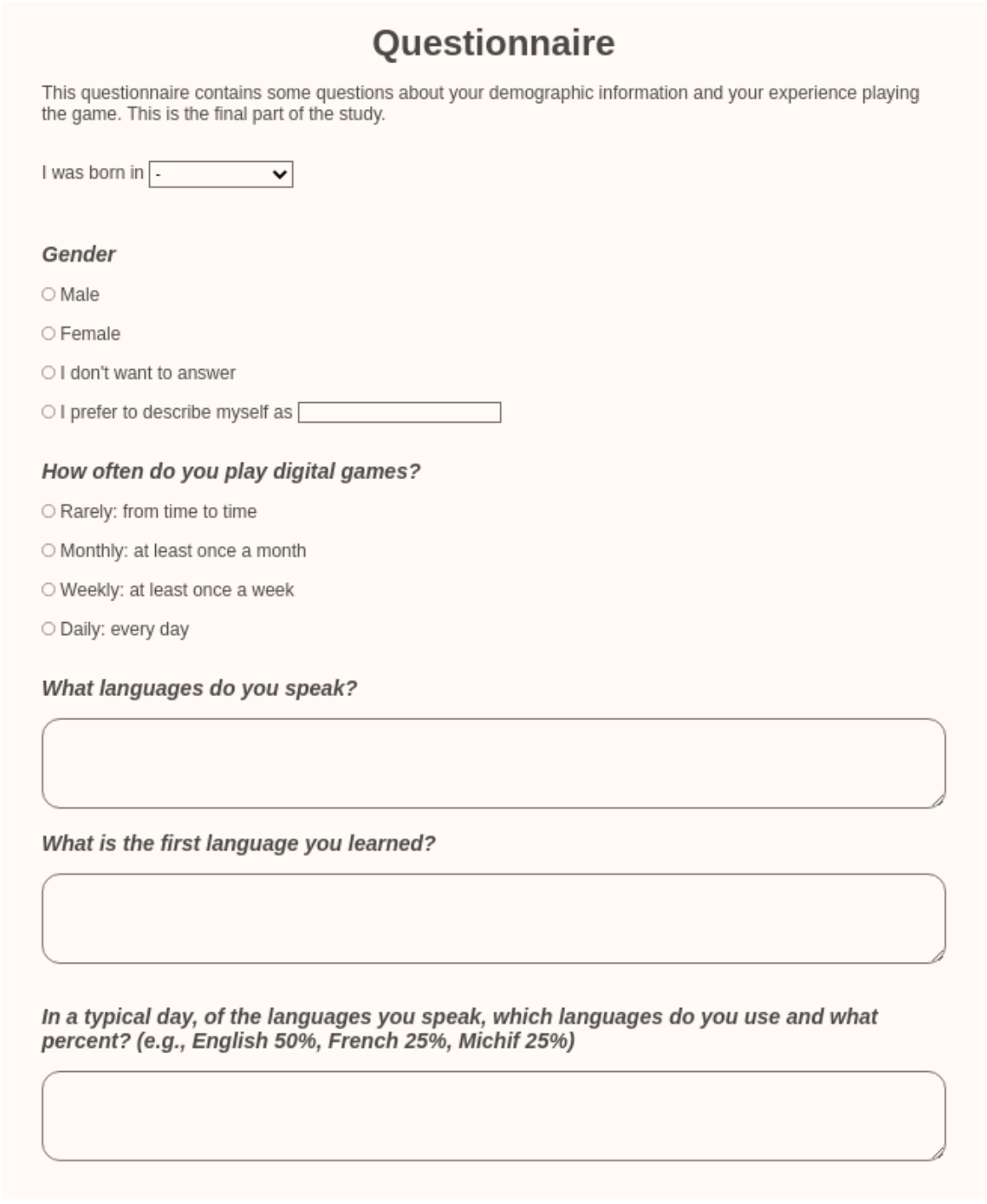
Best, Delaney

Study link: [removed]

You are receiving this email after giving written permission to Heather Souter. If you are receiving this email in error, feel free to email me or ignore the message.

A.4 Study Questionnaire

Figure A.3: Southern Michif SoundHunters study questionnaire part 1.



