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Characterizing Speech Sound Productions in Bilingual Speakers of Jamaican Creole and English: Application of Durational Acoustic Methods

Michelle León,[a] Karla N. Washington,[a,b,c] Victoria S. McKenna,[a,d,e] Kathryn Crowe,[f,g] Kristina Fritz,[h] and Suzanne Boyce[a]

[a] Department of Communication Sciences & Disorders, University of Cincinnati, OH [b] Department of Speech-Language Pathology, University of Toronto, Ontario, Canada [c] Department of Communicative Sciences and Disorders, New York University, NY [d] Department of Biomedical Engineering, University of Cincinnati, OH [e] Department of Otolaryngology–Head and Neck Surgery, University of Cincinnati, OH [f] School of Education, Charles Sturt University, Bathurst, New South Wales, Australia [g] School of Health Sciences, University of Iceland, Reykjavík [h] Department of Psychology, California State University Northridge, Los Angeles

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ABSTRACT

Purpose: This study examined the speech acoustic characteristics of Jamaican Creole (JC) and English in bilingual preschoolers and adults using acoustic duration measures. The aims were to determine if, for JC and English, (a) child and adult acoustic duration characteristics differ, (b) differences occur in preschoolers' duration patterns based on the language spoken, and (c) relationships exist between the preschoolers' personal contextual factors (i.e., age, sex, and percentage of language [%language] exposure and use) and acoustic duration.
Method: Data for this cross-sectional study were collected in Kingston, Jamaica, and New York City, New York, United States, during 2013–2019. Participants included typically developing simultaneous bilingual preschoolers (*n* = 120, ages 3;4–5;11 [years;months]) and adults (*n* = 15, ages 19;0–54;4) from the same linguistic community. Audio recordings of single-word productions of JC and English were collected through elicited picture-based tasks and used for acoustic analysis. Durational features (voice onset time [VOT], vowel duration, whole-word duration, and the proportion of vowel to whole-word duration) were measured using Praat, a speech analysis software program.
Results: JC-English–speaking children demonstrated developing speech motor control through differences in durational patterns compared with adults, including VOT for voiced plosives. Children's VOT, vowel duration, and whole-word duration were produced similarly across JC and English. The contextual factor %language use was predictive of vowel and whole-word duration in English.
Conclusions: The findings from this study contribute to a foundation of understanding typical bilingual speech characteristics and motor development as well as schema in JC–English speakers. In particular, minimal acoustic duration differences were observed across the post-Creole continuum, a feature that may be attributed to the JC–English bilingual environment.
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Bilingual populations are rapidly increasing in the United States, almost tripling in size since 1980, and now represent 45% of people born in the Unites States (Zeigler & Camarota, 2019). With this growth in linguistic diversity, there is an increased likelihood that speech-language pathologists (SLPs) will have bilingual speakers on their caseloads. However, there is insufficient information about the speech characteristics of diverse, bilingual populations to support SLPs in accurately evaluating child speech. Because speech patterns such as durational features can vary based on language and dialect (Lisker & Abramson, 1964), understanding acoustic durational characteristics can support the establishment of developmental speech

Correspondence to Karla N. Washington: karla.washington@utoronto.ca.
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norms, contribute to information about the development of motor control, and advance the establishment of valid speech assessments (Vorperian & Kent, 2007). In response to this need, documenting and categorizing duration characteristics across speakers of different languages could assist SLPs in (a) improving the accuracy of their speech assessment and (b) reducing the possibility of misdiagnosis of speech function in bilingual clients.

Research with bilingual populations has identified differences in speech features based on the influence of one language on the other (i.e., cross-linguistic effects; Hambly et al., 2013) and differences in motor planning and sequencing based on diverse language experiences (Speights Atkins et al., 2017). Although this knowledge is helpful to SLPs, there is a need to understand which speech sound patterns resulting from specific language pairings are typical (Hambly et al., 2013), so that typical and atypical patterns can be differentiated. Categorizing typical speech patterns in all the languages a bilingual person uses and determining how these patterns differ from monolingual users of these languages are essential steps needed to support valid assessment and differential diagnosis of typical and typical speech skills in bilingual children.

Speech assessment has typically relied on SLPs' perceptual judgment and analysis, usually from a single observation in the clinical setting (Ishikawa et al., 2017; Kent, 1996 ; Kent & Rountrey, 2020). Some advantages of perceptual analysis of speech include convenience, time, and cost efficiency (Kent, 1996). Although perceptual analysis has been commonly used, its reliability, accuracy, and susceptibility to errors and biases have been called into question (Kent, 1996; Kent & Rountrey, 2020). Acoustic inquiry (i.e., analysis using acoustic methods) can address the limitations of perceptual analysis by providing objective and consistent descriptions of speech sound patterns (Ishikawa et al., 2017). Acoustic analysis is not often used clinically for a variety of reasons (e.g., time constraints and lack of awareness and training); however, its use in clinical settings can lead to improved diagnoses in bilingual populations if used and interpreted appropriately (Kent & Kim, 2003).

The purpose of this study was to develop an understanding of an understudied bilingual population's speech pattern profiles (specifically Jamaican Creole [JC]-English–speaking bilingual preschoolers) by examining a set of acoustic durational measures of speech in both of their spoken languages. Drawing on recommendations for practice (McLeod et al., 2017), adult participants from the same linguistic community were included to provide models of acceptable JC–English speech patterns. We also implemented culturally responsive methods from a previous study (León et al., 2022) by using an adapted protocol of speech elicitation and interpretation for this population (Washington et al., 2017). The adapted Diagnostic Evaluation of Articulation and Phonology (DEAP; Dodd et al., 2006) protocol includes a range of response variations that are typical in the Jamaican population. The influence of contextual factors on this set of speech duration characteristics was also explored to increase understanding of this bilingual population's linguistic profile.

Acoustic Speech Sound Measurement

Durational characteristics are key components of speech and intelligibility that influence how listeners perceive and distinguish individual sounds. Durational characteristics can provide evidence of speech and motor development (Tingley & Allen, 1975) and be used for monitoring treatment progress (Neel, 2010). Additionally, durational values can be used to support the assessment of speech disorders through objective indicators that signal typical and atypical speech patterns (Macrae et al., 2010). Three duration parameters are examined in this study: voice onset time (VOT), vowel duration, and whole-word duration. The proportion of vowel to word duration was also examined. Previous works using these measures have identified acoustic features that may be distinct in the Jamaican population (Coy & Watson, 2020; León et al., 2022). Therefore, these measures are useful and potentially clinically relevant in that they can inform typical speech characteristics in JC–English speakers.

