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Design and Evaluation of a Smartphone Keyboard for Plains Cree Syllabics

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Abstract

Plains Cree is a less-resourced language in Canada. To promote its usage online, we describe previous keyboard layouts for typing Plains Cree syllabics on smartphones. We describe our own solution whose development was guided by ergonomics research and corpus statistics. We then describe a case study in which three participants used a previous layout and our own, and we collected quantitative and qualitative data. We conclude that, despite observing accuracy improvements in user testing, introducing a brand new paradigm for typing Plains Cree syllabics may not be ideal for the community.

Keywords: cree, syllabics, smartphone

1. Introduction

Figure 1: The virtual keyboard layout introduced in this paper for typing Plains Cree syllabics on iOS and Android smartphones.

To reclaim an minority language in the digital space, the language must be used and shared online. However, minority language users of new media often resort to a majority language when writing online (Keegan et al., 2015). There is a need for quality mobile support for minority languages (Cassels, 2019), such as Plains Cree. Having a good mobile keyboard enables the language to be used online, and encourages the language's use at home and in the classroom. There is no well-established keyboard layout for Plain Cree syllabics, although there have been plenty of alternatives for smartphones (First Peoples' Cultural Council, 2016; van Esch et al., 2019; Houle, 2018; Moshagen et al., 2016). In this paper, we explore the existing keyboard layouts, describe a few areas of improvement, and propose our own smartphone keyboard layout for writing in Plains Cree syllabics (Figure 1). We describe how we created our layout basing its key locations on ergonomics research and corpus statistics. We then describe a case study wherein we had participants use our keyboard and compared it to an existing solution. We conclude by discussing the preferences we learned from the case study.

2. nêhiyawêwin: the Cree Language

Plains Cree (ISO 639-3: crk) or its endonym, ᓀᐦᐃᔭᐍᐏᐣ (*nêhiyawêwin*) is a member of the Algonquian language family. It is the westernmost language of the Cree language continuum, and has been historically spoken by the *nêhiyawak* people in an area spanning present day north and central Alberta, central Saskatchewan, and the eastern edge of British Columbia. As with many Indigenous languages in Canada, the use of Plains Cree was actively suppressed by government and institutional efforts (The Truth and Reconciliation Commission of Canada, 2015).

Plains Cree is written primarily in two orthographies. The most commonly supported orthography by computers and smartphones is the **standard Roman orthography** (**SRO**), an alphabet that borrows the consonants *ptkcshmnywrl* and vowels *êiao* from the Latin script (ISO 15924: Latn), and denotes long vowels with either macron (ē ī ō ā) or circumflex (ê î ô â) diacritics. Note that there is no short *e* vowel.

3. ᒐᐦᑭᐯᐦᐃᑲᓇ: Writing in Syllabics

Syllabics or ᒐᐦᑭᐯᐦᐃᑲᓇ (*cahkipêhikana*) (ISO 15924: Cans) is a writing system created in the 1800s to write the Swampy Cree language (Stevenson, 1999). Syllabics are used to write many Canadian Indigenous languages and often have different conventions language to language. Such languages include Inuktut, Eastern Cree dialects, and Dene languages, among others. Their use for Plains Cree will be the focus of this paper.

The syllabics writing system is similar to an **abugida**—its primary graphemes represent a **consonant-vowel pair**, with the **shape** of each grapheme indicating the consonant of the pair, and the **orientation** of the grapheme indicating the vowel of the pair.

For example, the graphemes ᐯ, ᐱ, ᐳ, ᐸ all have the same shape, which represents a syllable starting with the /p/ sound; these graphemes represent the syllables /pe/, /pɪ/, /po/, /pɐ/, respectively. The graphemes ᑲ, ᓴ, ᒐ, ᒪ are all oriented in the same way (the tips "point" to the southwest) which means they all contain the /ɐ/ vowel; these graphemes represent the syllables /kɐ/, /sɐ/, /t͡sɐ/, /mɐ/, respectively.

Syllables in Plains Cree have the general shape (C)(w)V-(C)(C), where C is a consonant and V is a vowel, and w is

Category	Elaboration	Example		
		Syllabic	IPA	SRO
V	Vowel	ᐋ	/ɑː/	â
wV	Syllable with /w/ as onset	ᐚ	/wɑː/	wâ
CV	Syllable with consonant onset	ᒌ	/t͡siː/	cî
CwV	Syllable with consonant + /w/ onset	ᓌ	/nwɑː/	nwâ
final	Coda	ᐤ	/w/	w

Table 1: The different syllabic categories used in this paper.

the /w/ sound[1] (Wolfart, 1996). Given that most syllables in Plains Cree are predominately CV or CwV, the syllabics writing system is particularly well-suited for writing Plains Cree. Further, the writing system is thought to be more Indigenous and authentic than using the borrowed Latin writing system, thus it holds greater cultural value.

3.1 Diacritics

The onset of a syllable, if present, is a consonant, or a consonant with an intervening /w/ sound. The /w/ sound is written in syllabics as a dot to the right-side of the (C)V syllabic. For example, ᑌ represents the /te/ syllable; ᑘ, with a dot to the right, represents the /twe/ syllable.

