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Children's participation in /u/-fronting in Ontario English

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Abstract

This study investigates how children aged 4 to 12 years participate in /u/-fronting, a phonetically conditioned change in Ontario English in which the high back vowel /u/ is initially more fronted after coronal consonants than in other contexts. A picture naming task was used to elicit vowel tokens from children and their parents, and F1 and F2 measurements were extracted using *FAVE*. Children in all three age groups (4-6, 7-9, 10-12 years) were found to have significantly higher F2 values for /u/ (indicating more fronting) than adults in the non-coronal environment. This pattern does not appear to follow the predicted pattern of incrementation of sound change by older children. Instead, the findings may reflect overgeneralization of /u/-fronting, with young children extending the change to a new phonetic context during acquisition, or an earlier start to the incrementation of this variable in this population.

Keywords: /u/-fronting; sound change; Ontario English; transmission; incrementation

Introduction

This study examines the role of child learners in /u/-fronting, a vowel change in progress in many varieties of English worldwide. Research on /u/-fronting in adults across North America shows that young speakers produce /u/ with a more advanced position in the vowel space than older speakers do (e.g., Boberg, 2008, 2010:225-231, 2011; Labov et al., 2006:152-168). In most of these studies, the youngest speakers are adolescents, and the potential participation of children in the change is not examined. However, the sociolinguistic and diachronic literature acknowledges that children are implicated in sound change. Labov (2001:446-465, 2007) has proposed that generational changes involve the process of incrementation, in which pre-adolescents detect age-related differences in variant use in their community and shift their systems in the direction of change. Historical linguists have highlighted another possible site of innovation in the process of language acquisition, theorizing that young children

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may introduce and/or advance linguistic changes as they reanalyze the adult input transmitted to them (e.g., Halle, 1962; Kiparsky, 1974; Lightfoot, 1979, 1997).

A growing body of empirical work at the intersection of sociolinguistics and language acquisition provides support for both mechanisms of change, while highlighting the complexity of the factors influencing children's acquisition of variable forms. Many studies have shown an adolescent peak in apparent time in the use of innovative variants (e.g., Holmes-Elliott, 2016; Labov, 2001:446-465; Tagliamonte & D'Arcy, 2009), reflecting incrementation effects that have also been confirmed in real-time research (e.g., Denis et al., 2019; Holmes-Elliott, 2021). Other recent work has demonstrated that young children do not always replicate their parents' variable productions from the outset (e.g., Hall & Maddeaux, 2020; Smith & Holmes-Elliott, 2022). These input-divergent patterns in children, arising from cognitive, developmental, or other factors, may align with the direction of change in a particular variable, while also interacting with social factors during the incrementation process. However, while the contributions of adolescents to generational linguistic change are well-attested, the potential participation of preschoolers and school-age children remains understudied.

In this paper, I aim to investigate how children aged 4 to 12 years participate in a widespread sound change in progress, /u/-fronting, by comparing their productions with those of their parents in Ontario, Canada. In the following section, I review the theories and empirical research regarding children's contributions to language change and introduce the variable of interest, /u/-fronting. I then describe the methods of the study, before presenting and discussing the results for /u/ productions by age group and other linguistic and social factors.

Background

Theoretical perspectives on children and linguistic change

Among sociolinguists, the prevailing view of how linguistic changes progress across generations of speakers is Labov's (2001:415-465, 2007) model of transmission and incrementation. This model proposes that young children initially replicate the variable linguistic patterns of their caregivers faithfully, and then undergo "vernacular re-organization" (Labov, 2001:415) between the ages of about 4 and 17. During this time, children discover that their older peers are more advanced in changes than they (and their caregivers) are and begin to shift their own productions in the direction of change through the process of incrementation (Labov, 2007:380). Incrementation "may take the form of increases in frequency, extent, scope, or specificity of a variable" (Labov, 2007:346), and is assumed to be led by female speakers, explaining the fact that men tend to lag a generation behind women in most linguistic changes. In female speakers, childhood incrementation leads to an adolescent peak in the use of innovative forms at around age 17, when an individual's linguistic system stabilizes. In this way, the model predicts that adolescents will show more advanced participation in changes in progress than younger children who have not yet undergone vernacular reorganization, as well as more advancement than older speakers who acquired the

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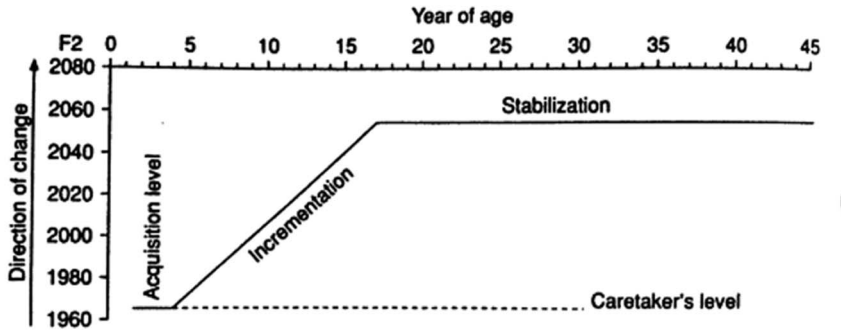


Figure 1. A linear model of incrementation for a single female speaker from 1 to 45 years of age. Reproduced from Labov (2001:448, Figure 14.1) with permission of John Wiley & Sons — Books; permission conveyed through Copyright Clearance Center, Inc.

change at an earlier stage. Labov's (2001:448) simplified model[1] of this process is presented in Figure 1, showing a linear increment in F2 values (representing a vowel that is fronting over time) each year throughout childhood in a single female speaker.

While incrementation focuses on the role of pre-adolescents, several diachronic linguists have proposed that mechanisms of child language acquisition (or transmission) may also be a source of language change. Kiparsky (1974:262), for example, described historical change as resulting from "imperfect learning, in which residues of the intermediate grammars created by children during the acquisition of language are carried over into the adult system." In this view, children's innovative grammars must be similar enough to the adult grammar to overcome potential correction and become adopted by the wider community, leading to changes across generations of speakers. The specific mechanisms in child language learning that introduce innovation to the system are not examined in detail in this literature. However, more recent work has begun to consider the inherent tendencies children may bring to the task of language learning and what predictions these can lead to in terms of changes in variable patterning over time. In the next section, I turn to the empirical research on children's acquisition of variation and change.

Child acquisition of linguistic variation and change

The incrementation model has gained empirical support from numerous sociolinguistic studies examining changes in progress across all domains of language. In phonology, Labov's (2001:455-460) study of nine vowel changes in Philadelphia showed that female speakers ages 13 to 16 years were more advanced in every change than those under 13, as well as older speakers, exemplifying the predicted adolescent peak. Holmes-Elliott (2021) studied three phonological changes, including /u/-fronting, and both her real- and apparent-time findings support the theory that pre-adolescent learners extract the age-based patterns in their community and increment changes in progress. Studies of morphosyntactic and discourse-pragmatic changes also confirm Labov's (2001:446-465) model: Tagliamonte and D'Arcy (2009) found adolescent peaks for five of their

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six variables, while Denis et al. (2019) provided real-time evidence for incrementation of the quotative *be like* in the same community.

Alongside these robust age effects, results have been more varied for the predicted gender effects in incrementation, suggesting that other factors such as the type or stage of change may be relevant to the process. In Tagliamonte and D'Arcy's (2009) study, both male and female speakers showed adolescent peaks in morphosyntactic and discourse-pragmatic variables, contrary to Labov's (2001:455-460) findings for phonological changes. The authors suggested several possible explanations for this lack of the predicted gender difference, including the different levels of grammar undergoing change; the social embedding of the change; and its origin, rate, or stage of development. In any case, their study revealed that men do indeed participate in the incrementation process, but at a slower rate than women. Holmes-Elliott (2016) further investigated the relationship between gender and incrementation in an apparent-time study of a male-led change, TH-fronting, and confirmed an adolescent peak in both male and female speakers. The peak was more pronounced in the female participants, a finding that Holmes-Elliott (2016) attributed to two factors: the late stage of the change in men, with women at an earlier and more active stage, and female children's initial acquisition of the more conservative patterning of their mothers, followed by increased incrementation in this group.