Questionnaire

This questionnaire contains some questions about your demographic information and your experience playing the game. This is the final part of the study.

I was born in -

Gender

- Male
- Female
- I don't want to answer
- I prefer to describe myself as

How often do you play digital games?

- Rarely: from time to time
- Monthly: at least once a month
- Weekly: at least once a week
- Daily: every day

What languages do you speak?

What is the first language you learned?

In a typical day, of the languages you speak, which languages do you use and what percent? (e.g., English 50%, French 25%, Michif 25%)

Figure A.4: Southern Michif SoundHunters study questionnaire part 2.

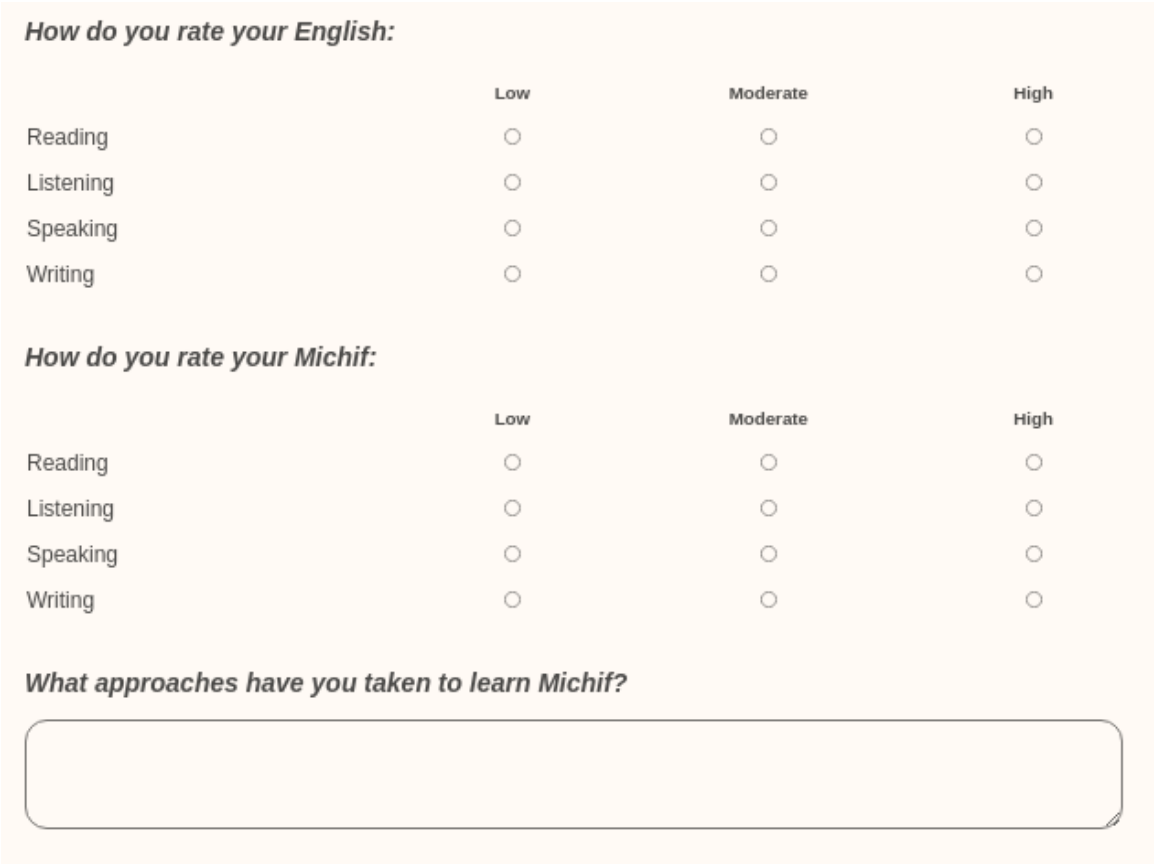
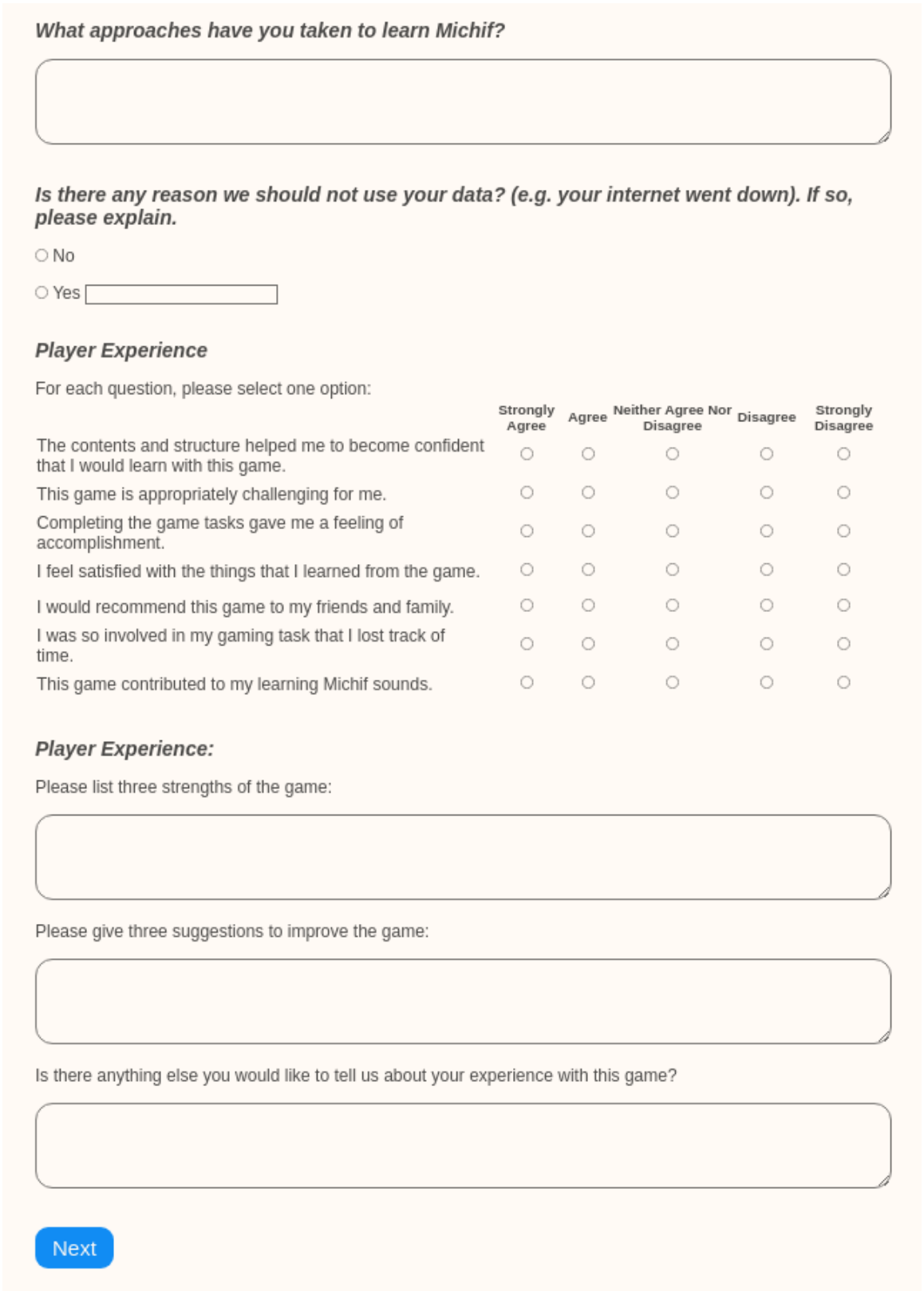