Effects of Contextual Factors on Durational Acoustic Measurements

Incorporating contextual factors, as defined in the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY; World Health Organization [WHO], 2007), in the description of speech is important in gaining a detailed understanding of the communication skills of bilingual children (McLeod et al., 2017) and for supporting communication function generalization in various settings (Westby & Washington, 2017). The child contextual factors of interest in this study are child internal factors (i.e., age and sex) and external factors (i.e., the percentage of language [%language] use and exposure). As emphasized in the biopsychosocial model of the ICF-CY, contextual factors impact children's overall functioning, including their communication (see Westby & Washington, 2017). Some speaker-specific contextual factors also affect durational speech patterns. The relationship between duration measures (VOT, vowel duration, and whole-word duration) and the contextual factors of age, sex, and language exposure/use, addressed by cross-linguistic effects, are considered and discussed below. Understanding the impact of these contextual factors on durational skills can provide insight into this bilingual population's speech and possibly motoric control development. Furthermore, increased awareness of expected duration patterns (i.e., average durational values) can eventually support the advancement of normative data.

Age

Due to development and maturation, it has been suggested that perceptual and motor capabilities (Auszmann & Neuberger, 2014; Kent, 1976), physiological changes (Kent, 1976), environmental changes (e.g., language experiences; Smith, 1992), and sociocultural influences (Kent & Rountrey, 2020) can change with age. Research in support of this view has demonstrated that young children's segments, including individual speech sounds and words, are longer and more variable in their duration when compared with the same segments produced by adults (Kent, 1976; S. Lee et al., 1999; Macrae et al., 2010; Smith, 1992). With the maturation of speech motor development, children's variability and duration reduce to eventually match adult speech (Smith, 1992; Tingley & Allen, 1975). This maturation is believed to occur around preadolescence for VOT patterns (Tingley & Allen, 1975; Whiteside & Marshall, 2001) and at around 3–7 years of age for vowel patterns (Kent & Rountrey, 2020). However, some studies suggest adultlike vowel patterns (e.g., similar acoustic duration) do not occur until early adolescence (Auszmann & Neuberger, 2014).

Sex and Gender

Sex and gender are two separate constructs that have also been shown to have an impact on speech duration patterns. Anatomical, physiological, and social gender role differences contribute to differences between cisgender female and male speech (Pépiot, 2015). Several studies have revealed that durational characteristics of speech are longer for female adults when compared to male adults, including VOT (English speakers: Pépiot, 2015; Swartz, 1992; Whiteside & Marshall, 2001; French speakers: Pépiot, 2015) and vowel duration (English speakers: Holt et al., 2015; S. Lee et al., 1999). Pépiot (2015) found longer whole-word duration in pseudowords produced in sentences in monolingual female than male individuals in General American English and Parisian French. Contrarily, results from Oh (2011) demonstrated longer VOT in male speakers than female speakers (e.g., aspirated stops in Korean) and differences in the speech of female speakers across languages (e.g., longer VOT duration in English but not in Korean). These differences between sexes have often been attributed to anatomical differences that develop during puberty, such as a difference in vocal tract length and the thickness of the vocal folds (Oh, 2011; Pépiot, 2015). However, these differences may also be related to social and cultural factors associated with gender roles, such as efforts made by women speakers to achieve more intelligible speech than men (Simpson, 2009) or to language-specific patterns (Oh, 2011). Despite the considerable amount of literature that has been published on differences in durational values between female and male individuals, some studies' results have not shown any significant difference between participants based on sex (e.g., Lundeborg et al., 2012).

Evidence of this relationship in children is equivocal. Most studies have focused on VOT and vowel duration, but less is known about whole-word duration differences between female and male children. VOT patterns have been found to vary between female and male children, depending on both the age of the child and on the plosive examined (Whiteside & Marshall, 2001). For vowel duration, many studies have not found significant sex differences (Jacewicz et al., 2011). However, it should also be noted that some studies that measured children's speech duration have not included an analysis of the effect of sex or gender (e.g., VOT: MacLeod, 2016; VOT and vowel duration: S. A. S. Lee & Iverson, 2012). This inconsistency in the literature signals a need for more data on the impact of sex on durational patterns in child speech development.

Cross-Linguistic Effects

Phonemic categories can vary among languages, impacting timing distributions and acoustic features (Lisker & Abramson, 1964). A large volume of published studies describes the role of possible interactions between languages, often referred to as cross-linguistic effects (Paradis & Genesee, 1996). Cross-linguistic effects are the carryover of characteristics from one language to another within an individual, which can be detected in bilingual speech (Paradis & Genesee, 1996). This is observed within the speech learning model (Flege, 1995), as bilingual speakers use assimilation or dissimilation to distinguish the phonetic language categories. Assimilation refers to merging multiple languages' phonetic categories, and dissimilation refers to developing separate phonetic categories for each language. This model has focused primarily on sequential bilingualism in adults (S. A. S. Lee & Iverson, 2012) where a person gains proficiency in one language before exposure to a second language rather than simultaneous bilinguals, who concurrently gain proficiency in two or more languages early in their development.

Bilingual speakers occasionally produce acoustic duration distributions and patterns that vary from monolingual speakers (e.g., Fabiano-Smith & Bunta, 2012). An implication of cross-linguistic effects across two languages is the possibility of interaction with bilingual children's developing motor control. This interaction is poorly understood. Some studies suggest that although there may be different phonological systems for each language, motor control does not differ by language in bilingual speakers (e.g., Holm et al., 1997). In contrast, other studies propose that articulatory planning and organization vary by language, as demonstrated by different coarticulation (Manuel, 1987) and articulatory patterns by speakers of various languages (e.g., English and Turkish speakers; Boyce, 1990). Said differently, less is known about whether bilingual speakers follow the same course as monolingual speakers or if the interaction creates a separate trajectory for bilingual speakers (S. A. S. Lee & Iverson, 2012). This separation could be observed as motor control differences in all the languages bilingual speakers use or in only one of the languages spoken.