Long vowels are denoted by putting a dot on top of a syllabic; for example, given the short vowels ᐃ (/ɪ/), ᐅ (/o/), ᐊ (/ɐ/), adding a dot diacritic on top of these vowels yields the long vowels, ᐄ (/iː/) ᐆ (/oː/), and ᐋ (/ɑː/), respectively. Note: although ᐁ (/e/) is considered to be a long vowel, it does not take a diacritic, as there is no short /e/ vowel.

3.2 Finals

Codas in Plains Cree, if present, are one or two consonants written using syllabics called *finals*. Finals appear anywhere in a word where a consonant cannot be paired with a vowel or an intervening /w/. For example, the word for horse, /mɪstɐtɪm/, is written as ᒥᐢᑕᑎᒼ in syllabics. The finals correspond to /s/ and /m/ phonemes, respectively, and are the two consonants in the word that are *not* followed by a vowel or a /w/ + vowel pair. There are three special finals: ᐦ for writing /h/ anywhere in a word; ᐤ for words that end with /w/; and ᕽ for words that end with /hk/; Every consonant in Plains Cree has a corresponding final syllabic, though these are not transparently related to their corresponding **CV** syllabic shape.

3.3 Categorizing Syllabics

In this paper, we define five categories for the Plains Cree syllabics: **V**, **wV**, **CV**, **CwV**, and **final** (Table 1). The keyboards described in this paper (Sections 4, 5) each have different methods of typing characters in each category.

4. Prior Work

We describe an existing solution to type Plains Cree syllabics on smartphones: the **FirstVoices Keyboards** app.

[1]This is an oversimplification of Plains Cree phonotactics. For a full explanation, see Wolfart (1996).

4.1 The FirstVoices Layout

Figure 2: The FirstVoices Plains Cree syllabics layout.

The **ᓀᐦᐃᔭᐍᐏᐣ (Plains Cree)** keyboard layout (Figure 2) was created by the First Peoples' Cultural Council as part of their **FirstVoices Keyboards** app (2016). The FirstVoices Keyboards app is a suite of smartphone keyboard layouts that covers all Indigenous languages in Canada. The technology that allows the creation of many keyboard layouts is Keyman (2020), a keyboard creation engine. Keyman is embedded within the FirstVoices Keyboards app, and all of the keyboard layouts it provides—including **ᓀᐦᐃᔭᐍᐏᐣ (Plains Cree)**—can be used standalone with the (separate) Keyman app. Throughout the rest of this paper, we will refer to this layout as the **FirstVoices** layout.

The FirstVoices layout uses a two *page* system: the initial page (Figure 2) displays all **V** and **CV** syllabics that have the underlying /ɐ/ and /ɪ/ vowel. Below the CV syllabics are all of the **finals**, with the exception of ᕽ. Pressing the [⇧] key switches to the second page, which displays all **V** and **CV** syllabics that have the underlying /e/ and /o/ vowel, as well as keys for ≤ (/l/), ≥ (/r/), and ᕽ.

To type a syllabic with a long vowel, the typist first types the **V** or **CV** syllabic with the corresponding short vowel. Then, the typist must press the [˙] key, which has the effect of adding a long vowel dot to the previously entered **V** or **CV** syllabic. To type a **wV** or **CwV** syllabic, one must first type the corresponding **V** or **CV** syllabic, including long vowel dot, and then press the [·] key; this places a middle dot after the corresponding syllabic.

This layout has the advantage of having a shallow learning curve; All **V** and **CV** syllabics are one or two presses away. However, since there are 40 **V** and **CV** syllabics, plus 13 finals, this keyboard makes the decision to split them in half. Notably, syllables with the vowels /ɐ/ or /ɪ/ are more common in Plains Cree, so the keyboard made the right choice in prioritizing which syllabics are immediately selectable. That said, the keyboard is still cramped; on our test device, most keys on this layout are 5mm wide.

The FirstVoices layout produces dubious Unicode character output. The Unified Canadian Aboriginal Syllabics block of Unicode defines unique characters for all **V**, **wV**, **CV**, and **CwV** syllabics and includes finals specifically for use in Western Cree syllabics (The Unicode Consortium, 2019b). The FirstVoices layout does not produce precomposed characters for **CwV** syllabics; instead, it appends U+1427 CANADIAN SYLLABICS FINAL MIDDLE DOT to emulate a /w/ diacritic, despite the character actually encoding a final. Another oddity is that this layout sometimes opts to produce *look-alike* finals, instead of the characters specifically intended for Western Cree. Additionally, the keyboard has no key for the full-stop used in Plains Cree syllabics (namely: ᙮).

4.2 Other Layouts

The Gboard application (van Esch et al., 2019) has an Android-only Cree syllabics layout. The layout is "pan-Cree", aiming to cover all Cree dialects. Covering all dialects in one layout has the effect that, out of 48 syllabics keys immediately available to type on the primary page, 18 keys (37.5%) are *completely unused* in Plains Cree syllabics orthography. Given that the Gboard layout is Android-only, we will not discuss it further. To our knowledge, there are a few other smartphone keyboards for Cree syllabics (Houle, 2018; Moshagen et al., 2016), however, we were unable to install them as the system-wide keyboard on our test device. As such, they will also not be discussed any further.