Figure A.5: Southern Michif SoundHunters study questionnaire part 3.



What approaches have you taken to learn Michif?

Is there any reason we should not use your data? (e.g. your internet went down). If so, please explain.

○ No

○ Yes

Player Experience

For each question, please select one option:

	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
The contents and structure helped me to become confident that I would learn with this game.	○	○	○	○	○
This game is appropriately challenging for me.	○	○	○	○	○
Completing the game tasks gave me a feeling of accomplishment.	○	○	○	○	○
I feel satisfied with the things that I learned from the game.	○	○	○	○	○
I would recommend this game to my friends and family.	○	○	○	○	○
I was so involved in my gaming task that I lost track of time.	○	○	○	○	○
This game contributed to my learning Michif sounds.	○	○	○	○	○

Player Experience:

Please list three strengths of the game:

Please give three suggestions to improve the game:

Is there anything else you would like to tell us about your experience with this game?

Next

A.5 Thematic Analysis Grouping

Table A.1: Participants' responses relating to perceived learning & effective teaching

Feedback Question	Theme	Quotation
Please list three strengths of the game.	Perceived Learning	P11: Good way to learn to identify sounds, kept my attention, repeated so helped learning
		P12: It kept me interested, I liked listening while moving my hands to find the sounds, and I felt myself improving as I played
	Effective Teaching Strategy	P1: Repetition of sounds, various sounds, interaction.
		P2: The longer sounds were really helpful in recognizing the spelling (which I struggle with) and with time it may improve my Michif.
		P3: The video game provided ample opportunity for sound recognition, vital for visual learning. Sound recognition activities may assist audio learners connect to the visual aids with interactive practise models|
		P4: I like that it gave immediate feedback when you got something right or wrong. I like that if you got a wrong answer you were able to continue trying for the right answer
		P6: Learning while playing. Learners may grasp sounds better over shorter period of time.
		P7: It forced focus.
		P8: Getting to listen to different speakers; hearing specific sounds in isolation
		P9: It helps me narrow in the sounds, I pay attention to listening instead of try to figure out the whole word
		P11: Good way to learn to identify sounds, kept my attention, repeated so helped learning
		P14: It made me listen more carefully to the beginning sounds. I could see how the sounds break down and match that with how they're written/said.
		P16: Helps to differentiate sounds

Please give three suggestions to improve the game.	Learning / Teaching Strategy Suggestion	P2: Perhaps pairing words and their sound or their meanings may be helpful in learning the sounds themselves
		P4: Stopping the game when you select a wrong answer, and having that wrong answer say their own respective sound so people can hear the difference between the sound they're trying to find, and the wrong sound they selected. Before each section, having a list of audio recordings for people to go through and hear all the sounds they'll be looking for in the section
		P8: After each round provide example sentences using some of the sounds learned
Is there anything else you would like to tell us about your experience with this game?	Perceived Learning	P2: If I were to play it more I can see my spelling improving the more that I practice!
	Good Learning Resource	P3: This could be a great tool for development of skill levels and can help asses a students comprehension of course materials, etc.
		P4: Overall it looks like a great learning resource for Michif!
		P6: I think this would be a great way to teach youth a language.
		P10: I think it is such a good idea to create games to learn languages.

Table A.2: Participants' responses relating to Michif SoundHunters being appropriately challenging

Feedback Question	**Theme**	**Quotation**
Please list three strengths of the game.	Simple/easy to use	P2: 1.The longer sounds were really helpful in recognizing the spelling (which I struggle with) and with time it may improve my Michif. 2.The speed of the game was not too fast or too slow - it was challenging enough, but not too challenging. 3. The instructions were well mapped out and clear

		P5: Easy and usable format. Fair speed. Interesting concept
		P6: Not too complicated to play. Learning while playing. Learners may grasp sounds better over shorter period of time.
		P10: The idea is good. It is relatively simple to use the keys. The instructions were good
		P16: Helps to differentiate sounds. Competitive. Simple to understand
	Appropriately challenging	P2: 1.The longer sounds were really helpful in recognizing the spelling (which I struggle with) and with time it may improve my Michif. 2.The speed of the game was not too fast or too slow - it was challenging enough, but not too challenging. 3. The instructions were well mapped out and clear
		P4: -I liked that each section build on one another. -I like that it gave immediate feedback when you got something right or wrong. -I like that if you got a wrong answer you were able to continue trying for the right answer
		P5: Easy and usable format. Fair speed. Interesting concept
		P7: hearing Michif speakers use the sounds in a mostly casual way was helpful bc it was challenging.. It was challenging. It forced focus..
		P17: - challenging. - offers authentic Michif pronunciation. - offers double-vowel Southern Michif writing system
		P18: fun, appropriate challenge level
Please give three suggestions to improve the game.	Not challenging enough	P2: 1. Some of the singular consonants were difficult to distinguish because the sounds were too short. The longer consonant vowel clusters were much more helpful, and easier to recognize as the sounds were clearer. 2. Perhaps pairing words and their sound or their meanings may be helpful in learning the sounds themselves. 3. The health bar was a bit too slow to decline - I was not worried about losing at all, and mechanically, there were some points where I could not shoot the right answer because previous answers consistently blocked the correct answer until it was almost too close to the bottom.