Previous studies have reported different VOT patterns in bilingual children compared with monolingual speakers during specific ages and in at least one language (e.g., Spanish–English: Fabiano-Smith & Bunta, 2012; German–Spanish: Kehoe et al., 2004; Korean–English: S. A. S. Lee & Iverson, 2017). For example, Fabiano-Smith and Bunta (2012) found that bilingual children's VOT duration differed from their monolingual peers in English but not Spanish. They discussed the possibility of cross-linguistic influence of Spanish on VOT (especially with bilabial plosives), demonstrated through shorter duration than in English. Kehoe et al. (2004) found distinct VOT patterns in their bilingual German-Spanish–speaking child participants. The three patterns produced by bilingual children included (a) no cross-linguistic influence, (b) delay of target realization, and (c) transfer of features. The patterns produced were inconsistent across their bilingual speakers, suggesting an intricate relationship between unique language backgrounds and durational patterns. Additionally, although our previous study with bilingual children and adults (León et al., 2022) did not directly compare JC–English speakers to British English speakers, we concluded that our participants' English VOT characteristics resembled British VOT features. Specifically, the production of prevoicing for voiced consonants aligns with British VOT values that tend to range from prevoicing to positive values (Docherty, 2011).

Vowel duration can vary in bilingual speakers. Ronquest (2012) found that Spanish–English bilingual adult speakers produced marginally, but consistently, longer vowel duration in Spanish than monolingual speakers of Spanish. Similarly, Srinivasan (2018) found that Spanish-English–speaking children in their study produced longer /æ/ and /ɛ/ vowel durations in English compared with monolingual English speakers. However, duration for /ɪ/ and /ʌ/ was similar to monolingual English counterparts. There has been a limited analysis of cross-linguistic effects on whole-word production in the literature with little agreement in the results. For example, Kehoe (2022) did not find bilingualism to affect word duration for children in French, whereas Dodane and Bijeljic-Babic (2017) did. This was demonstrated by bilingual children producing longer vowel duration in French than monolingual children.

Cross-linguistic effects in dialects of different languages are also of interest. Varying patterns across dialects of the same language have been demonstrated (Coy & Watson, 2020; Holt et al., 2015; Jacewicz et al., 2011). Coy and Watson (2020) compared children's acoustic data of four corner vowels across different dialects of English, including American English, British English, and Jamaican English (as spoken by Jamaican children). They found that duration was significantly shorter for most vowels in Jamaican English than in American English. However, the duration of British English and Jamaican English vowels were more similar. The vowel /i:/ was produced longer in Jamaican English than in American and British English. Holt et al. (2015) examined vowel duration of Southern American English. They found that adult speakers of African American English produced longer vowels than speakers of White American English. Additionally, Jacewicz et al. (2011) found significant differences in vowel duration in Midwestern and Southern American English dialects. Adult and child speakers of the Southern dialect produced the vowels /ɪ/, /ɛ/, /ʊ/, and /o/ longer than speakers of the Midwestern dialects.

The Jamaican Language

Although some research findings regarding bilingual children can be generalized to different languages, it is important to consider cultural and linguistic differences specific to a bilingual speaker's language pairing. As a population, Jamaicans represent a growing community within the United States (approximately 20% of Caribbean-born population; U.S. Census Bureau, 2017) and other countries across the globe (e.g., Canada and the United Kingdom). As such, this population warrants increased attention in the communication disorders literature. In Jamaican society, most people are considered simultaneous (exposed to and learning two or more languages shortly after birth) and balanced (relatively equal proficiency in both languages) bilingual speakers of JC and English. JC is derived from its lexifier language, English. Because of this, the two languages have a shared linguistic foundation, expressed on the post-Creole continuum. This continuum involves phonetic and lexical variations for words, with one end having more English-based productions and the other containing more JC-influenced productions. The continuum contains variable pronunciations for different words acceptable for JC–English speakers. It is important to note that JC is an independent language (Irvine-Sobers, 2018). There are phonetic and phonological differences, or rules, specific to each language. For example, the JC phonetic inventory has fewer consonants (22 compared with 24) and vowels (12 compared with 20) than English (Dib, 2019; Jamaican

Language Unit, 2009). Additionally, in JC, [h] does not serve as a contrastive phoneme (Irvine-Sobers, 2018).

As is common in bilingual speakers of other languages, cross-linguistic interactions are expected in speakers of JC and English (Karem & Washington, 2021). Additionally, a characteristic of JC–English speakers is that many words can be produced in various ways (Washington et al., 2017). Incorporating the knowledge that these speech patterns (i.e., phonological and lexical variability) are typical in post-Creole productions (León et al., 2022; Speights Atkins et al., 2017) improves the accuracy of Jamaican speech interpretation.

Purpose

Understanding various language pairings is important to inform accurate and appropriate speech assessment and therapeutic decisions. The need for more research on typical bilingual speech development is particularly pressing for understudied language pairings, such as JC and English. Characterizing typical acoustic duration patterns allows for the precise distinction of atypical speech patterns in children with speech sound disorder (SSD). Using the methods proposed by León et al. (2022), we extend a culturally adapted DEAP protocol (Dodd et al., 2006; Washington et al., 2017) developed for JC–English speakers to guide the speech duration measures across languages spoken. This protocol was used based on findings that, compared with the standard DEAP protocol, the adapted approach captured a greater variety of speech features from the post-Creole continuum.

The purpose of this study was twofold and was addressed using three research questions (RQs). The first objective was to describe typical JC-English–speaking bilingual children's acoustic speech patterns in both languages spoken by comparing their acoustic duration measures to adult participants from similar linguistic backgrounds. Adult speech was used as the model for the expected speech patterns in typical Jamaican bilingual speakers (RQ1). For our second objective, we focused only on JC-English–speaking preschoolers and considered contextual factors that influenced acoustic duration performance (RQ2 and RQ3). The following RQs were addressed.

1. Do adult and preschool patterns of acoustic duration measures differ for productions in JC and English?
2. Do acoustic duration patterns of preschoolers' productions in JC differ from their productions in English?
3. What is the relationship between preschoolers' contextual factors (age, sex, language exposure, and use) and acoustic patterns of durations (VOT, whole-word duration, and vowel duration) in JC and English?