In general, these findings from the sociolinguistic literature suggest that children's participation in language change is related to social factors: as pre-adolescents seek to align themselves with their slightly older peers, they further advance changes in progress in their community. However, few of these studies have included children younger than 9 years old, making it difficult to evaluate the claims of the transmission side of the model. An emerging body of work investigates the relationship between language acquisition and language variation and change more directly, using both naturalistic and experimental paradigms. For example, MacKenzie's (2019) work on the role of individual cognitive differences in actuating sound change included the childhood case of /t/-glottalization in Buckie (Smith & Holmes-Elliott, 2017). MacKenzie (2019) highlighted how preschool-aged children initially misanalyzed the syllabic consonant environment as an intervocalic one, showing a lower rate of glottal replacement in the former environment than their caregivers. By pre-adolescence, children showed the same rate of glottalization as adults in the syllabic consonant environment, reflecting a developmental change in their mental representations. Smith and Holmes-Elliott (2022) expanded on these findings in their real-time study of glottal replacement, examining children's spontaneous productions in preschool and pre-adolescence. As preschoolers, 13 of the 14 children replicated the rates of use of their caregivers, and all the children showed the expected increment in glottal replacement by pre-adolescence. However, transmission from caregivers to their children was not entirely faithful, as preschoolers showed some differences in glottal stop use across linguistic contexts compared to both their caregivers and the community. By pre-adolescence, these children's systems had changed to resemble those of the community in most respects, but with higher overall rates of glottal replacement and a flattening of constraints; however, one particular context (the medial onset context, e.g., *nineteen*) continued to resist glottal replacement throughout childhood. Smith and Holmes-Elliott (2022) explored developmental-articulatory and typological explanations for these differences

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between children and adults, as well as the stigma against glottal stops that may influence caregiver use. Their work confirmed that children's incrementation of change is influenced by many factors, both developmental and social, while also suggesting that some innovative reanalyses by preschoolers may persist throughout childhood.

On the experimental side, studies of artificial language learning have aimed at uncovering potential cognitive biases in language learners of different ages. When learning artificial languages with inconsistent patterns of variation, Hudson Kam and Newport (2005, 2009) showed that children almost always regularize the use of the variants, whereas adults tend to match the probabilities of forms in the input. It is important to note, though, that sociolinguistic variation is not inconsistent in this way, and no variationist studies to date have found that children regularize. With artificial languages that do contain predictable sociolinguistic patterns, such as gender-based variation, children also initially show more regularization than adults (Samara et al., 2017). However, with more exposure to the artificial language in this study, the learners' tendency to regularize decreased, raising the question of how long these cases of imperfect learning might persist in a child's grammar.

In experiments with real languages, some recent studies have suggested that these kinds of child learning errors or biases can align with directions of historical change. Cournane (2014, 2015) has focused on the modal cycle, in which modals such as *must* gradually lose their root (obligation) meanings and become epistemic. In her picture- and sentence-preference tasks, 5-year-olds over-generated the epistemic interpretation of sentences like *The girl must take a bath*, anticipating the next phase of this cyclic change, a bias that Cournane and Pérez-Leroux (2020) related to the children's stage of syntactic development. In an elicitation study, Hall and Pérez-Leroux (2022) examined a change in progress in the possessive alternation between *-s* and *of*, in which *-s* is gradually gaining in frequency with certain types of inanimate possessors. They found that 4- to 6-year-old children produced *-s* more frequently than older children and adults while following the same constraints, showing a type of overgeneralization of this form. Pre-adolescents also showed marginally more use of *-s* than both their younger peers and adult speakers, suggesting that socially driven incrementation may still be active as a separate process from the initial change seen in younger speakers.

Based on these acquisition studies, Cournane (2019) has proposed a model of linguistic change that incorporates processes of both transmission-based change and incrementation, with an individual child learner's path plotted against their caregiver input, as shown in Figure 2. While this model provides a general path of potential development for an individual faced with variable input, more research is needed to make specific predictions about the mechanisms of child language acquisition and how these might affect changes in progress. Labov (2007) observed that incrementation may affect the patterning of a variable in many ways, including the frequency of variants and the scope or specificity of constraints. The studies reviewed thus far suggest a few possible influences on these processes, such as the type of change in progress, its social embedding, and the stage or rate of change. Developmental tendencies such as overregularization or misanalysis of constraints may also play a role, interacting with social and linguistic factors throughout the childhood incrementation process.[2] In the following section, I focus more specifically on the variable of interest, /u/-fronting, reviewing the

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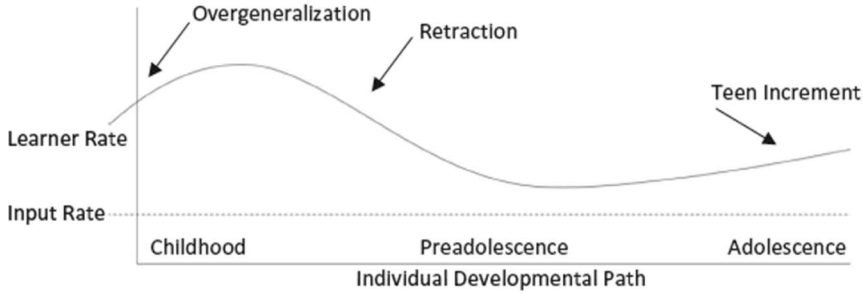


Figure 2. Reverse-U model of incrementation. Reproduced with permission of Walter de Gruyter and Company from Cournane, Ailís (2019:143, Figure 11). A developmental view on incrementation in language change. *Theoretical Linguistics* 45(3-4):127-150; figure does not belong to OA license.

evidence to date on variation and change in this vowel, before presenting my research questions and predictions.

Variation and change in /u/-fronting

Origins and factors in /u/-fronting

In the *Atlas of North American English* (*ANAE*), Labov and colleagues (2006:152-168) identified the fronting of /u/ as an active sound change across almost all of North America at the time. There is some disagreement in the literature as to the origin of this change. Labov (2010:106-111) proposed that North American /u/-fronting arose from the loss of the historical /j/ glide after coronal consonants in words such as *dew, suit*, and *tune*, resulting in a merger between /ju/ and /u/ in this context (i.e., no distinction between *dew* and *do*) by the mid-twentieth century. The fronting of /u/ after coronal consonants functioned as a compensatory change for the loss of this onset glide, and in later stages of the change, /u/ became fronted after non-coronal consonants as well, which Labov (2010:107) attributed to "the binding force of the phoneme /uw/." Other proposals ascribe /u/-fronting after coronal consonants to coarticulation, with the front position of the tongue extending into the following vowel. Harrington et al. (2008) explored these coarticulation effects in both production and perception, linking more advanced /u/-fronting to younger listeners' lack of compensation for the fronting effects of preceding coronals. Relatedly, Boberg (2010:231) attributed the widespread fronting of /u/ to "natural phonetic pressures on back vowels" that also affect /ow/, given the greater articulatory energy required to maintain a high-back tongue position.