5. Design and Development of the Keyboard

After studying the strengths and weaknesses of the layout presented in Section 4, we sought to make our own syllabics layout for smartphones with the following goals:

1. All syllabics must be **accessible on the primary page**.
2. Only keys used in **Plains Cree** should be on the primary page.
3. It must facilitate efficient **two-thumbed typing**.
4. Its Unicode output must produce **pre-composed** syllabic code points.

With these goals in mind, we present our method for developing this layout, which we will henceforth refer to as the **Keyman layout**. The **Keyman layout** is a "build-a-syllable" dynamic layout, designed specifically for use with the Plains Cree language.

5.1 Creating an Ergonomic, Two-handed Layout

Upon using the **FirstVoices** layout, the authors of this paper felt that, in order to facilitate fast and accurate typing, this layout could do better to improve the *placement* of the syllabic characters.

As such, we sought research in the ergonomics of thumbed-input on smartphones. We focused on two-thumbed input, as most smartphone keyboard layouts position the virtual keyboard at the very bottom of the screen, where one would hold the phone with either one or two hands, using one's thumbs to tap on the keyboard's keys.

Park and Han (2010) discuss the design and placement of touchscreen targets for *one-handed* interaction on a mobile phone. The authors tested the effects of 5mm, 7mm, and 10mm targets on a 5×5 grid on a smartphone display. They measured study participants' first transition time—how long it takes to go from a neutral position to any target on the screen; the task completion time—how long it takes to press the *correct* target on the screen; the number of errors made; and the pressing convenience—the participants' subjective opinion of how easy it is to press a target. We have calculated the median of all metrics measured in Park and Han (2010). We opted to use the 7mm grid, as it strikes a good balance between allowing for a great number of keys, and it is not as error-prone as smaller layouts. This indicated which 7mm targets are good places to assign keys, and which targets to avoid.

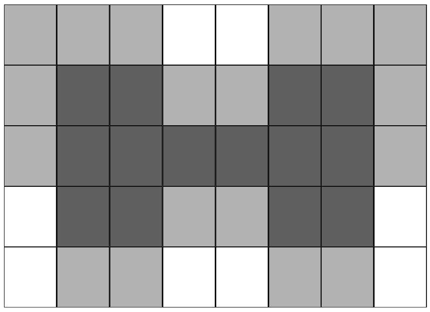

Figure 3: The superposition of the original right-handed grid and the mirrored left-handed grid. Lighter areas are worse places to assign keys, and darker areas are better places to assign keys.

Now that we know which areas of the layout are easier and less error-prone to touch, and which areas are more error prone, and more difficult to touch, we can begin placing keys on the layout.

We decided, that in order to support **two-thumbed typing**, we would create a "build-a-syllable" keyboard, where **CV** syllabics would be assembled by typing a consonant final first, then followed by the appropriate vowel. We placed **consonants** and **vowels** on opposite side of the keyboard. This way, when typing **CV** syllable sequences, the typist alternates between thumbs, allowing simultaneous articulation of their thumbs. For example, while the left thumb is finishing the articulation of typing a consonant, the right thumb is starting the articulation of typing a vowel. This follows the design recommendations set by Norman and Fisher (1982), who state that a keyboard should equalize the load of both hands, maximizing sequences where keys are typed by alternating hands.

Since Park and Han (2010) only collected data for *right-handed* touches, we made the assumption that this figure can be mirrored horizontally to account for left-handed usage. We then determined the width of a grid of 7mm wide keys, with a 1mm gap between keys that would comfortably fit the width of a contemporary smartphone. Using a smartphone with a screen width of 68mm, we calculated $8 \times 7\text{mm} + 7 \times 1\text{mm} = 63\text{mm}$. Thus we determined that the grid should be 8 keys wide. We then superimposed both the original right-handed grid, and the mirrored left-handed grid, assuming that keys in the overlapping portion of the grid will take the median of measures from both the left-handed and right-handed button placements (Figure 3).

5.2 Placing Keys Based on Corpus Statistics

We wanted to place **frequent keys** in the darker areas in Figure 3, and **rare keys** in lighter areas. To get an idea of **key frequency**, we counted unigram and bigram frequency in the **Ahenakew-Wolfart corpus of Cree text** (Arppe et al., 2019).[2] This corpus is composed of a number of interviews and monologues recorded by Freda Ahenakew and H. C. Wolfart and includes roughly 73,000 Cree word tokens.

[2] The full results are available: https://gist.github.com/eddieantonio/1b0f25f1c6d78e6dfb611f490a0822c7

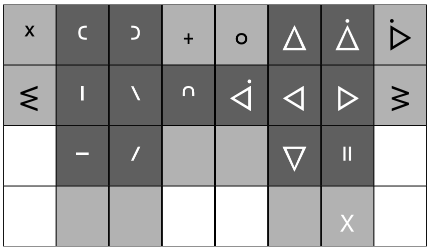

Figure 4: The grid of our placements with syllabics keys filled in. Lighter areas indicate harder-to-type keys; darker areas indicate easier-to-type keys.