Method

Study Approval

Study approval for the Jamaican Creole Language Project was obtained from the institutional review board and the University of Cincinnati and Faculty of Medical Sciences Ethics Committee, University of the West Indies, Mona Campus, Jamaica. Additional support and permission were obtained from the Early Childhood Commission, Government of Jamaica, and each participating early learning center where data were collected. Licensure for speech therapy practice in Jamaica was obtained from the Council for Professions Supplementary to Medicine. Consent was obtained from all adult participants. Preschoolers' parents provided consent, and preschoolers provided verbal assent.

This Study

This study implements methodology from a previous study (see León et al., 2022)—first, by using a culturally responsive and adapted DEAP scoring protocol developed for the Jamaican population and, second, by using the same durational analysis protocol used by León et al. (2022) for determining onset and offset segments. The participant data were drawn from a corpus of data, the Jamaican Creole Language Project (see Washington et al., 2017), in which quality audio recordings for acoustic analysis of speech were available for 120 children and 15 adults. The audio recordings and parent report data were collected during 2013–2019 and comprise the data reported in this article. The same corpus of children and adults is reported by León et al. (2022); however, the previous analysis was in the English language only, whereas our work here focuses on JC and English.

Participants

Children

A subset of 120 typically developing simultaneous bilingual children from the Jamaican Creole Language Project database used in the León et al. (2021) study was included in this study. Children were recruited from four different schools in Kingston, Jamaica, and one school in New York, United States. They were included based on the following criteria, participants (a) used JC and English at home and at preschool, as reported by parents and teachers using questionnaires; (b) were aged 3;0–5;11 (years;months); (c) passed binaural hearing screening at 25 dB (1, 2, and 4 kHz); (d) had no parent-reported neurological or pervasive developmental disorders; (e) met age-based criterion on the Oral Motor subtest of the DEAP (Dodd et al., 2006); (f) achieved a standard score of ≥ 72 on the Primary Test of Nonverbal Intelligence (Ehrler & McGhee, 2008); and (g) achieved a mean score of ≥ 4.12 on the English Intelligibility in Context

Scale (ICS; McLeod et al., 2012a) and the Intelligibility in Context Scale–Jamaican Creole (ICS-JC; McLeod et al., 2012b; Washington et al., 2017). A cutoff score of 4.12 or above for *both* the ICS and the ICS-JC were applied as León et al. (2021) reported appropriate sensitivity and specificity levels for Jamaican preschoolers. Preschool participants' ages ranged from 3;4 to 5;11 (M = 4;11, SD = 6.7), and the sample consisted of 67 (55.8%) female and 53 male (44.2%) participants. Most child participants were in the 4-year-old (female: n = 35, male: n = 31) and 5-year-old (female: n = 29, male: n = 21) age ranges. Information on children's sex was extracted from parental report. Information on children's gender identity was not collected.

Adults

Audio recordings of 15 JC-English–speaking adults, aged 19;0–51;7 (M = 38;9, SD = 10.7) were included in this study. Most were female (n = 12, 80.0%). Adults were recruited from Kingston, Jamaica, and belonged to the same linguistic community as the child participants, but none were parents of the children enrolled. Adult participants self-reported being bilingual and having typical hearing acuity. Their highest education levels ranged from primary school (n = 1), high school (n = 9), trade school (n = 1), to college/university (n = 4).

Materials

DEAP

The DEAP (Dodd et al., 2006) is a norm-referenced speech assessment tool for children aged 3;0–8;11. Although Jamaican preschoolers are outside the normed sample, the DEAP has been previously used in a validation study with Jamaican children to ensure all phonemes were screened (Washington et al., 2017). Previous studies have utilized a culturally adapted protocol of the DEAP, which was developed in collaboration with the Jamaican Language Unit. This adapted protocol includes a range of culturally appropriate response variations from the DEAP based on adult English and Jamaican phonological systems. As such, the adapted DEAP protocol accounts for the post-Creole continuum, allowing for more response variation (lexical and phonological responses) than the standard DEAP protocol (León et al., 2022). For example, for the item *girl*, the adapted protocol accepts productions beyond the standard response [gɝl] and includes [gɜl], [gɜɹl], [gɜːɹl], [gyal], [gyal pɪknɪ], and [gyal pikni] response options.

For this study, audio recordings of select single-word responses to the 30-item DEAP Articulation subtest were the sources of data. To maintain the consistency of the included words, a subset of stimulus words from the DEAP Articulation subtest were selected for the analyses based on meeting the following structural criteria: (a) being monosyllabic, (b) containing singleton consonants in initial word position (i.e., no clusters), and (c) containing consonant–vowel–consonant (CVC) phonotactic structures in initial placement. Based on these criteria, 22 of 30 words qualified for inclusion. However, one stimulus word was included with a slight exception. The commonly used abbreviation "tv" ([tivi]), instead of "television," was included and met the criteria by having an initial CVC phonotactic structure. This resulted in a total of 23 words included as stimuli in this research. The exclusion criteria for the words were (a) being multisyllabic (yellow, zebra, orange), (b) containing a consonant cluster in initial word position (snake, crab), or (c) containing a rhotic consonant or vowel (chair, ring). The single-word criteria were chosen to control for their effects on durational patterns. However, in being responsive to the wide variety of productions that exist on the post-Creole continuum (León et al., 2022), additional lexical and phonological response variations from the adapted DEAP protocol were considered. Responses extended from the DEAP stimulus words, which are all CVC, and were included if they fell within the following phonotactic structures: CVC, CVCV, and CVCC. Therefore, the initial CVC phonotactic structure was included to maintain similar structure across culturally appropriate productions and to analyze the impact of different phonetic contexts.

Parent Questionnaires

Parent questionnaires were completed as part of the Jamaican Creole Language Project (see Abu El Adas et al., 2020; Washington et al., 2021). Parent responses regarding the child's age, sex, language exposure, and language use ("What percentage of the week would your child speak and hear these languages?") were used in the current project. The responses to the mentioned questions informed the contextual factors included in the analyses.

Procedure

Data Collection

Audio recordings, collected in quiet rooms and in an authentic school environment, from participants provided acoustic data to be analyzed. Recordings were completed using Zoom H4N or H6N portable recorders with a Movo LV4-C XLR unidirectional cardioid lavalier microphone attached to the fitted vest. Samples were digitized with a sampling rate of 22 kHz and 24-bit encoding.