In line with these proposals, most research on /u/-fronting compares the F2 position of /u/ in post-coronal environments /t d n s z ʃ tʃ dʒ/ with non-coronal or "elsewhere" conditions, including /p b m f k g/.[3] The only exception to this pattern is the context of a following /l/: this environment strongly disfavors /u/-fronting in most dialects, except in Southern American English (Koops, 2010; Labov et al., 2006:152-168) and Manchester English (Baranowski, 2017). In regions where /u/-fronting is complete, apparent-time studies confirm that the allophonic distinction diminishes among younger speakers in the later stage, as /u/ becomes fronted in non-coronal as well as coronal contexts (Baranowski, 2008; Fridland & Bartlett, 2006; Harrington

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et al., 2008; Jansen & Mompean, 2023; Koops, 2010; Labov, 2010:106-111). Apart from these age effects (discussed further below), /u/-fronting does not appear to be strongly associated with social factors. Studies typically do not find significant relationships with social group or speaking style (e.g., Fridland, 2008; Haddican et al., 2013; Holmes-Elliott, 2021), and there is generally no social commentary about the change, although Eckert (2011) associated /u/-fronting with the speech of Californian Valley Girls and surfers. Findings for gender are mixed: most earlier studies showed the expected lead by female speakers (e.g., Baranowski, 2008; Eckert, 2011; Labov et al., 2006:152-168), while more recent work showed no consistent patterning (e.g., Holmes-Elliott, 2021; Jansen & Mompean, 2023). In addition, Jansen and Mompean (2023) found no effect of word frequency in their review of studies of /u/-fronting in Received Pronunciation, suggesting that usage-based factors do not noticeably affect this variable.

In most of these studies, the youngest speakers included were adolescents and young adults, who showed more /u/-fronting overall than older speakers. However, a few studies have included pre-adolescents, providing some preliminary information about children's potential participation in the change. Baranowski's (2008) study of back vowel fronting in Charleston, SC, included nine speakers ages 8 to 18 years, who showed stronger fronting of /u/ than older speakers in both coronal (/Tuw/) and non-coronal (/Kuw/) environments. Holmes-Elliott's (2021) real-time panel study of /u/-fronting in Southern British English showed less overall /u/-fronting in children's speech at 9 to 11 years old than a few years later at ages 13 to 15 years, and an apparent-time comparison with older speakers confirmed the presence of an adolescent peak among 15- to 17-year-olds. The phonetic conditioning of /u/ also showed slight weakening over time, with non-coronal fronting starting to catch up to the coronal environment in the speech of 13- to 15-year-olds. These findings suggest incrementation of /u/-fronting over the (pre-)adolescent years, as older children detect and advance the change in progress in their community.

A few studies from other dialect regions have briefly considered /u/ productions in younger children, without providing detailed analyses of allophonic effects. Roberts (1997) reported that 3- and 4-year-old children in Philadelphia had acquired the local fronting of both /u/ and /ow/, showing one child's mean /u/ position in the high front quadrant of the vowel space. McGowan and colleagues (2014) also provided evidence of /u/-fronting in several 42-month-olds from three dialect regions in the USA, as well as strong within-subject variability in the F2 of /u/, and considered these findings to be reflective of regional dialect features. These findings suggest that /u/ is worth examining further in child populations, given that children as young as three appear to show adult-like patterns of regional variation, at least for the overall position of /u/. I now turn to a review of the literature on /u/-fronting in the Ontario English context.

/u/-fronting in Ontario English

In the *ANAE*, Labov et al. (2006:101, 103) identified Toronto as a region that showed extreme /u/-fronting in the coronal environment and moderate /u/-fronting after non-coronals at the time. Boberg (2008, 2010:225-231, 2011) further investigated /u/-fronting in speakers from eight regions across Canada in the *Phonetics of Canadian English (PCE)* project and found significant age effects, with speakers born after 1965

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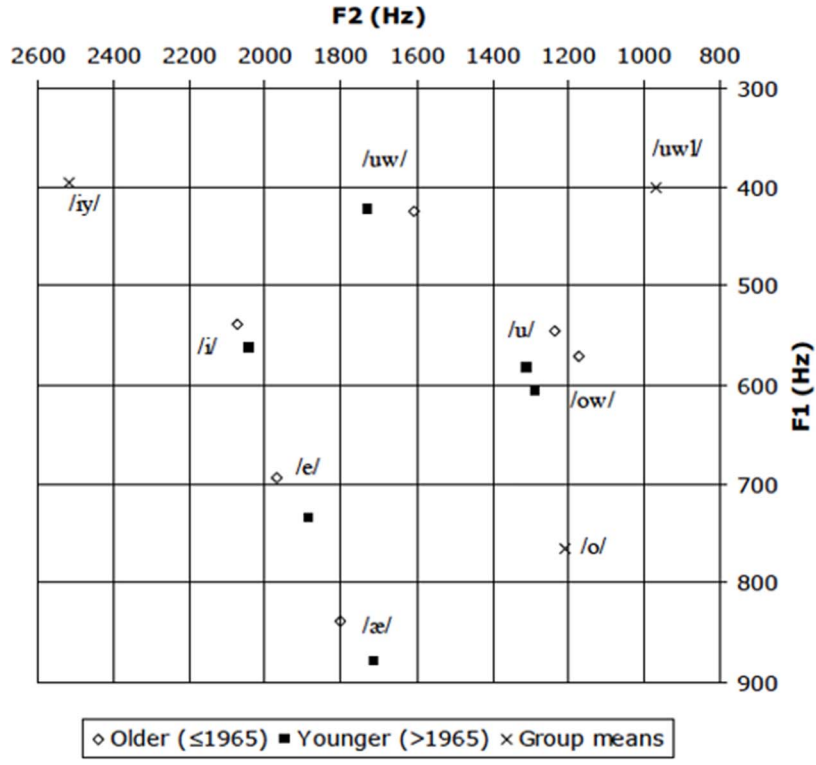


Figure 3. Age differences in vowel positions in the *PCE* data. Reproduced from Boberg (2010:230, Figure 5.3) with permission of Cambridge University Press through PLSclear.

producing more fronted /u/ than older speakers. In addition to these apparent-time results, Boberg (2021:132-134) conducted a real-time analysis of North American film and television speech and found young female actors from Ontario and British Columbia to be among the most advanced in /u/-fronting. In terms of phonetic context, Boberg (2008, 2010:225-231, 2011) separated the pre-/l/ environment from all others and showed that /u/ before /l/ remained in the traditional high back position in Canadian English. These results are shown in Figure 3, along with the rest of the vowel space for speakers before and after 1965; the vowel of interest is /uw/, with the pre-/l/ context identified as /uwl/ (and the vowel labeled /u/ corresponding to /ʊ/).

Boberg (2011) reported that the most innovative speakers, including several from Ontario, were moderately to extremely advanced in /u/-fronting compared to those from less urbanized areas, and female speakers were more advanced in the change than males. Boberg's (2008) word-level analyses revealed the word *do* to be the most advanced overall, appearing close to /i/ in the vowel space, followed by central productions of *tooth, too,* and *soon*, while *boots* and *food* showed only moderate

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advancement from the pre-/l/ position. In his subsequent work, Boberg (2010:232-241, 2011) examined a few individuals' productions in more detail; these analyses confirmed that both older and younger speakers produced /u/ variably, with more fronting of coronal-initial words such as *do* than other words. However, the few young women he profiled (born between 1979 and 1983), including two from Ontario, appeared to be in a later stage of the change: their post-coronal tokens occupied the high front quadrant of the vowel space (behind /i/), and /u/ after non-coronals was fronted to the central position.

In more recent research in Ontario, Smith (2018) compared speakers of different age groups from Toronto and three northern communities and found more fronting by younger adults (ages 20 to 39 years) in the non-coronal context (/Kuw/) in each location, with /Kuw/-fronting progressing more slowly in the north than in Toronto. Denis et al. (2023) focused on Multicultural Toronto English, a multiethnolect spoken by young, racialized speakers in the region, finding that most of their speakers aged 11 through 25 years were fronting /Tuw/ and /Kuw/ in ways consistent with Normative Canadian English. Female speakers showed more fronting than males, which the authors pointed out may be reflective of the typical male lag in incrementation and/or the male speakers' "agentive resistance" to the normative pattern (Denis et al., 2023:56).