Most texts in the corpus are some sort of narrative being told to the interviewer. The corpus is written entirely in SRO, but since the mapping between SRO and syllabics is (for the most part) straightforward, SRO letter frequencies are informative when creating a "build-a-syllable" keyboard.

First, we placed generic keys, such as the spacebar, the return key, the full-stop key (᙮) and the backspace key in areas that are frequent among QWERTY smartphone keyboard layouts. Then, we placed the most frequent consonant, ᐠ (/k/) in the dark area on the left-hand side; then, we placed the most frequent vowel, ᐊ (/ɐ/), in the right-hand area of the grid. We continued this by placing higher frequency keys in the darker areas of Figure 3, and then placing lower-frequency letters in lighter areas. Consonants were placed primarily on the left-hand side, while all 7 vowels were placed on the right-hand side. Most of the placement of the keys were based on the corpus statistics, however some keys were placed for aesthetic value. For example, the ᓬ (/l/) and ᕒ (/r/) were placed opposite of each other, since both are only used for loanwords from English and French. The <hk> digraph occurred 5414 times in the corpus; thus, <hk> is less frequent than <c>—so we placed it in a harder-to-type place. In total, we assigned 12 consonants, 7 vowels, and ᕽ (/hk/), and for a total of 20 keys, requiring at least three rows of 8 keys per row. Since we only require three rows for syllabic characters, and an extra row for the spacebar and punctuation, we removed the top row from Figure 3; this row is reserved for presenting predictive text suggestions, however predictive text is not addressed in this paper. The final layout we obtained is in Figure 4.

Note that the hyphen occurred 14,740 times in the corpus; the hyphen is used in SRO as a *morpheme separator*, especially, to separate prefixes from the verb stem. Upon consultation with Cree syllabics writers (Wolvengrey, 2018; Ogg, 2018), we decided the equivalent to a hyphen in syllabics should be a **thin, non-breaking space**. For this we used U+202F NARROW NO-BREAK SPACE or the NNBSP. This follows the precedent set by Mongolian orthography, in which the NNBSP is used as a thinner space that separate affixes *without introducing a word break* (The Unicode Consortium, 2019a). The full-sized space is still used as a word separator.

To write the thinner, non-breaking space, we added a *secondary spacebar* above the regular spacebar. Much like the thinner space itself, the secondary spacebar is thinner than the regular spacebar. This key was positioned above the regular space, and centered horizontally.

5.3 Development with Keyman Developer

As its name suggests, we made the **Keyman** layout using the Keyman Developer software (2020).

To create a "build-a-syllable" *dynamic layout*—where some keys change based on the consonant just typed—we implemented the keyboard using several *layers*. "Layers" is the term that Keyman Developer refers to as *pages* in the rest of this paper; however, while a page in a layout such as FirstVoices consists of completely different keys, in the Keyman layout, we employed layers to implement *variations* of the primary page.

We created Keyman layers for the primary page (the *default* layer) and created layers for all possible **CV**, and **CwV** consonant "shapes". All of these layers were identical, except that the keys for the vowels were changed to reflect the previously typed consonant. For example, starting from the default layer (Figure 5a), typing the ᐠ (/k/) final switches to the kV layer (Figure 5b), which swaps all of the vowel syllabics with all possible **kV** syllabics, namely, ᑫ, ᑭ, ᑯ, ᑲ, ᑮ, ᑰ, ᑳ. Pressing any of these keys replaces the ᐠ with the indicated **kV** syllabic. If instead, one presses ᐤ (/w/), the keyboard switches to the kwV layer (Figure 5c), swapping all the vowels once again with all **kwV** syllabics—ᑵ, ᑹ, ᑽ, ᑿ, ᑻ, ᑾ, ᒁ. Pressing a **kwV** syllabic replaces the ᐠᐤ with the appropriate syllabic. In this way, a syllabic is "built" by first typing a final, then optionally typing ᐤ, and finally its corresponding vowel is selected.

Layer switching was accomplished using Keyman's next-layer directive for keys. In addition, each non-default layer visually highlights the keys that differ from the default layer, as well as highlighting which consonant keys have been pressed (Figures 5b, 5c).

In total, the keyboard contains 19 layers: the default layer, 9 **CV** layers, 8 **CwV** layers, and a *numeric* layer to type Arabic numerals and additional punctuation. Since duplicating the same layer several times with minor changes is an error-prone process, we wrote Python code to generate the .keyman-touch-layout file that defines the layout. The source code to generate the layout is open-source and can be found online.[3]

The **Keyman layout** can be installed on either iOS (iPhone) or Android smartphones by downloading the Keyman app,[4] and then then installing the nrc_crk_cans layout, either within the app, or online.[5] We have also written a short tutorial for using the layout on Keyman's website.[6]

6. Evaluation

In order to evaluate the Keyman layout, we opted to measure the accuracy, pleasantness, and general efficacy of both the FirstVoices and Keyman layouts. This evaluation was composed of two main components: quantitative data collected during controlled typing experiments (Section 6.2.1) and qualitative data collected by questionnaire

[3]https://github.com/eddieantonio/plains-cree-touch-keyboard/tree/master/release/nrc/nrc_crk_cans/extras

[4]https://keyman.com/downloads/

[5]https://keyman.com/keyboards/nrc_crk_cans

[6]https://help.keyman.com/keyboard/nrc_crk_cans/1.0.1/nrc_crk_cans.php

(a) Default layer (b) kV layer (c) kwV layer

Figure 5: Switching layers in the Keyman layout. (Note: images have been scaled down).