The children's speech samples consisted of single-word responses to the DEAP Articulation subtest administered in JC and English. To distinguish the two languages, different SLPs unknown to the child who were native speakers of JC and English administered the DEAP in each language, in sessions counterbalanced by language. The SLPs provided verbal cues for the children to respond in either JC or in English, as necessary. The children's responses were most often spontaneously produced (on > 95% of occasions) during the picture elicitation task. A series of cues were given to the children if they did not spontaneously respond or if responses were incorrect. The series of cues started with phonemic (e.g., /p/) or semantic cues (e.g., "it lives on a farm, it's a __"), followed by binary forced-choice cues, with the target response said first (e.g., "is it a *pig* or a donkey?"). Finally, if an acceptable target word had still not been produced, the SLP asked the child to repeat the target word. Of note, there were some responses from the acceptable target word variations that the children did not produce (e.g., [pɪgɪ], [pɔk], [tits], [tut], [gyal], [gyal pikni], [bwai pikni], [tɛlɪvɪdʒən], [lam], and [ʤɛlɪ]).

The adults' speech samples were productions for the word variations of the DEAP Articulation subtest (Washington et al., 2017). Although JC-English–speaking SLPs verbally modeled the different word variations, the adults only produced the variations within their repertoire (León et al., 2022). As a result, Jamaican adults did not produce some U.S. General English standard responses. For example, phonemes varied (e.g., [θɔm] for [θʌm]), and epenthesis frequently occurred (e.g., [bɔlə] for [bɔl]). Nonetheless, the speech samples provided by each adult contained acceptable response variations along the post-Creole continuum. Comparing children's speech performance to appropriate adult target productions is a recommended practice known as relational analysis (McLeod et al., 2017). The adult speech patterns were used as model patterns that could be similarly produced in typically developing children. Incorporating adult patterns provided guidelines for distinguishing typical differences (e.g., typical speech features from the cross-linguistic effect of languages) and atypical differences caused by a delay or disorder.

Data Analysis

Acoustic Duration Analysis

All audio recordings were transcribed using broad transcription and acoustically measured using Praat speech analysis software (Version 6.1.40; Boersma & Weenink, 2018). The subset of 23 words was analyzed using four parameters to determine durational measurement: VOT (Lisker & Abramson, 1964), whole-word duration (Macrae et al., 2010), vowel duration (House, 1961), and the proportion of vowel to word duration. All analyzed words shared the same initial word shape (CV). Team members followed a protocol that provided detailed guidelines for acoustically marking the onset and offset boundaries for words in different phonetic contexts for the four different acoustic measures (see León et al., 2022). For example, as described by León et al. (2022), the onset boundary for whole-word duration starting with a nasal consonant was placed at the first pitch period associated with the low-frequency nasal murmur. The offset boundary for words ending in nasals was placed at the last pitch period of the low-frequency nasal murmur. For words beginning and ending in affricates, the onset was marked at the start of the release burst high-frequency noise, and the offset was placed at the end of the frication noise. The onset and offset for words that began and ended in plosives were placed at the start of the high-frequency noise of the release burst, from the first upward, zero-crossing associated with the release burst. The VOT onset was identified at the start of the high-frequency noise associated with the release burst, and the offset was marked when the voicing of the following vowel began. Pitch periods were used to support the identification of voicing. In this study, we defined prevoicing as any voicing prior to the release burst, regardless of any pausing in voicing. Therefore, the onset for prevoicing was placed at the beginning of the voicing before the release burst. The offset for prevoicing was placed at the beginning of the release burst. The acoustic waveforms and the wideband spectrograms were visually and auditorily inspected to determine acoustic boundaries.

Utterances were excluded from the study if the waveform and/or spectrogram were interrupted (e.g., background noise), making it difficult to establish the onsets/offsets. A total of 968 tokens for VOT, 1,743 tokens for vowel duration, and 1,734 tokens for whole-word duration were included in JC. Nine hundred ninety-one tokens for VOT, 1,728 tokens for vowel duration, and 1,732 tokens for whole-word duration were used in English. The tokens were phonetically transcribed and coded based on their transcription to allow for a direct comparison between the same word structures. Words were considered errors if they were produced as distortions, did not match the target sound, and/or did not match the culturally appropriate varieties predetermined in the adapted DEAP protocol. Words considered errors were not analyzed.

VOT plays a large role in the perceptual differentiation of phonemic categories (Lisker & Abramson, 1967) and are affected by different factors including age, sex, languages spoken by the speaker, and the word's phonotactic structure (Swartz, 1992). VOT is impacted by phonetic structures of words and sentences, including the vowel that follows the initial plosive, the manner of articulation, and the voicing of the consonant following the vowel (Swartz, 1992). For example, in English, VOT values are often longer for initial voiceless plosives compared with voiced consonants (Nakai & Scobbie, 2016). Due to the influence of this phonetic structure, the words used in this study to measure VOT were also categorized by voicing. Nine words that began with plosives and that included voice and voiceless cognate pairs were included for VOT measurement. VOT measures were recorded as positive values when onset boundaries for target words were placed from the start of the plosive energy release burst to the onset of voicing (Lisker & Abramson, 1964). VOT measures were recorded as negative values when voicing was present before the plosive energy burst and, therefore, measured from the initial voicing to the plosive burst, otherwise referred to as prevoicing (Adi et al., 2016).

Vowels were classified by their phonetic symbol (e.g., /ɑ, ɛ, ɪ/) to compare duration across JC and English. The vowel duration, whether monophthong or diphthong, was compared and analyzed based on their phonetic transcription; in other words, monophthongs were not analyzed with diphthongs. Segmental-specific phonetic and articulatory contexts impact durational measures. For example, vowel duration is longer when followed by a voiced consonant plosive than a voiceless plosive (Neel, 2010). Therefore, voicing of the consonant following the vowel (i.e., CVC) was incorporated into the statistical analyses for vowel duration.

Whole-word and vowel acoustic duration measurements were obtained from 17 words from the subset. Although all words had the same initial word shape (CV), various word forms were included in the whole-word analyses to include various culturally acceptable words as part of the post-Creole continuum. To account for these variations, words were labeled phonetically. Words were also classified by the place of articulation (POA) and the manner of articulation of the first consonant (i.e., CVC). The manner of articulation categories included glides (/w, j/), liquids (/l/), affricates (/ʧ, ʤ/), plosives, and fricatives. Plosives were divided by oral plosives (/p, b, t, d, k, g/; referred to solely as "plosives" hereafter) and nasal plosives (/m, n, ŋ/; referred to as "nasals"). Nasals were separated because their production involves airflow in the oral and nasal cavities, and therefore, their acoustic features differ from plosives produced orally. Fricatives were also subgrouped and categorized as "nonstrident fricatives" for the consonant sounds /f, v, ɵ, ð/ and categorized as "stridents" for /s, z, ʃ, ʒ/. Fricatives were grouped separately due to greater acoustic energy for strident than nonstrident sounds (Neel, 2010). The proportion of vowel to word duration was calculated by dividing the vowel duration value from the whole-word duration value.