Finally, in the most direct precursors to the present study, Hall and Maddeaux (2020) and Hall (2020) examined /u/ productions by children aged 4 to 12 years and adults (both parents and non-parents) in Ontario. These studies separated coronal and non-coronal environments for /u/, using a combination of picture naming and reading list data,[4] and found that children showed more /u/-fronting than adults in the non-coronal onset environment. More specifically, the youngest children (ages 4 to 6 years) had higher F2 values for /u/ in the non-coronal environment than both older children (ages 10 to 12 years) and adults. The authors interpreted these results as reflecting overgeneralization by young children: 4- to 6-year-olds appeared to be extending the change to a new environment, thereby advancing /u/-fronting to its final stage. As outlined in the following sections, the present study aims to confirm these earlier findings by including more participants (48 children versus 24 and 40 in the previous studies) and only one source of data (picture naming, rather than picture naming only for the youngest children and a mix of picture and reading list data for the older children and adults), in order to further assess children's contributions to the /u/-fronting change in Ontario English.

Research questions

Based on the preceding review, /u/-fronting is a promising variable to investigate for evidence of children's participation in vowel change: children acquire /u/ relatively early, but it is unclear whether the linguistic and social factors that condition /u/ in Ontario adults also regulate children's productions. In addition, this variable has a clear expected trajectory of change, given that research on other varieties shows that the allophonic distinction between coronal and non-coronal contexts disappears as the change nears completion. In this study, I aim to examine /u/ productions by Ontario children ages 4 to 12 years and their parents in order to answer the following questions:

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1. Do children differ from adults in /u/-fronting?
2. How is /u/-fronting constrained by phonetic context, gender, and age group?

If children initially replicate their input, then the youngest children in this study should show the same overall /u/-fronting patterns as their parents. However, children may instead advance the change by generalizing /u/-fronting across phonetic contexts, showing the erosion of constraints that is typical of late-stage changes. If this change is related to children's tendency to overgeneralize in acquisition, then I would predict more fronting in the youngest children in the non-coronal context compared to their parents' /u/ position in this environment. Older children might show the same patterns observed in the younger children, or they might diverge; we may see incrementation effects as older children advance the change beyond the level of young children and adults, potentially generalizing to the non-coronal environment at this later stage. On the other hand, the older children might retreat from the overgeneralized patterns seen in younger children as they continue to learn the allophonic conditioning of /u/. Based on previous work, I may also expect to find significant gender effects, with female speakers leading the change overall or in certain age groups and/or phonetic contexts. The following section details the methods used to investigate these hypotheses.

Methods

Participants

In order to examine vowel productions across childhood, 48 child participants were recruited through daycare centers and professional contacts and separated into three age groups: 4- to 6-year-olds, 7- to 9-year-olds, and 10- to 12-year-olds. Children were included in the study if they were monolingual English speakers (with a maximum rating of 2 on the "Other language" scale in the background questionnaire—see Appendix A), raised in the Greater Toronto Area (GTA) or a nearby community since at least age two, and reported as typically developing by their parent(s) and/or teacher. Data were collected from an additional 23 child participants who did not meet the inclusion criteria for reasons of language background (14 children), having recently moved to Ontario (one child), reported language-learning difficulties (two children), inability to complete the tasks (two children), and noisy recordings (four children).

The majority of primary caregivers of the child participants self-reported their ethnicity as white or European (42/48), with university-level education (33/48), and white-collar occupations (36/48). Most primary caregivers were monolingual English speakers, and the primary language spoken in all households was English, but a total of 13 parents reported speaking another language with at least an intermediate level of proficiency (level 3 or above on the background questionnaire—see Appendix B).

For children who completed the study in their homes, one or both parents were also invited to participate, and a total of 23 parents of 25 of the child participants took part. The majority of these parents were monolingual English speakers, with five reporting intermediate or higher proficiency in another language that was not typically spoken in the home. With the exception of three parents who did not complete the questionnaire, all parent participants indicated white or European ethnicity and college or university-level education, and 17 out of 20 of the parents worked in white-collar occupations.

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Table 1. Study participants by age group and gender

	4- to 6-year-olds	7- to 9-year-olds	10- to 12-year-olds	Parents (ages 30-49 years)	Total
Males	8	8	8	4	28
Females	8	8	8	19	43
Total	16	16	16	23	71

Table 2. /u/ items in the word list by preceding/following context

Vowel	Coronal onset	Non-coronal onset	Lateral coda
/u/	soup	moon	tool
	suit	boots	pool
	juice	goose	
	two	food	

Table 3. Other vowel items in the word list

Vowel	Word					
/i/	bee	beak				
/ɪ/	six	kick	big	sit	milk	
/ej/	gate	cake				
/ɛ/	web	ten	bed	leg		
/æ/	map	cat	back	jam	pals	bat
	sad	bag	man	bad	flag	can
/ʌ/	cups	bug				
/ʊ/	book	cook				
/ow/	boat	coat				
/ɑ/	stop	dot	hot	sock		
/aj/	sign	tie	light	kite	side	slide
/aw/	down	cow	house	out	loud	

Table 1 shows the total number of participants in the study, separated by age group and gender.

Procedures and materials

To elicit all of the stressed monophthongs and diphthongs[5] of Canadian English in a variety of allophonic environments, a list of 56 common monosyllabic words was compiled. Ten of the words featured the vowel /u/ in the relevant phonetic contexts of a coronal onset (alveolars and palatals), non-coronal onset (labials and velars), and lateral coda (with any onset), as shown in Table 2. The remaining 46 words given in Table 3 were included to complete the vowel space and aid in vowel normalization.

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This picture shows a… **"cat"**	This face isn't happy, it's… **"sad"**
	

Figure 4. Sample pictures and prompts for the vowel elicitation task.

To elicit these vowels from both children and adults, I designed a picture naming task. This task was developed as an adaptation of the reading list approach to studying phonological variation, using pictures instead of written words to allow younger children with limited literacy skills to participate. Roberts and Labov (1995) similarly used a picture naming game with children to elicit vowels in various phonetic contexts, finding that it was effective with this population and did not result in the style shifting effects often seen in adults reading word lists. Pilot testing of the picture naming task with seven children indicated that this method was effective with those in the target age range.

Pictures representing each word in Tables 2 and 3 were obtained from the *OpenClipArt* website and presented in random order in a *PowerPoint* presentation. The words were elicited via sentence completion (see Figure 4 for two sample prompts), and children and parents were asked to repeat each word twice. Appendix C provides the full set of instructions for the vowel task and the list of items in order.

Each participant's speech was recorded on a Zoom H4 recorder with an external Audio-Technica l AT831b lavalier microphone. Before or during each child's session, the caregiver completed a written background questionnaire to elicit demographic information about the family (see Appendix A).

Analysis

The picture elicitation data were first transcribed into *ELAN* (version 5.3, ELAN, 2018), and then the onsets and offsets of each vowel were annotated in *Praat* (Boersma & Weenink, 2016) using the *FAVE*-align tool (Rosenfelder et al., 2014). *FAVE*-extract (Rosenfelder et al., 2014) was used to measure F1 and F2 frequency values at five points throughout each target vowel. To minimize formant tracking errors, the *FAVE* script uses gender-specific formant ranges for extraction (0-5000 Hz for adult males, 0-5500 Hz for adult females); for children, the female range was used. F1 and F2 measurements from the 35% point for each vowel were plotted for each speaker and manually checked for measurement errors, which were then corrected by hand.