		P3: Game Levels with increasing speed and sound challenges. Multi player. Online interactive.
Is there anything else you would like to tell us about your experience with this game?	Appropriately challenging	P3: I enjoyed the game, difficulty level was right for an early to mid level player. this could be a great tool for development of skill levels and can help asses a students comprehension of course materials, etc.

Table A.3: Participants' responses relating to game content & visual design

Feedback Question	**Theme**	**Quotation**
Please list three strengths of the game.	Recording related	P2: 1.The longer sounds were really helpful in recognizing the spelling (which I struggle with) and with time it may improve my Michif. 2.The speed of the game was not too fast or too slow - it was challenging enough, but not too challenging. 3. The instructions were well mapped out and clear
		P7: hearing Michif speakers use the sounds in a mostly casual way was helpful bc it was challenging.. It was challenging. It forced focus..
		P8: Getting to listen to different speakers; hearing specific sounds in isolation; fun
	Culturally Appropriate	P17: - challenging. - offers authentic Michif pronunciation. - offers double-vowel Southern Michif writing system
Please give three suggestions to improve the game.	Not appropriate (culturally or otherwise)	P1: In the first or second frame, some words sounded like static. Provide more space between some deer as I often knew the word but shot the wrong one. Maybe shooting the bottles, pin wheels, etc. would feel "safer" or more age-friendly.
	Content /structuring suggestion	P2: 1. Some of the singular consonants were difficult to distinguish because the sounds were too short. The longer consonant vowel clusters were much more helpful, and easier to recognize as the sounds were clearer. 2. Perhaps pairing words and their sound or their meanings may be helpful in learning the sounds themselves. 3. The health bar was a bit too slow to decline - I was not worried about losing at all, and mechanically, there were some points where I could not shoot the right answer because previous answers consistently blocked the correct answer until it was almost too close to the bottom.

		P6: Improve audio, little bit of background music, advance into whole words, phrases etc.
		P7: many times I believed I hit the deer and then had to chase it down and sometimes it would disappear even tho I saw the arrow hit it. Maybe if the whole deer was a target, it seemed to be just the head.. There were some sounds that I couldn't decipher at all. Some that were r sounds and another one so that I ended up just trying to shoot all of the deer so I could find out what the sound was supposed to be.. Maybe if the sounds were also presented in a sentence? I don't know how you'd do that, but context can help me figure out a sound...but I'm not sure what the goal is. To just hear the difference between sounds?.
		P8: Some sounds are not isolated enough (especially single-letter sounds) and contain a vowel sound with the consonant; after each round provide example sentences using some of the sounds learned
		P9: It should be progressive- starting of with the syllables, constants and word.
		P15: 1. better graphics, overall design (occasionally the deer overlapped and you had to just randomly shoot hoping to hit the right one). 2. more words, less sound fragments. 3. some of the sounds could have had better enunciation, or been clearer
		P18: short phrases in addition to sounds
Is there anything else you would like to tell us about your experience with this game?	Content /structuring suggestion	P1: Add more sounds if possible and longer words.
	Culturally Appropriate	P2: Great job on the game! I really loved the concept of hunting and incorporating that into the game! It really added to the game! The game was also fun! I quite enjoyed it and if I were to play it more I can see my spelling improving the more that I practice! I am so glad that you are doing this project! It is such a wonderful idea!
		P6: I think this would be a great way to teach youth a language.

		P9: I enjoyed the game, reminded me of playing Attari - i might be smart to update the graphics for the young folks. I love that is a hunting game.