(Section 6.2.2). The remainder of this section describes the demographics of participants and the methodologies of the quantitative and qualitative analyses.

6.1 Participants

For the purposes of this case study, we recruited three participants from the Edmonton, Alberta, Canada area. Participants were recruited through open calls at the University of Alberta and targeted recruitment of Plains Cree speakers with syllabics literacy. Participants ranged from 22–52 years of age (with a mean age of 32.67). Females composed two of the three participants, and all three participants identified as First Nations or Métis. Two of the three participants completed all parts of the study. Every participant had an extensive background in typing on smartphones, regularly communicated in Plains Cree, and used syllabics on a smartphone or computer at least multiple times a week. Given that testing focused on reproducing stimuli, fluency in Plains Cree was not a requirement, but familiarity with syllabics and smartphones was. Figure 6 provides basic demographic information for participants and their relationship to both Cree and syllabics on a 5-point Likert scale measuring how much they agreed with each statement.

Although no participants had made use of our Keyman layout previous to this study, Participants A and C both had prior experience using the FirstVoices layout. Participant B had no prior experience with either of the layouts studied. Although participants would have ideally had no knowledge of either layout tested, considering that there are only a few options available for typing syllabics on a smartphone, prior experience was unavoidable. Worth noting is that, despite being *able* to read and write syllabics, Participant B expressed discomfort in doing so.

6.2 Methodology

We invited each participant to a 90 minute study, conducted at the University of Alberta. The 90 minute study comprised of a typing study to collect quantitative data regarding the speed and accuracy of each keyboard layout, followed by a short questionnaire to collect qualitative data.

6.2.1 Quantitative Methodology

To collect quantitative data regarding the speed and accuracy of using both keyboard layouts, we had participants take part in a typing experiment. The typing experiment was facilitated by one of the authors.

Participants were given a Samsung A10 smartphone running the Android 9.0 operating system for the duration of the typing test. The Samsung A10 is 155.6mm tall, 75.6mm wide, and 7.9mm thick. It has a diagonal screen size of 6.2 inches (157mm). The typing experiment was presented using an ad hoc web application, running in standalone mode. We have posted the source code of this application online.[7]

The following methodology was repeated twice—once for the FirstVoices layout, and then again for the Keyman layout. First, one of the two keyboard layouts was selected by the study facilitator. The study facilitator then left the room, giving participants a chance to **learn** and **practice** using the layout, privately, and at their own pace. We intentionally did not teach participants how to use the selected layout; instead, participants had to teach themselves how to use it. We presented 10 hand-picked words as prompts on a single screen. Participants were asked to type the prompts in a text box positioned directly underneath it. These prompts could be completed in any order. It was not mandatory for participants to type these prompts accurately; it was only mandatory that each prompt was attempted. No data were collected during this period.

After the practice period, the participants asked the study facilitator back into the room. Then, participants were given a chance to ask the facilitator how to type *specific* character sequences. The study facilitator would instruct in a rehearsed and structured form, for any question asked by the participant. Once satisfied, participants moved on to the typing task. The facilitator instructed participants to type each prompt as quickly and as accurately as possible. The facilitator left the room again to allow the participant to complete the typing task in private. We presented 30 sentences of Plains Cree syllabics to participants for each layout. We used a different set of 30 sentences for each layout, resulting in 60 different sentences presented in the study. Before seeing each stimulus, participants were allowed to take a break, if desired. The sentences used as stimuli were first prompted without a text box for 30 seconds to prime participants. This was to encourage participants to fully read the stimulus. After the 30 second priming period, a text box would appear, allowing participants to type the prompt.

We manually constructed stimuli sentences to test the most common syllabics observed in the Ahenakew-Wolfart corpus (Arppe et al., 2019). This was chosen over directly pulling sentences from the mentioned corpus because the conversational nature of the sentences required excessive editing. Furthermore, many of the "clauses" in the corpus were defined by speech pauses, and include multiple clauses that made little sense without the requisite context. In order to capture behaviour as naturally as possible, participants

[7] https://github.com/eddieantonio/typing-test.