All 6,000 corrected vowel measurements were normalized using the Lobanov (1971) method via the *NORM* suite (Thomas & Kendall, 2007). The vowels were plotted using the *ggplot2* (Wickham, 2016) and *phonR* (McCloy, 2016) packages, and linear mixed effects analyses of the normalized and scaled F2 values for /u/ were carried out using

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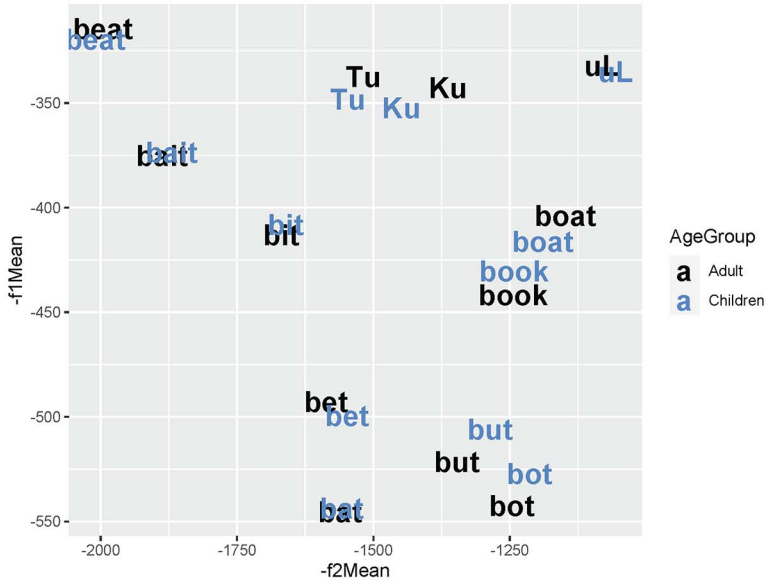


Figure 5. F1 × F2 vowel space (Lobanov-normalized and scaled to Hz) for children and adults, with /u/ split by context (children $n = 4029$, adults $n = 1971$).

the *lme4* (Bates et al., 2015) and *lmerTest* (Kuznetsova et al., 2017) packages in the *R* environment (R Development Core Team, 2021).

Results

Children versus adults by context

The first step in the analysis involved plotting the vowel space for all adult and child participants, as shown in Figure 5, in order to confirm the change in progress in /u/. For all vowels except /u/, a *bVt* word is used to represent all tokens of that particular vowel. For the target vowel, /u/, the tokens are split by phonetic context: Tu represents /u/ following all coronal consonants, uL is /u/ following any onset but preceding /l/, and Ku is /u/ following velar and labial (non-coronal) consonants. (See Appendix D, Table D1, and Appendix E, Table E1, for the means and standard deviations of the raw, Lobanov-normalized, and normalized and scaled F1 and F2 measurements of /u/ for children and adults, separated by phonetic context.)

Figure 5 (and Table D1 and Table E1) indicates that there are both age-related and contextual differences in /u/ productions. All speakers show more /u/-fronting in the post-coronal environment than following other consonants, while /u/ in the pre-/l/ context remains in the high back position. However, children appear to have a smaller difference between /u/ productions in the Tu and Ku contexts than adults do, reflecting more fronting of /u/ in the non-coronal context. Figures 6 and 7 further illustrate these contextual differences in the two groups, showing more overlap between tokens in the Tu and Ku contexts in children than adults.

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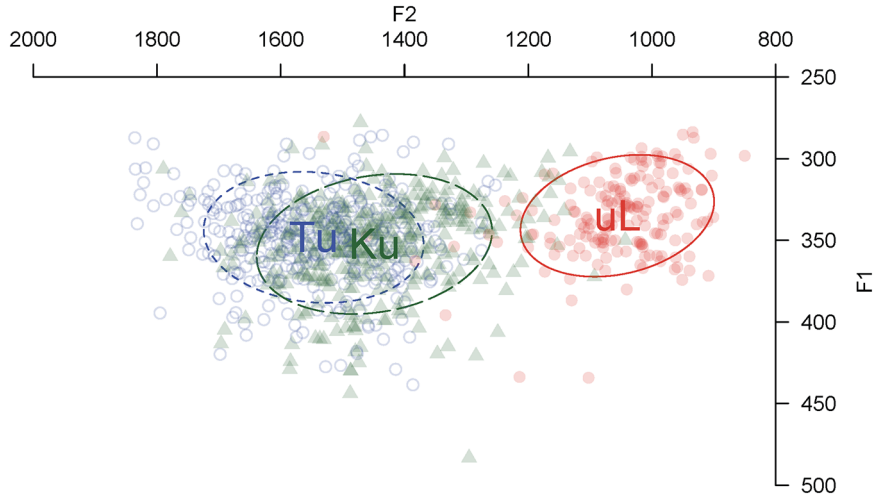


Figure 6. /u/ by context in child speakers ($n = 922$).

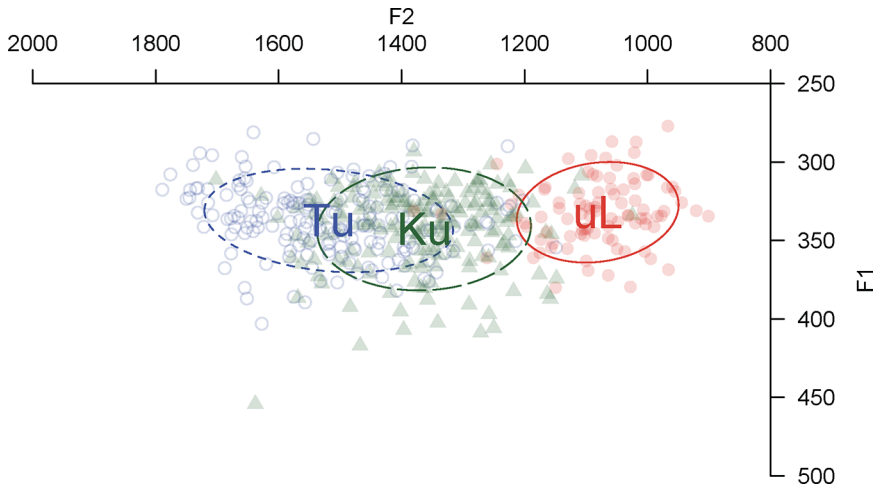


Figure 7. /u/ by context in adult speakers ($n = 454$).

Age group, context, and gender

I now turn to the main comparisons of interest based on the transmission and incrementation model, which predicts differences in apparent time between adult speakers and the three age cohorts of children, as well as potential gender differences. More specifically, it is expected that older children will be more advanced in /u/-fronting than the other age groups, with a smaller degree of difference between the coronal and non-coronal contexts, and female speakers should show more /u/-fronting than male speakers. Table 4 provides the descriptive statistics for these comparisons, presenting

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Table 4. Token counts and mean scaled F2 values of /u/ by context, gender, and age group

	Tu		Ku		uL		Total	
Group	*n*	Mean (Hz)	*n*	Mean (Hz)	*n*	Mean (Hz)	*n*	Mean (Hz)
Females	**338**	**1536**	**338**	**1432**	**164**	**1067**	**840**	**1402**
Adult	152	1522	151	1380	76	1083	379	1377
4-6 y.o.	61	1528	61	1476	31	1046	153	1409
7-9 y.o.	63	1556	64	1480	31	1074	158	1430
10-12 y.o.	62	1559	62	1467	26	1036	150	1430
Males	**218**	**1540**	**212**	**1403**	**106**	**1061**	**536**	**1391**
Adult	30	1502	29	1279	16	1073	75	1324
4-6 y.o.	61	1540	59	1430	27	1082	147	1412
7-9 y.o.	63	1559	62	1427	31	1038	156	1403
10-12 y.o.	64	1540	62	1411	32	1060	158	1392
Total	**556**	**1538**	**550**	**1421**	**270**	**1065**	**1376**	**1398**

the token counts and mean normalized and scaled F2 values of /u/ by context, gender, and age group.

Table 4 indicates partial confirmation of the expected differences: female speakers show more fronting overall than males, particularly in the Ku context, and the older groups of female children front /u/ more overall and in the Tu context than both younger children and adults. However, the findings for the Ku context do not appear to follow predictions, as the younger two groups of children show more fronting than the oldest group (as well as adults). To test these effects, I next ran a mixed effects linear regression model using the *lmer* function of the *lme4* package in *R* (Bates et al., 2015) on the normalized and scaled F2 values of /u/, with random intercepts for speaker and word.[6] Age group was entered as a fixed factor, with adults set as the baseline contrast, to examine how 4- to 6-year-olds, 7- to 9-year-olds, and 10- to 12-year-olds compare to their parents. The other fixed factors were gender, with females used as the baseline contrast, and context, with the most advanced post-coronal (Tu) context serving as the baseline, compared to non-coronal (Ku) and pre-lateral (uL) contexts. The model also included interactions between age group and context and gender and context, to test for differences in patterning across linguistic contexts between speakers of different genders and age groups. The model was stepped using the *drop1* function of the *lmerTest* package (Kuznetsova et al., 2017), showing both sets of interactions (between context and each of the other two factors) to be significant. Table 5 provides the results of the model.