Table A.4: Participants' responses relating to game mechanics & game-based learning

Feedback Question	**Theme**	**Quotation**
Please list three strengths of the game.	Something inherit to gamified learning is good	P6: Not too complicated to play. Learning while playing. Learners may grasp sounds better over shorter period of time.
		P9: It helps me narrow in the sounds, I pay attention to listening instead of try to figure out the whole word, i enjoy the game element
		P12: it kept me interested, I liked listening while moving my hands to find the sounds, and I felt myself improving as I played
		P15: 1. easy to understand. 2. wouldn't take much time to play (could put in a little time or a lot at a single sitting and it would be ok. 3.builds in skill level
		P16: Helps to differentiate sounds. Competitive. Simple to understand
Please give three suggestions to improve the game.	Game mechanic suggestion	P2: 1. Some of the singular consonants were difficult to distinguish because the sounds were too short. The longer consonant vowel clusters were much more helpful, and easier to recognize as the sounds were clearer. 2. Perhaps pairing words and their sound or their meanings may be helpful in learning the sounds themselves. 3. The health bar was a bit too slow to decline - I was not worried about losing at all, and mechanically, there were some points where I could not shoot the right answer because previous answers consistently blocked the correct answer until it was almost too close to the bottom.
		P3: Game Levels with increasing speed and sound challenges. Multi player. Online interactive.

		P4: -once a correct answer has been selected, removing the other deer from the screen in that round (so that you can move onto the next round more quickly). -stopping the game when you select a wrong answer, and having that wrong answer say their own respective sound so people can hear the difference between the sound they're trying to find, and the wrong sound they selected. -Before each section, having a list of audio recordings for people to go through and hear all the sounds they'll be looking for in the section
		P13: very hard to hit the target , even though i knew which sounds then other letters would be in the way and couldn't hit on time. I would just use the mouse but then It wouldn't be a shooting game so not sure. hit the letter and it would say the sound?
		P16: Make all volumes the same. Ensure audio is clear. change the visuals between levels
Is there anything else you would like to tell us about your experience with this game?	Postive Game	P3: I enjoyed the game, difficulty level was right for an early to mid level player. this could be a great tool for development of skill levels and can help asses a students comprehension of course materials, etc.
		P6: I think this would be a great way to teach youth a language.
		P9: I enjoyed the game, reminded me of playing Attari - i might be smart to update the graphics for the young folks. I love that is a hunting game.
		P10: I think it is such a good idea to create games to learn languages.
	Negative Game	P7: The game was stressful for me. Shooting the right deer was difficult. I'm not sure if I learned anything I was so focused on shooting the right deer. maybe I did though I don't know.

Table A.5: Participants' responses relating to technical & game-based difficulties

Feedback Question	**Theme**	**Quotation**

Please give three suggestions to improve the game.	Technical Difficulty	P7: many times I believed I hit the deer and then had to chase it down and sometimes it would disappear even tho I saw the arrow hit it. Maybe if the whole deer was a target, it seemed to be just the head.. There were some sounds that I couldn't decipher at all. Some that were r sounds and another one so that I ended up just trying to shoot all of the deer so I could find out what the sound was supposed to be.. Maybe if the sounds were also presented in a sentence? I don't know how you'd do that, but context can help me figure out a sound...but I'm not sure what the goal is. To just hear the difference between sounds?.
		P10: Sometimes there are too many deer on the screen, and you have to almost wait for. the one you choose to drift into shooting range. The sounds are not standardized/normalized in audio terms, but rather sound like they are clips from multiple different people and sometimes hard to hear the difference in sounds starting with a few of the consonants.. people.. Sometimes, especially when there were too many deer on the screen, the arrows did not fire when the space button was pressed
		P12: consistently repeat the sounds, sometimes the sound was not not repeated although when it was repeated sometimes the first letter was cut off, the recording was cut too short
	Difficulty with game play	P1: In the first or second frame, some words sounded like static. Provide more space between some deer as I often knew the word but shot the wrong one. Maybe shooting the bottles, pin wheels, etc. would feel "safer" or more age-friendly.
		P2: 1. Some of the singular consonants were difficult to distinguish because the sounds were too short. The longer consonant vowel clusters were much more helpful, and easier to recognize as the sounds were clearer. 2. Perhaps pairing words and their sound or their meanings may be helpful in learning the sounds themselves. 3. The health bar was a bit too slow to decline - I was not worried about losing at all, and mechanically, there were some points where I could not shoot the right answer because previous answers consistently blocked the correct answer until it was almost too close to the bottom.