Reliability

A research team engaged in transcription and acoustic extraction of the participants' speech samples. All members were provided with training on the Jamaican phonological system and on accurately transcribing Jamaican phonemes. The training included independently transcribing speech samples in JC and English using Phon (Hedlund & Rose, 2020), a software program for phonological transcription with known clinical contributions (McAllister Byun & Rose, 2016). Specifically, members transcribed the same files using the "blind transcription" feature. It also allowed review of any discrepancies so that consensus could be reached using the Shriberg et al. (1984) protocol.

Furthermore, all members completed training in the processes related to the durational measures analyzed in this study. Interrater reliability was accomplished for all team members prior to beginning analyses. The intraclass correlation coefficient (ICC) for intrarater training reliability ratings were established using the *irr* R package (Gamer et al., 2019). Koo and Li (2016) guidelines were followed for interpreting ICC values. Training reliability was established to be 90% and above (range: 90.2%–99.8%), indicating good-to-excellent reliability (refer to Koo & Li, 2016). Interrater reliability was also completed for a sample of 10.0% (n = 13) of participants in JC and English for the acoustic duration parameters (VOT, whole-word duration, and vowel duration). The interrater reliability was assessed by the first author who was blind to the duration measures of the other team members. Interrater reliability ratings were accomplished using IBM Statistical Package for the Social Sciences (SPSS; Version 27) and were deemed excellent in JC (VOT mean: 94.3%, range: 91.6%–96.2%, average difference between raters' voiceless VOT: 0.001, average difference between raters' voiced VOT: 0.0003; whole-word duration mean: 97.0%, range: 95.9%–97.7%; vowel duration mean: 95.7%, range: 94.3%–96.8%) and good to excellent in English (VOT mean: 90.1%, range: 84.8%–93.5%, average difference between raters' voiceless VOT: 0.004, average difference between raters' voiced VOT: 0.003; whole-word duration mean: 94.5%, range: 92.5%–95.9%; vowel duration mean: 95.5%, range: 93.9%–96.7%).

Statistical Analysis

IBM SPSS (Version 27) was used to analyze data for RQ1 and RQ2. Minitab statistical software (Version 21.1) was used to analyze data for RQ3. As mentioned previously, the protocols allowed for various culturally appropriate response options (e.g., [pɪg, pɪgə, pɪgi, pɪgɪ]). Words were matched by phonological transcription. The most frequently produced variations for each word were included. To maintain sufficient statistical power, words with response frequencies below 20% were excluded. See responses included in JC and English on Supplemental Material S1. When appropriate (RQ1 and RQ2), the results are reported first for JC and then followed by English data.

RQ1 was addressed by conducting a repeated mixed-measures analysis of variance (ANOVA) model for VOT, with speaker group (adult, child), voicing (voiced, voiceless), and POA (bilabial, alveolar, velar) as fixed factors and participant as a random factor. The multiple productions by the speakers were grouped for these VOT analyses. Tukey's pairwise comparisons with Bonferroni correction were conducted as post hoc analyses, and effect sizes were calculated and reported as Cohen's d. Cohen's

(1988) effect size interpretation was used: 0.2 is a small effect, 0.5 is a medium effect, and 0.8 or larger is a large effect. To further address RQ1, a multivariate ANOVA (MANOVA) was calculated to determine differences and alignment between adults' and preschoolers' vowels, whole words, and proportion of vowel to word acoustic duration measurements in JC and English. These analyses were run by word (i.e., matched by broad phonological transcription) for two main reasons: first, to include various culturally acceptable words (e.g., [tiθ] [tit] [tits]) and, second, to control the effects of phonotactic structures on duration. Corresponding univariate one-way ANOVAs were completed for each dependent variable for significant results, followed by a Tukey's post hoc test to understand further where those differences lie. The effect size partial eta squared (η_p^2) are also reported, and the following interpretation was used (Cohen, 1988): .01 is a small effect, .06 is a medium effect, and .14 is a large effect.

RQ2 was addressed by conducting a nonparametric Wilcoxon signed-ranks test to determine the median differences between the preschoolers' acoustic duration measurements in each language. Effect sizes are calculated as r and reported.

RQ3 was addressed by conducting linear mixed-effects multiple regression models for each preschooler's acoustic duration parameters to understand the effect of children's contextual factors (sex, age, %language exposure, and %language use) in JC and English. However, additional fixed factors pertinent to the measurements were included to control for variance. The fixed factors included were voicing and POA for VOT, voicing of the subsequent consonant for vowel duration, manner of articulation for whole-word duration, and manner of articulation and voicing of the subsequent consonant for proportion. The mixed-effects models met assumptions of normality and homoscedasticity of residual distributions. Data points with residual distributions greater than 4.5 were excluded. The effect sizes (η_p^2) are also reported, and the interpretation mentioned above was used (Cohen, 1988). Lastly, post hoc analyses were not reported for the covariate fixed factors due to our primary interest being the contextual factor variables.

Results

RQ1. Do Adult and Preschool Patterns of Acoustic Duration Measures Differ for Productions in JC and English?