Due to the interactions, the fixed effects in Table 5 are interpreted as simple effects, applying at the reference levels of the other factors. For context, /u/ in the coronal (Tu) environment is significantly farther forward than Ku and uL in the reference group of adult female speakers. For age group, the female speakers in the older two groups of children have a Tu position that is slightly more fronted than that of the female adults. However, the interactions are more revealing of differences between the age groups across contexts, as all three of the child groups show significantly more fronting than

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Table 5. Mixed effects linear regression on /u/ F2 values by context, age group, and gender

Random effects						
Groups	**Name**	**Variance**	**SD**			
Speaker	(Intercept)	1602	40.02			
Word	(Intercept)	2474	49.74			
Residual		9839	99.19			
Number of objects: 1376; Speakers: 71; Words: 14						
Fixed effects						
	Estimate	SE	df	*t*-value	*p*-value	
(Intercept)	1519.37	25.28	14.89	60.11	<0.001	***
Context (baseline: intercept/Tu in adult females)						
Ku	−150.69	32.77	12.31	−4.60	<0.001	***
uL	−456.59	41.88	12.84	−10.90	<0.001	***
Age group (baseline: intercept/adult females in the Tu context)						
4-6 y.o.	18.40	18.07	122.00	1.02	0.311	
7-9 y.o.	39.80	17.98	119.46	2.21	0.029	*
10-12 y.o.	32.66	17.97	119.45	1.82	0.072	.
Gender (baseline: intercept/female adults in the Tu context)						
Male	−3.83	13.71	120.83	−0.28	0.781	
Interactions						
Ku: 4-6 y.o.	91.45	17.11	1288.98	5.35	<0.001	***
uL: 4-6 y.o.	−35.13	20.96	1292.26	−1.68	0.094	.
Ku: 7-9 y.o.	72.67	16.93	1290.57	4.29	<0.001	***
uL: 7-9 y.o.	−64.78	20.66	1286.95	−3.14	0.002	**
Ku: 10-12 y.o.	63.20	16.93	1287.21	3.73	<0.001	***
uL: 10-12 y.o.	−69.55	21.10	1288.68	−3.30	0.001	**
Ku: male	−57.85	13.00	1291.77	−4.45	<0.001	***
uL: male	11.82	16.00	1291.32	0.74	0.460	

Notes: Significance codes: < 0.001 '***,' < 0.01 '**,' < 0.05 '*,' < 0.1 '.'

the adults in the Ku condition; in other words, the non-coronal onset condition appears to be the locus of the change in progress. Figure 8 further illustrates the interactions between age group and context.

As shown in Figure 8, all groups have a similar overall position in the post-coronal (Tu) environment, with slightly more fronting by the older two groups of children in this context. In the pre-lateral (uL) context, the child groups have a slightly less advanced /u/ position than the adults; since this context is not implicated in the change in progress, this difference is not explored further. The area of interest is the non-coronal condition: here we see that all three groups of children are extending the change to this new environment, showing more fronting in the Ku environment than adults.

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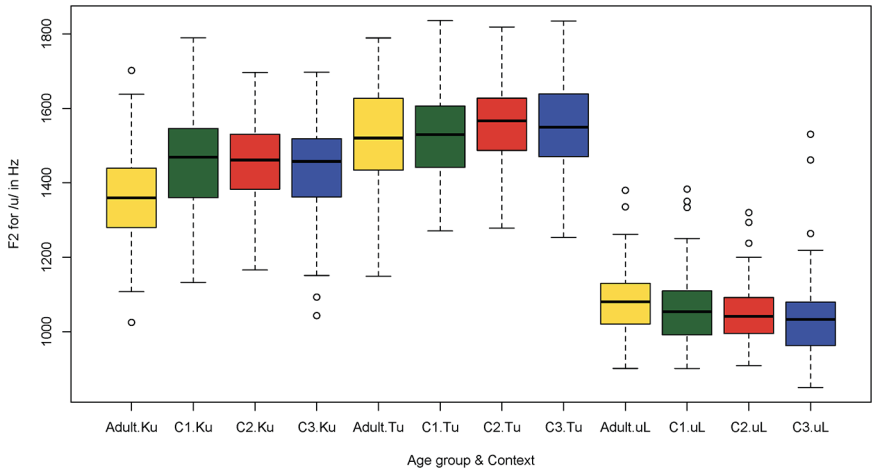


Figure 8. F2 values (normalized and scaled to Hz) for /u/ by age group (C1 = 4 to 6, C2 = 7 to 9, C3 = 10 to 12) and context (Ku, Tu, uL).

Post-hoc effects testing using *emmeans* (Lenth, 2023) clarifies the findings for age group, context, and gender, and Figure 9 plots the effects of each factor on the scaled F2 of /u/. Adults are predicted by the model to show less fronting than all three groups of children in both the Ku and Tu contexts. However, the age-related difference in estimated mean F2 values is much larger in the Ku environment (around 100 Hz versus approximately 40 Hz for Tu), where there is very little overlap in the confidence intervals for adults versus children. Among the children, the older two groups lead in Tu-fronting, while the younger two groups lead in Ku-fronting. These predicted F2 differences are much smaller (approximately 20 Hz for Tu and 15 Hz for Ku), with largely overlapping confidence intervals for the three child groups in both environments. Male speakers in all three age groups are also predicted to front less in the Ku context than female speakers, while the other two contexts look very similar in male and female speakers.

To further compare the child groups in post-hoc testing, a second mixed effects model was conducted using only the child data. The youngest children served as the baseline age group, and the same reference levels were used for gender (female speakers) and context (Tu) as in the original model, along with random intercepts for speaker and word. Stepping the model using the *drop1* function revealed that only the interaction between gender and context was significant; age group was not a significant factor (on its own or interacting with context), and was therefore removed from the model. Context was significant in the child data, with less fronting in both the non-coronal (estimate = −76.28, $p = 0.034$) and pre-lateral (estimate = −508.73, $p < 0.001$) contexts than the coronal one. The significant interaction between context and gender indicates less fronting in the Ku environment by male speakers (estimate = −53.13, $p < 0.001$) than females. These results confirm that all three child groups have similar degrees of overall /u/-fronting, as well as fronting by context, while demonstrating the same interaction between gender and context as seen in the full model.

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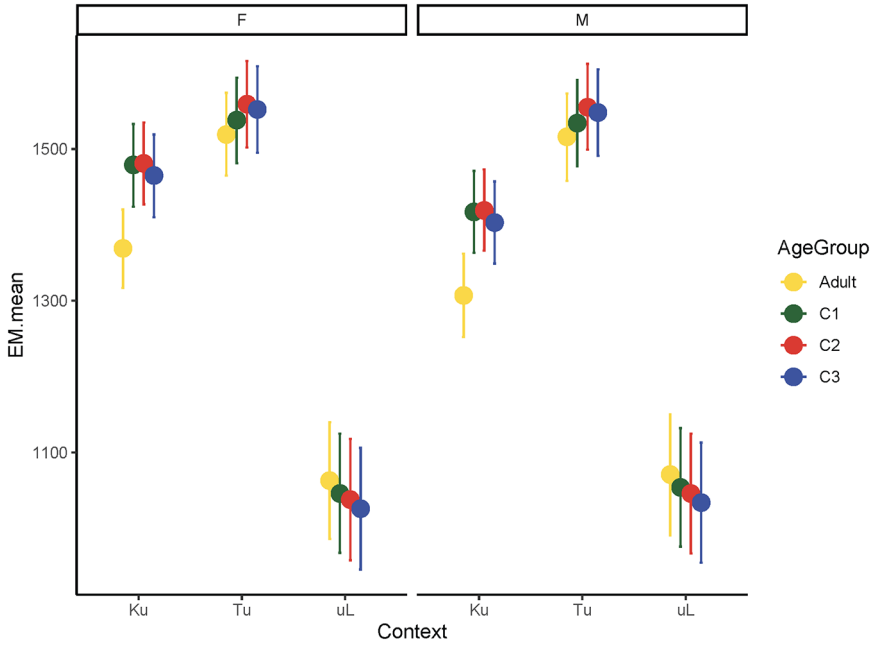


Figure 9. Estimated marginal means for F2 of /u/ by age group (C1 = 4 to 6, C2 = 7 to 9, C3 = 10 to 12), context (Ku, Tu, uL) and gender (F, M).