		P5: Sometimes the audio was so short it was difficult to figure out what the beginning or ending sound was.. I often hit the wrong target because I missed and there were so many deer on the screen.
		P7: many times I believed I hit the deer and then had to chase it down and sometimes it would disappear even tho I saw the arrow hit it. Maybe if the whole deer was a target, it seemed to be just the head.. There were some sounds that I couldn't decipher at all. Some that were r sounds and another one so that I ended up just trying to shoot all of the deer so I could find out what the sound was supposed to be.. Maybe if the sounds were also presented in a sentence? I don't know how you'd do that, but context can help me figure out a sound...but I'm not sure what the goal is. To just hear the difference between sounds?.
		P10: Sometimes there are too many deer on the screen, and you have to almost wait for. the one you choose to drift into shooting range. The sounds are not standardized/normalized in audio terms, but rather sound like they are clips from multiple different people and sometimes hard to hear the difference in sounds starting with a few of the consonants.. people.. Sometimes, especially when there were too many deer on the screen, the arrows did not fire when the space button was pressed
		P13: very hard to hit the target , even though i knew which sounds then other letters would be in the way and couldn't hit on time. I would just use the mouse but then It wouldn't be a shooting game so not sure. hit the letter and it would say the sound?
		P15: 1. better graphics, overall design (occasionally the deer overlapped and you had to just randomly shoot hoping to hit the right one). 2. more words, less sound fragments. 3. some of the sounds could have had better enunciation, or been clearer
	Recording related issue	P1: In the first or second frame, some words sounded like static. Provide more space between some deer as I often knew the word but shot the wrong one. Maybe shooting the bottles, pin wheels, etc. would feel "safer" or more age-friendly.

		P5: Sometimes the audio was so short it was difficult to figure out what the beginning or ending sound was.. I often hit the wrong target because I missed and there were so many deer on the screen.
		P6: Improve audio, little bit of background music, advance into whole words, phrases etc.
		P7: many times I believed I hit the deer and then had to chase it down and sometimes it would disappear even tho I saw the arrow hit it. Maybe if the whole deer was a target, it seemed to be just the head.. There were some sounds that I couldn't decipher at all. Some that were r sounds and another one so that I ended up just trying to shoot all of the deer so I could find out what the sound was supposed to be.. Maybe if the sounds were also presented in a sentence? I don't know how you'd do that, but context can help me figure out a sound...but I'm not sure what the goal is. To just hear the difference between sounds?.
		P8: Some sounds are not isolated enough (especially single-letter sounds) and contain a vowel sound with the consonant; after each round provide example sentences using some of the sounds learned
		P10: Sometimes there are too many deer on the screen, and you have to almost wait for. the one you choose to drift into shooting range. The sounds are not standardized/normalized in audio terms, but rather sound like they are clips from multiple different people and sometimes hard to hear the difference in sounds starting with a few of the consonants.. people.. Sometimes, especially when there were too many deer on the screen, the arrows did not fire when the space button was pressed
		P11: more clear sound clips. some clips were slightly cut off.
		P12: consistently repeat the sounds, sometimes the sound was not not repeated although when it was repeated sometimes the first letter was cut off, the recording was cut too short
		P15: 1. better graphics, overall design (occasionally the deer overlapped and you had to just randomly shoot hoping to hit the right one). 2. more words, less sound fragments. 3. some of the sounds could have had better enunciation, or been clearer

		P16: Make all volumes the same. Ensure audio is clear. change the visuals between levels
		P17: Audio needs to be clearer.
Is there anything else you would like to tell us about your experience with this game?	Technical Difficulties	P8: I first tried to play on an iPad pro with keyboard and the sound stopped working in the game after the first 3 sounds. I had to switch to a computer and start over.
		P12: sometimes sounds were on top of each other and impossible shoot the right one, sound quality changed with different sounds, sometimes louder or softer and had to adjust my volume a few times, a couple of times I hit all the sounds and none were correct (can't remember which ones)
		P13: I couldn't get the hang of it and would keep missing the target. My space bar was too slow.
	Recording issue	P12: sometimes sounds were on top of each other and impossible shoot the right one, sound quality changed with different sounds, sometimes louder or softer and had to adjust my volume a few times, a couple of times I hit all the sounds and none were correct (can't remember which ones)