VOT—JC

Levene's test for JC indicated equal variances, $F(11, 698.596) = 13.43$, $p < .001$, when based on median values with an adjusted degrees of freedom. There were significant main effects found for group, $F(1, 956) = 27.32$, $p < .001$, $\eta_p^2 = .03$; voicing, $F(1, 956) = 136.94$, $p < .001$, $\eta_p^2 = .13$; and POA, $F(2, 956) = 25.36$, $p < .001$, $\eta_p^2 = .05$. Findings revealed a significant two-way interaction for Group × Voicing, $F(1, 956) = 9.77$, $p = .002$, and for Voicing × POA, $F(2, 956) = 5.49$, $p = .004$. The other potential interactions were not significant. Post hoc analyses were completed for significant interactions using Tukey's pairwise comparisons with Bonferroni correction, yielding an alpha criterion of $p < .025$ and $p < .016$ for two and three comparisons, respectively, as well as effect size calculations of Cohen's d. Statistically significant mean differences between children and adults were found for voiced ($p < .001$, $d = 0.91$), but not for voiceless plosives ($p = .206$, $d = 0.39$). Children produced longer voiced VOT ($M = 22$ ms [average of all VOT productions, including prevoicing]) compared with adults; the adults consistently exhibited prevoicing ($M = -40$ ms [average of all VOT productions, including prevoicing]). Statistically significant differences were also found between voiced bilabial and alveolar plosives ($p < .001$, $d = 0.80$), in addition to voiced bilabial and velar POA ($p < .001$, $d = 0.72$). Similarly, significant differences were found for voiceless bilabial and alveolar ($p < .001$, $d = 0.67$) and for bilabial and velar POA ($p = .005$, $d = 0.64$).

VOT—English

Levene's test for English indicated equal variances, $F(11, 758.76) = 12.25$, $p < .001$, when based on median values with an adjusted degrees of freedom. Significant main effects were found for group, $F(1, 960) = 29.84$, $p < .001$, $\eta_p^2 = .03$; voicing, $F(1, 960) = 136.73$, $p < .001$, $\eta_p^2 = .13$; and POA, $F(2, 960) = 27.75$, $p < .001$, $\eta_p^2 = .06$. Findings revealed a significant two-way interaction for Group × Voicing, $F(1, 960) = 12.24$, $p < .001$, and for Voicing × POA, $F(2, 960) = 7.60$, $p = .001$. The other potential interactions were not significant. Significant interactions were further examined using Tukey's pairwise comparisons with Bonferroni correction. Cohen's d effect sizes were also reported. Like in JC, significant mean differences were found between children and adults for voiced ($p < .001$, $d = 0.94$), but not for voiceless plosives ($p = .208$, $d = 0.31$). Children produced longer voiced VOT ($M = 24$ ms) compared with adults ($M = -37$ ms). Unlike JC, there were statistically significant differences between all voiced POA, but not between any voiceless POA. Differences were found between voiced bilabial and alveolar plosives ($p < .001$, $d = 0.44$), voiced bilabial and velar plosives ($p < .001$, $d = 0.44$), and voiced alveolar and velar POA ($p < .001$, $d = 0.18$). Lastly, to briefly summarize, Table 1 is included to provide the children's and adult's VOT average duration and standard deviation for both JC and English voiced and voiceless plosives.

Table 1. Children and adult voice onset time average duration (*M*) and standard deviation (*SD*) in Jamaican Creole (JC) and English in milliseconds.

Speaker group		JC		English	
		Voiced	Voiceless	Voiced	Voiceless
Children	*M*	14	84	17	87
	SD	112	86	82	95
Adults	*M*	−54	74	74	74
	SD	85	34	34	34

Vowel, Whole-Word Duration, Vowel-to-Word Proportion—JC

A MANOVA was employed with speaker group (children and adults) as independent variables. Vowel duration, whole-word duration, and the proportion of vowel to word duration were included as dependent variables. Words were matched and grouped by broad phonological transcription. The results of the MANOVA in JC yielded significant differences ($p < .05$) between the two groups (children and adults) on the combined variables of whole-word and vowel duration for words: "pig" ([pɪɡə]), "teeth" ([tit]), "fish" ([fɪʃ]), "thumb" ([tɔm]), "this" ([dɪs]), "socks" ([sɔks]), "legs" ([lɛgz]), "watch" ([watʃ]), and "house" ([haʊs]). Additionally, these words demonstrated medium-to-large effect sizes (η_p^2 range: .07–.49; see Supplemental Material S2). The differences were nonsignificant for the remaining words. Although [ʃip], [lɛg], and [fʊt] were nonsignificant, these words presented with medium effect sizes. Additionally, [saks] was also nonsignificant; however, it was presented with a large effect size (see Supplemental Material S2). Using a Bonferroni correction, each follow-up ANOVA was tested at an alpha level of .016 (.05/3; see Supplemental Material S3). There were statistically significant differences between children and adults on the first vowel duration for words: "pig" ([pɪɡə]), "teeth" ([tit]), "fish" ([fɪʃ]), "thumb" ([tɔm]), "socks" ([sɔks]), "legs" ([lɛgz]), and "house" ([haʊs]). Children produced all vowels longer than adults. Additionally, significant differences between children and adults were found for whole-word duration: "pig" ([pɪɡə]), "teeth" ([tit]), "this" ([dɪs]), "socks" ([sɔks]), "legs" ([lɛgz]), and "house" ([haʊs]). For all words except "this" ([dɪs], child: $M = 441$ ms, adult: $M = 635$ ms), children produced longer whole-word duration than adults. Lastly, there were statistically significant differences between children and adults on proportion of vowel to words, with children producing longer duration: "pig" ([pɪɡə]), "thumb" ([tɔm]), and "this" ([dɪs]).

Vowel, Whole-Word Duration, Vowel-to-Word Proportion—English

The results of the MANOVA in English yielded significant differences between the two groups, children and adults, on the combined variables of vowel duration, whole-word duration, and proportion of vowel to word duration for the words "pig" ([pɪg], [pɪɡə]), "teeth" ([tit]), "fish" ([fɪʃ]), "this" ([ðɪs], [dɪs]), "socks" ([saks], [sɔks]), and "jam" ([dʒam]). These words demonstrated large effect sizes (η_p^2 range: .11–.42; see Supplemental Material S4). The differences were nonsignificant for the remaining words. Although nonsignificant, the following words ([van], [tɔm]) had medium effect sizes. The post hoc ANOVAs were tested at a .016 (.05/3) alpha level with a Bonferroni correction (see Supplemental Material S5). Significant differences were found between children and adults on vowel duration for the words "teeth" ([tit]), "fish" ([fɪʃ]), and "socks" ([saks], [sɔks]). All children produced vowels longer than the adults. Additionally, significant differences between children and adults were found for whole-word duration: "teeth" ([tit]), "this" ([ðɪs], [dɪs]), and "socks" ([sɔks]). Children produced words longer than adults for all words except for "this," which adults produced with longer duration ([ðɪs], child $M = 246$ ms, adult $M = 588$ ms; [dɪs], child $M = 337$ ms, adult $M = 635$ ms). Lastly, there were statistically significant differences between children and adults on the proportion of vowel to word for the words "pig" ([pɪɡə]), "fish" ([fɪʃ]), and "this" ([ðɪs], [dɪs]). Again, the proportion duration was mostly longer for children than adults, except for the words "pig" ([pɪɡə], child $M = 463$ ms, adult $M = 498$ ms) and "this" ([ðɪs], [dɪs], child $M = 110$ ms, adult $M = 240$ ms), which were produced longer by adults.