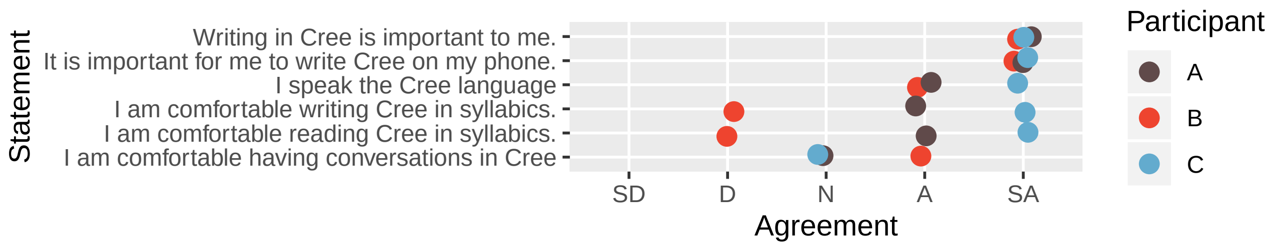

Figure 6: Likert scale responses for participant demographics. Responses from left-to-right are strongly disagree, disagree, neutral, agree, and strongly agree.

were not presented with individual words, but grammatical clauses or sentences. Sentences were constructed to be fully grammatical clauses that could be easily understood, even if incomplete (e.g. the English subordinate clause: *if I ever see him again…*). There are 95 individual syllabics used in this corpus. Because constructing a set that covers all 95 syllabics would require a large number of sentences, only those characters in the 90th percentile by frequency were tested. The remaining syllabics occurred fewer than 20 times in a corpus of over 200,000 characters. The number of sentences presented was capped at 30 per layout to maximize the number of syllabics tested without overly taxing participants, as participants took roughly 80 minutes to complete two sets of 30 sentences (60 sentences in total).

Data was collected starting when the participant tapped on the text box, issuing a *focus event*. Upon focusing the text box, the keyboard would pop-up, allowing the participant to type. We collected timing information for each key tapped by the participant, including the backspace key. Keystroke events were collected in JavaScript by registering an event handler on the HTML <textarea> used for the text box, listening on all input DOM events. Timestamps were collected by recording the return value of performance.now(), which yields timestamps with a 0.1 ms time resolution on Google Chrome 78 for Android (McIlroy and Kyöstilä, 2018). Input events were collected until the participant tapped the Done button, in the upper left-hand corner of the screen.

We measured the speed of each layout by determining the time intervals between the user starting (the *focus event*) and finishing each stimuli (pressing the Done button). We then divided these times by the number of characters in each of the presented stimuli to determine the average time-to-type per character for each sentence. We did this because not all stimuli sentence contained the same number of characters.

In addition to speed, we assessed the accuracy of each layout. To determine each layout's accuracy we compared stimuli and input data via ocreval (Santos, 2019). In addition to error rates, we reviewed the various errors and categorized them into distinct types.

6.2.2 Qualitative Methodology

Qualitative data was collected directly after the typing experiment via an online questionnaire administered on a laptop given to each participant. Qualitative assessments were measured in two ways: an open ended invitation for the participant to provide any general feedback on each layout, as well as a set of 5-point Likert scale agreement ratings (as described for participant demographics). These ratings were composed of the following seven statements:

1. I would use this keyboard again to type Cree syllabics.
2. I would recommend this keyboard to my friends, family, and/or students.
3. Overall, I like using this keyboard.
4. I can type quickly with this keyboard.
5. This keyboard was easy to use.
6. I can type on this keyboard without making mistakes.
7. I could find each syllabic easily on this keyboard.

Participants were also asked to give any feedback they had in a free-form response for each layout.

The results of both the qualitative and quantitative assessments are presented and described in the rest of this paper.

7. Results

This section details the quantitative results (i.e., accuracies and averages) and qualitative results (i.e., questionnaire responses) of this case study.

7.1 Quantitative Results

The foremost quantitative result that we have access to is the accuracy rate of each layout. Regardless of ease or enjoyability, a keyboard that is prone to mistakes is an inferior keyboard. Table 2 details the accuracies of each layout for each participant. Overall, the two keyboards layouts performed quite similarly, though the FirstVoices layout appears to have a very slight advantage, with a mean of 96.50% compared to the Keyman layout's 96.06%. Due to having a negative reaction to using the Keyman layout, Participant B declined to progess beyond the practice stage on this layout.

As shown in Table 2, there appears to be significant differences between participants. Participant A's FirstVoices results were 5% higher in accuracy than their Keyman layout's results. Conversely, Participant C's Keyman layout accuracy was roughly 1.5% higher than their FirstVoices results. Participant B's FirstVoices results were lower than both Participant A's and Participant C's results.

The actual types of errors for each layout generally took one of three forms: mis-orienting characters (typing ᐯ instead of ᐱ), errors with a w-dot (adding one where there was none, not typing one when prompted), and general insertions/deletions of completely incorrect characters. Interestingly, regardless of participant, the FirstVoices layout tended to have a larger variety of errors. Conversely,

	FirstVoices	Keyman
Participant A	98.88%	93.70%
Participant B	93.70%	N/A
Participant C	96.92%	98.42%
Mean	96.50%	96.06%

Table 2: Keyboard Accuracies

the Keyman layout errors were largely those of spacing: the Keyman layout's novel feature— the thin, non-breaking space—was never used by Participant A and was frequently missed by Participant C. Spacing errors alone made up 31 out of 43 (72%) of the Keyman layout's errors. Since the thin spaces are a feature of the Keyman layout alone, when we disregard these errors, the overall accuracy of the Keyman layout rose to 98.8%, two percent points higher than the FirstVoices keyboard.