In summary, the results of these analyses show that children ages 4 through 12 front /u/ more than adults in the non-coronal context, and female speakers of all ages show more fronting in this environment than their male counterparts. This finding largely follows the predictions of the incrementation model, as younger female speakers are expected to be more advanced in the change. However, the more specific comparisons between age groups are less expected in incrementation: while the older two groups (ages 7 through 12) show slightly more fronting than adults and younger children in the traditional coronal context, all three groups of children are significantly more advanced in fronting than adults in the innovative non-coronal context. These results are discussed further in the following section.

Discussion

This study examined /u/-fronting, a vowel change in progress in Ontario English. The results show that both children and adults front /u/ the most when it appears after a coronal consonant. In this traditional context for fronting, all speakers have an /u/ position near the middle of the vowel space, with children ages 7 through 12 showing slightly more fronting than both younger children and adults. In the non-coronal onset condition, however, children ages 4 through 12 have notably higher F2 values for /u/ than their parents and more overlap with /u/ in the coronal context. In addition, female speakers of all ages show more advanced fronting in the non-coronal environment than male speakers do.

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Labov's (2001:415-465, 2007) model of transmission and incrementation predicts that the youngest children should faithfully match their parents' systems, while older children should be more advanced in the change, incrementing the change towards the adolescent peak. The present results fulfill this expectation in the coronal environment, where 4- to-6-year-olds resemble their parents, and older school-age kids and pre-adolescents show more fronting. The innovative non-coronal context, however, has a different pattern: here, all three groups of children, including the youngest ones, exceed adult levels of /u/-fronting by close to 100 scaled Hz. These findings, like those of Smith and Holmes-Elliott (2022), suggest that children's initial variable patterns do not always match those of their parents or community. Instead, children in all three age groups appear to be advancing the change in /u/ to its final stage, when the allophonic distinctions diminish and /u/ becomes fronted in all environments (except for the uL context). These results recall those of Harrington et al. (2008), who found less coarticulatory influence on /u/ in younger than older speakers and linked these production findings to younger listeners' reduced compensation for coarticulation in speech perception.

Because this is an apparent-time analysis, rather than a real-time view of how children's productions develop, there are multiple possible interpretations of these findings. One is that they represent a type of overgeneralization in the transmission process: 4- to 6-year-old children may participate in the /u/-fronting change by extending it to the non-coronal environment during acquisition. This flattening of phonetic constraints could be analogous to young children's regularization of variable morphosyntactic forms, particularly given that front allophones of /u/ statistically occur more frequently than back allophones (Harrington et al., 2008). Older children in the same generation may then be maintaining this degree of Ku-fronting throughout childhood, rather than further incrementing the change. Another possibility is that the 4- to 6-year-olds in this study did match their parents' patterns more closely at an earlier stage, reflecting faithful transmission, and are now showing incrementation effects. Children start school at age four in Ontario, and many of the young participants in this study had older siblings; it may thus be the case that they have already begun shifting their productions towards those of their older peers. Given that corner vowels like /u/ are typically acquired by around age two (Stoel-Gammon & Herrington, 1990), and that Smith and Durham's (2019) studies show remarkable sociolinguistic development even before age five, this possibility cannot be ruled out. However, the incrementation model would still predict further incrementation of Ku in the older groups, rather than similar degrees of change in the position of /u/ in all three groups of children.

Overall, the results of this study suggest that /u/-fronting has progressed to a more advanced stage in Ontario than was evident in earlier research. Boberg (2008, 2011) found Ontario speakers to be extremely advanced in /u/-fronting in the coronal context, but with non-coronal onsets he showed only moderate fronting beyond the pre-/l/ position for /u/. In the present study, even the adult speakers show Ku tokens that are closer to Tu than to uL, and for children, the difference between Tu and Ku is about 40% smaller (in scaled Hz values) than that of adults. In this way, children appear to be leading the change. This finding supports Baranowski's (2008) results for /Kuw/-fronting in 8- to 18-year-old speakers in Charleston, SC, but also extends this stage of the change to a younger age range. Unlike Holmes-Elliott's (2021) study of Southern

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British English, in which adolescents ages 13 to 15 and 15 to 17 years showed more fronting after non-coronal onsets than 9- to 11-year-olds, all three child groups in this study showed similar degrees of Ku-fronting. This discrepancy could reflect dialectal differences in the rate or stage of the /u/-fronting change, or differences in study design (discussed further below). Alternatively, it may be the case that Ontario adolescents would also show a peak for Ku-fronting beyond the level of younger children. In that case, incrementation would presumably begin in children older than 12, perhaps as a result of attaching social meaning to the variable; this question is left as a topic for future research.

The gender effects in this study likely also reflect the advanced stage of the change: no overall gender effect was found, likely because all speakers now show extreme /u/-fronting after coronals, where the change appears to be complete. Only the non-coronal onset environment is currently variable, both in children and adults, and this is where female speakers show more fronting. Given the well-established sociolinguistic pattern of female speakers leading changes in progress, it may therefore be expected that women and girls will continue to lead in the non-coronal context until the change nears completion, when men and boys will catch up.

The present findings differ slightly from those of Hall and Maddeaux (2020) and Hall (2020), which made use of some of the same data. In those studies, older children (ages 10-12 years) showed less Ku-fronting than younger children (ages 4-6 years), suggesting potential retreat from initial overgeneralization of the /u/-fronting change. However, this discrepancy seems to result from the specific data included in each study: in our earlier work, we included reading list data from the older children and adults (but not the younger children, who were not yet readers), resulting in the addition of the word *coop* to the set of Ku tokens for these speakers. When this reading list data was removed, the older children no longer differed from the younger children in the non-coronal context. This may indicate some lexical specificity to the /u/-fronting change, such that *coop* is less fronted than other Ku words. Alternatively, the discrepancy across studies (and across age groups) may relate to speech style effects, with younger children showing different style-shifting patterns than older children and adults. For example, children's more advanced Ku-fronting could reflect a lack of style-shifting in the naming context, whereas their parents might have used a more conservative speech style for the naming task. However, it should be noted that although style-shifting can emerge later in children than other constraints on variable use, studies suggest that most children master this type of external conditioning between ages 4 and 8 years (e.g., Kerswill & Williams, 2000; Smith & Durham, 2019), and therefore at least the older children in this study would be expected to resemble adults in their approach to this task. In addition, style-shifting has not typically been reported in previous studies of /u/-fronting. In any case, future research should investigate this possibility by analyzing children's naturalistic speech, as well.

In general, the finding that young children are more advanced than their parents in /u/-fronting provides further evidence that transmission between generations is not always faithful, and supports the notion that child learners, and not only adolescents, can contribute to language change. While most recent work in this area has focused on grammatical change, including cyclic processes in the modal cycle (Cournane, 2014, 2015; Cournane & Pérez-Leroux, 2020), this study suggests that acquisition biases may

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also apply to the phonological domain. Cournane's (2019) reverse U-model (Figure 2) depicts this process, showing initial overgeneralization by the child learner, followed by retraction and then socially-driven incrementation. In the case of /u/-fronting, however, the apparent-time data shows evidence of later incrementation only in the post-coronal environment; in the innovative non-coronal context, the initial fronting pattern appears to be maintained in the older groups of children.