Table A.6: Participants' responses relating to overall enjoyment of Michif Sound-Hunters

Feedback Question	**Theme**	**Quotation**
Please list three strengths of the game.	Interesting	P5: Easy and usable format. Fair speed. Interesting concept
		P12: it kept me interested, I liked listening while moving my hands to find the sounds, and I felt myself improving as I played
	Fun	P8: Getting to listen to different speakers; hearing specific sounds in isolation; fun
		P13: would be fun for a learner, made you really listen to the sounds, made you say the sounds out loud
		P18: fun, appropriate challenge level

	Enjoyable	P3: I enjoy the opportunity to write out sounds, helps to retain and visualize for visual learners. The video game provided ample opportunity for sound recognition, vital for visual learning. Sound recognition activities may assist audio learners connect to the visual aids with interactive practise models.
		P9: It helps me narrow in the sounds, I pay attention to listening instead of try to figure out the whole word, i enjoy the game element
		P11: Good way to learn to identify sounds, kept my attention, repeated so helped learning
		P12: it kept me interested, I liked listening while moving my hands to find the sounds, and I felt myself improving as I played
		P14: It made me listen more carefully to the beginning sounds. I could see how the sounds break down and match that with how they're written/said.
Is there anything else you would like to tell us about your experience with this game?	Interesting	P5: No, it was very interesting.
		P17: Very interesting!
	Fun /Enjoyable	P2: Great job on the game! I really loved the concept of hunting and incorporating that into the game! It really added to the game! The game was also fun! I quite enjoyed it and if I were to play it more I can see my spelling improving the more that I practice! I am so glad that you are doing this project! It is such a wonderful idea!
		P3: I enjoyed the game, difficulty level was right for an early to mid level player. this could be a great tool for development of skill levels and can help asses a students comprehension of course materials, etc.
		P9: I enjoyed the game, reminded me of playing Attari - i might be smart to update the graphics for the young folks. I love that is a hunting game.

	Overall Positive	P2: Great job on the game! I really loved the concept of hunting and incorporating that into the game! It really added to the game! The game was also fun! I quite enjoyed it and if I were to play it more I can see my spelling improving the more that I practice! I am so glad that you are doing this project! It is such a wonderful idea!
		P3: I enjoyed the game, difficulty level was right for an early to mid level player. this could be a great tool for development of skill levels and can help asses a students comprehension of course materials, etc.
		P11: Thank you, keep up the good work!
		P15: It's a great start!

A.6 Participant Phonemic Awareness Test Scores & Learning Gains

Table A.7: Pre-test, post-test, and learning gain scores of all participants who completed the study in full. Note that for PID 8, learning gain cannot be calculated when the posttest score is 100%.

PID	Pretest Score	Posttest Score	Learning Gain
1	36.7%	37.5%	1.3%
2	67.8%	89.1%	66.1%
3	70.0%	73.4%	11.5%
4	82.2%	71.9%	-58.2%
5	65.6%	68.8%	9.3%
6	75.6%	76.6%	4.1%
7	57.8%	73.4%	37.1%
8	100.0%	100.0%	
9			
10	53.3%	57.8%	9.6%
11	56.7%	50.0%	-15.4%
12	78.9%	92.2%	63.0%
13			
14	54.4%	64.1%	21.1%
15	96.7%	90.6%	-181.3%
16	53.3%	71.9%	39.7%
17	66.7%	90.6%	71.9%
18			

A.7 Error Type Counts

Table A.8: Error type counts made by participants in the phoemic awareness pre- and post-tests.

Error Type	Pre-Test	Post-Test
French Spelling	18	14
English/Other Spelling	9	2
Added Letters	34	26
Replace Letters	39	40
Removed	42	42
Vowel Changes	36	41
Total	178	165

Table A.9: Vowel changes error counts made by participants in the phoemic awareness pre- and post-tests.

Vowel Change	Pre-Test	Post-Test
Short Vowel To Long	10	11
Long Vowel To Short	64	58
Same Length	45	33
Total	119	102