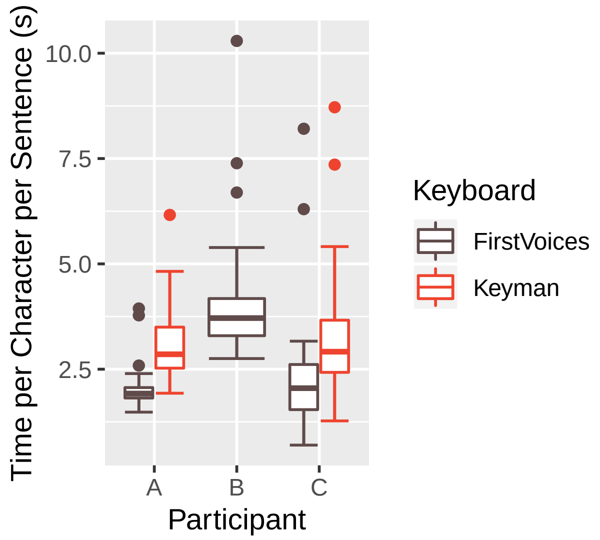

Figure 7: Average time-to-type per sentence (in seconds).

In addition to accuracy, we calculated the average time it took to type each character for each stimuli sentence. Because the number of characters varied between stimuli sentences, we opted to divided the total time it took to type each sentence by the number of characters in that sentence. This measure, *time-to-type*, was used to evaluate how fast a participant was able to type on each layout. Figure 7 plots the average time to type a character per stimuli sentence.

7.2 Qualitative Results

Participants as a whole preferred the FirstVoices layout. Figure 8 plots participant responses to each of the questions detailed in Section 6.2.2. The labels on the y-axes represent abbreviated forms of the questions from Section 6.2.2.

All three participants generally agreed with all statements for the FirstVoices layout, indicating positive attitudes toward the keyboard. The only negative ratings were from Participants A and C who disagreed that the keyboard allowed for accurate typing. Participant A also reported a neutral response toward the keyboard being quick to type on. Notably, all participants agreed that they would recommend the FirstVoices layout to friends and family, and that they would use the keyboard again. Participant C reported a strong agreement toward recommendation and regarding the ease to find keys on the keyboard (henceforth *navigability*). Results for the Keyman layout were more varied. Participant B *strongly disagreed* with all statements, suggesting a very negative impression of this layout. Participant C *disagreed* with all statements, except for describing ease of use, a statement with which they agreed. Participant A had mixed feelings: they disagreed that the Keyman layout was quick and navigable, were neutral as to how easy the keyboard was to use and how likely they were to recommend it, and agreed that they would use the keyboard again, liked the keyboard, and that the keyboard was accurate.

In freeform feedback for the keyboards, one participant reported issues with the FirstVoices spacebar being too small, and that the ᐦ key was too close to the backspace key, causing accidental deletions throughout the session. Participant A mentioned that they like the layout of the FirstVoices layout, and that once they realized each row contained syllabics with the same vowel, it became easy to use.

Regarding the Keyman layout, one participant described their issues as being that "This keyboard required too much thinking, slowing down the typing process. I liked the idea about it and its simplicity, but after a while I started not to like it just because it took too long." Another participant suggested that our layout was too rooted in English ideology, and that they did not think of syllabics of being procedurally generated first by a consonant to determine shape, and then by a vowel to determine orientation. This participant further suggested adopting a keyboard layout reminiscent of the "star chart" layout as described in Houle (2018). Although this layout is familiar to some, it is by no means learned by the majority of syllabics users.

Both layouts were criticized for being too small by multiple participants. They reported poor accuracy due to not being able to read key labels. One participant noted that the exclamation mark was unavailable on both layouts. In fact, this symbol was available on the Keyman layout, but required a long press to be accessed and so went unnoticed by this participant. Finally, one participant reported generally "having issues" with both keyboards and wanting a solution for mobile typing of Plains Cree syllabics; they made it clear, however, that the Keyman layout was not the solution they were looking for.

8. Discussion

The results described above expressed a general preference for the FirstVoices layout. On nearly every dimension, the FirstVoices layout was preferred over the Keyman layout, regardless of which participant was doing the ratings. It is worth noting, however, that Participants A and C report previous familiarity with the FirstVoices layout. Given their extremely limited exposure to the Keyman layout, the lack of confidence in using it is understandable. Accuracies were comparable between keyboards, though the FirstVoices' was slightly higher. However, most of the Keyman layout's errors were due to not using the non-breaking space, a feature not found in the FirstVoices layout. When ignoring these errors, the Keyman layout proved *more accurate*