Conclusion

The results of this study provide empirical support for the notion that young children are active participants in language change. Rather than the expected differences between younger and older children, all age groups of children were found to be more advanced in the later stage of /u/-fronting than their parents. Children appear to be leading the push towards completion of /u/-fronting by extending the change to a new context by as early as age four. This pattern could be seen as a type of overgeneralization in phonological acquisition, or as evidence that incrementation is already well underway for this variable in 4- to 6-year-old children. While future research including real-time data, adolescent speakers, and multiple speech styles would help to clarify the state of /u/-fronting in Ontario English, the present results suggest that children may participate in advancing linguistic changes earlier than predicted by the incrementation model.

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Competing interests. The author declares none.

Notes

1. Instead of this linear increment, Labov (2001:449-454) argued for logistic incrementation, which better matches the S-shaped curve of linguistic change over time. However, the expected profiles for younger children and pre-adolescents do not substantially differ between the two models: in both cases, 6- to 13-year-olds should show more advancement of the change than 4- to 5-year-olds (see Labov, 2001:Figures 14.2, 14.5).
2. While not the focus of this study, it should also be acknowledged that children's participation in language change may look very different in multilingual and multidialectal communities, as shown in Oxbury et al.'s (2025) work on Multicultural London English.
3. Labov et al. (2006:151) did not include /z/ or /dʒ/ as coronals, nor /p/ or /g/ as non-coronals, but they are listed here for consistency with other consonants with the same place of articulation. They included /r/ as a non-coronal; however, /r/ is excluded here as it is typically considered coronal based on tongue tip movement and is rarely included in other studies of /u/-fronting.
4. The adult data in these earlier studies came from both parents and non-parents; the parents participated in the same study as the children, completing both picture naming and word list reading tasks, while the non-parent adults took part in a similar study in the same community (Maddeaux, 2023) that involved only word list reading.
5. The diphthong /ɔj/ was not included, and the diphthongs /aw/ and /aj/ were elicited but not analyzed in this study.
6. There were 10 words containing /u/ in the task, but some participants pluralized four of the words in the picture naming task (*boots, suits, foods, tools*), so the total number of words in the model is 14.

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Appendix A

Background questionnaire for caregiver of child participant

Your child's participation is anonymous, but we need some **general information** about your family.

Your child:

☐ speaks English only ☐ speaks 2 languages ☐speaks 3 + languages

If your child speaks more than one language, please rate their level of fluency in each language using the scales below.

English

Knows very little English ←	1	2	3	4	5	Very fluent in English→

Other language(s): please specify _____

Knows very little other language(s) ←	1	2	3	4	5	Very fluent in other language(s) →

Does your child attend any of the following?

☐ French immersion ☐ French or other language classes in school

☐ weekend or after-school programs in another language

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Does your child have siblings? ☐ yes ☐ no

If your child has siblings, please list the age and gender of each:

Age of sibling	Gender of sibling	Age of sibling	Gender of sibling

Next, please fill out information about **your child's caregiver(s)**. The **primary caregiver** is the adult who spends the most time with the child. The **secondary caregiver** (if applicable) is also responsible for the child but does not spend as much time with them.

Your child's primary caregiver:

Age:

☐ under 20 ☐ 20 to 29 ☐ 30 to 39 ☐ 40 to 49 ☐ 50 to 59 ☐ 60 +

Gender: _____ Ancestry: _____

Place of birth (town & province/country): _____

Place(s) of residence in childhood & youth: _____

Current place of residence: _____

Education completed:

☐ elementary school ☐ high school ☐ community college ☐ university

Current occupation(s): _____

Does the primary caregiver speak another language(s)? ☐ yes ☐ no

If yes, please specify the language(s) and fluency level:

Knows very little ←	1	2	3	4	5	Very fluent→

Language(s): _____

Your child's secondary caregiver (if applicable):

Age:

☐ under 20 ☐ 20 to 29 ☐ 30 to 39 ☐ 40 to 49 ☐ 50 to 59 ☐ 60 +

Gender: _____ Ancestry: _____

Place of birth (town & province/country): _____

Place(s) of residence in childhood & youth: _____

Current place of residence: _____

Education completed:

☐ elementary school ☐ high school ☐ community college ☐ university

Current occupation(s): _____

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Does the secondary caregiver speak another language? ☐ yes ☐ no

If yes, please specify the language(s) and fluency level:

Knows very little ←	1	2	3	4	5	Very fluent→

Language(s): _____

Do **any other adults** play an important role in your child's home life? ☐ yes ☐ no

If yes, please briefly explain (e.g., grandparent, other relative, nanny, etc.)

Appendix B

Background questionnaire for adult participant

Your participation is anonymous, but we need some **general information** about you. Please state town and province/country where applicable.

Age:

☐ under 20 ☐ 20 to 29 ☐ 30 to 39 ☐ 40 to 49 ☐ 50 to 59 ☐ 60 +

Gender: _____ Ancestry: _____

Where were you born?

_____

Where did you live in your childhood & youth?

_____

Where do you live now?

_____

Education completed:

☐ elementary school ☐ high school ☐ community college ☐ university

Current occupation(s): _____

Do you speak another language(s)? ☐ yes ☐ no

If yes, please specify the language(s): _____

How fluent are you in this language?

Know very little other language←	1	2	3	4	5	Very fluent in other language→

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Appendix C

Vowel task instructions and item list

Say: **I am going to show you some pictures on the computer, and I will say a sentence about each one that I want you to finish. You only need to say one word to finish the sentence, but I want you to say each word twice. Let's try one.** (read prompts on slides for each item)

Set of items in order:

Item No.	Word	Item No.	Word	Item No.	Word
1	bed	20	tie	39	bag
2	sock	21	dots	40	pool
3	leg	22	soup	41	bee
4	kite	23	out	42	map
5	sit	24	cake	43	kick
6	cow	25	pals	44	bat
7	web	26	bad	45	can
8	sign	27	hot	46	boots
9	sad	28	juice	47	book
10	tools	29	milk	48	man
11	beak	30	sides	49	six
12	loud	31	back	50	gate
13	suit	32	stop	51	cups
14	light	33	cat	52	slide
15	boat	34	jam	53	flag
16	coat	35	down	54	house
17	food	36	two	55	ten
18	bug	37	big	56	cook
19	moon	38	goose		

Appendix D

Table D1. Means and standard deviations for raw (in Hz), Lobanov-normalized, and scaled (in Hz) F1 measurements of /u/ by context for children and adults

	Tu (raw)	Tu (normed)	Tu (scaled)	Ku (raw)	Ku (normed)	Ku (scaled)	uL (raw)	uL (normed)	uL (scaled)
Adults	419.02 (59.53)	−1.15 (0.22)	337.27 (21.64)	428.73 (64.55)	−1.09 (0.26)	342.64 (25.71)	407.70 (53.43)	−1.20 (0.21)	332.02 (20.90)
Children	485.13 (74.01)	−1.04 (0.27)	348.14 (26.42)	493.39 (78.43)	−0.99 (0.29)	352.25 (28.20)	455.30 (62.25)	−1.17 (0.25)	334.95 (24.48)

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Appendix E

Table E1. Means and standard deviations for raw (in Hz), Lobanov-normalized, and scaled (in Hz) F2 measurements of /u/ by context for children and adults

	Tu (raw)	Tu (normed)	Tu (scaled)	Ku (raw)	Ku (normed)	Ku (scaled)	uL (raw)	uL (normed)	uL (scaled)
Adults	1800.49 (283.30)	0.10 (0.54)	1518.47 (132.67)	1511.06 (264.47)	−0.54 (0.47)	1363.46 (113.96)	972.15 (165.97)	−1.70 (0.35)	1081.02 (85.82)
Children	2182.43 (319.01)	0.21 (0.48)	1546.84 (116.99)	1960.76 (365.13)	−0.19 (0.51)	1448.62 (125.20)	1063.15 (249.89)	−1.80 (0.42)	1055.98 (102.67)

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