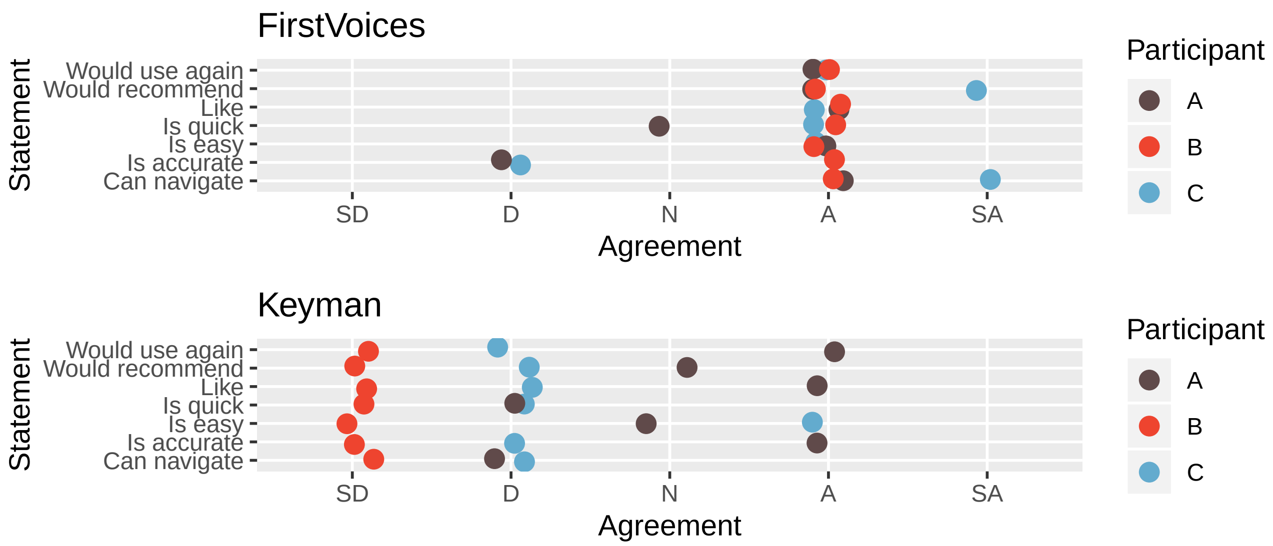

Figure 8: Responses to usage questionnaire about the layouts.

than FirstVoices keyboard. Further, the FirstVoices layout was observed to have a broader ranger of errors, though this may be due to the fact that it was the only keyboard used by Participant B, who exhibited a much higher error rate than the other two participants. The quantitative data suggest that despite being a more accurate keyboard, the Keyman layout was less pleasant to use.

In terms of qualitative assessments, all participants preferred the FirstVoices layout. Although some amount of preference is expected for a familiar keyboard layout, participants showed slower typing speeds on the Keyman layout and commented on the amount of effort it took to type on the Keyman layout. Although built from the ground up as a Cree-based keyboard, one that eschews European baggage, the Keyman layout supposed some amount of compositionally for the characters. Asking participants to first type a *final* version of a consonant and then presenting them with all syllabics using that consonant as an *onset* appeared to be unintuitive. Compared to the FirstVoices layout, which is a straightforward listing of all syllabics, participants had a harder time navigating through the keyboard to type the appropriate character. This in turn required a lot of thought. Considering that Plains Cree syllabic finals do not transparently map to the associated shape of their onset counterparts (e.g. ᐠ and /k/ shares no similarities to the shape of syllabics with /k/ as an onset, like ᑲ), it is possible that participants struggled to quickly determine which *final* was needed for a given syllabic shape. This disconnect may have significantly contributed to the experience of using the keyboard.

In addition to mental effort, the Keyman layout required a lot of comfort and familiarity with syllabics. It is unsurprising that Participant B, who was least comfortable in syllabics, was completely unwilling to use the keyboard.

Efforts to improve the ergonomics seemed not to factor much into participants reviews. Despite community members disliking the current options available for typing Plains Cree—including the FirstVoices layout—participants struggled throughout the case study with the new Keyman layout. It remains unclear as to whether or not this is an effect of having little experience with the keyboard. It is plausible that, once participants familiarized themselves with the Keyman layout, their opinions could change. We intentionally avoided giving participants explicit training, but the Keyman layout proved unintuitive; however, it would be interesting to know the opinions of typists who have gained significant experience on the layout, rather than the 90 minute session presented in this paper. Future evaluation could require a longer timescale, allowing participants to learn and practice the layouts.

9. Conclusion

This paper has described an attempt to build a mobile keyboard for writing in Plains Cree syllabics. To address community calls for a Cree worldview based syllabics keyboard, we built a keyboard layout using the Keyman infrastructure. This keyboard required participants to first select the consonant of the syllabic they wished to type before presenting them with a set of syllabics using that consonant as an onset. As there is no English on this keyboard, participants had to choose a consonant value based on the consonant's final character. This keyboard was tested in a case study along side the existing FirstVoices layout for comparison. Although accuracy was higher on the Keyman layout, participants unanimously preferred the FirstVoices layout. The Keyman layout was reviewed as hard to use, requiring much mental effort, and being unpleasant, and slow. The results of this paper indicate that, while there is a desire for alternatives to the solutions that currently exists, there is a high cost in introducing an unfamiliar typing system and asking people to adapt to it.

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