RQ2. Do Acoustic Duration Patterns of Preschoolers' Productions in JC Differ From Their Productions in English?

A Wilcoxon signed-ranks test was conducted to determine the effect of language on VOT, vowel duration, whole-word acoustic duration, and the proportion for vowel to whole-word duration measurements. Effect sizes were calculated ($r = Z/\sqrt{N}$; Rosenthal, 1993) and interpreted using Cohen's (1988) original conventions of small ($r = .10$–$.30$), medium ($r = .30$–$.50$), and large ($r = .50$–1.00) effect sizes. There was a statistically significant difference between the two languages ($p < .05$) for the vowel duration of the words "moon," "this," and "sheep": "moon" ([mun]) $n = 78$, $z = 2.24$, $p = .025$, $r = .25$, indicative of small effect size; "this" ([dɪs]) $n = 30$, $z = 2.52$, $p = .012$, $r = .46$, indicative of medium effect size; and "sheep" ([ʃip]) $n = 57$, $z = 2.30$, $p = .021$, $r = .31$, indicative of medium effect size. For the few statistically significant differences found in vowel duration, JC was longer than English. Vowel duration for [mun] was longer in JC ($M = 370$ ms, $Mdn = 363$ ms) than in English ($M = 337$ ms, $Mdn = 313$ ms). For the word variation [dɪs], vowel duration was longer in JC ($M = 156$ ms, $Mdn = 137$ ms) than in English ($M = 108$ ms, $Mdn = 91$ ms). There was also a statistically significant decrease for [ʃip], with vowel duration being longer in JC ($M = 264$ ms, $Mdn = 252$ ms) than in English ($M = 230$ ms, $Mdn = 204$ ms).

A statistically significant difference was also found for the vowel-to-whole-word proportion measure for "sheep" ([ʃip]) $n = 57$, $z = 2.66$, $p = .008$, $r = .35$, indicative of medium effect size. The proportion was longer in JC (M = 409 ms, Mdn = 395 ms) than in English (M = 367 ms, Mdn = 355 ms). There were no statistically significant differences between the median of the remaining words for vowel duration, VOT, or whole-word duration in the languages ($p > .050$).

RQ3. What Is the Relationship Between Preschoolers' Contextual Factors (e.g., Age, Sex, and Language Exposure and Use) and Acoustic Patterns of Durations (VOT, Whole-Word Duration, and Vowel Duration) in JC and English?

Separate mixed-effects multiple regression models were used in each language to determine the effects of sex, age, %language exposure, and %language use on the acoustic patterns of durations as dependent variables (VOT, vowel, whole word, and vowel-to-whole-word proportion), with participants as random predictors. Responses coded as errors (i.e., responses not linguistically or phonetically included within the DEAP protocols) were excluded from these models. Fixed factors were included as covariates to control for their effect on the duration measures; however, our main focus was the contextual factors, and thus, post hoc testing was not completed for covariates.

VOT—JC

The mixed-effects multiple regression analysis for VOT in JC included voicing and POA as covariate fixed factors. The linear mixed-effects analysis revealed that the variables accounted for 31.84% of the variance in the VOT values ($R^2_{adj} = .32$). The contextual factors of sex, age, %language exposure, and %language use were not significant. POA, voicing, and the interaction between POA × Voicing were significant predictors of VOT JC with medium ($\eta_p^2 = .07$), large ($\eta_p^2 = .14$), and small ($\eta_p^2 = .01$) effect sizes, respectively (see Table 2).

Vowel Duration—JC

The mixed-effects multiple regression model for vowel duration in JC was completed with vowel duration as the dependent variable, and vowel phoneme and voicing of the consonant following the vowel as covariate fixed variables. The voicing was based on the child's production. The predictors accounted for 49.84% of the variance for vowel duration ($R^2_{adj} = .50$). The contextual factors (sex, age, %language exposure, and %language use) were not significant. The vowel ($p < .001$) and voicing of the consonant following the vowel ($p < .001$) were significant predictors. The effect size was large for vowel ($\eta_p^2 = .30$) and medium for the voicing of consonant following the vowel ($\eta_p^2 = .10$; see Table 3).

Whole-Word Duration—JC

For whole word in JC, the linear mixed-effects model revealed that the predictor variables accounted for 39.26% of the variance of the whole-word measures ($R^2_{adj} = .39$). The contextual factors sex, age, %language exposure, and %language use were not significant. The manner of articulation was a significant predictor ($p < .001$), with a large effect size ($\eta_p^2 = .141$; see Table 4).

Vowel-to-Word Proportion—JC

The mixed-effects analysis for the proportion of vowel to whole-word duration in JC included manner of articulation and voicing of the consonant after the vowel (i.e., CVC̲) as fixed factors. A 39.59% of the variance ($R^2_{adj} = .40$) was accounted for by the predictor variables. None of the contextual factors (sex, age, %language exposure, and %language use) significantly predicted vowel-to-word proportion.

Table 2. Voice onset time linear mixed-effects analysis in Jamaican Creole with age, sex, percentage of language (%language) exposure, %language use, and place of articulation (POA) and voicing as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	0.09	0.45	0.20	.84	< .001	—
Sex (female)[a]	1.35	3.22	0.42	.68	< .001	—
%Language exposure	0.09	0.15	0.63	.53	.01	—
%Language use	−0.10	0.16	−0.61	.55	.01	—
POA[b]						
Alveolar	13.36	3.59	3.72	< .001*	.02	Small
Bilabial	−22.93	3.49	−6.57	< .001*	.06	Medium
Voicing (voiced)[c]	−26.53	2.60	−10.20	< .001*	.14	Large
POA × Voicing						
Alveolar voiced	−0.39	3.60	−0.11	.91	< .001	—
Bilabial voiced	−8.15	3.49	−2.34	.02*	.01	Small

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b]Velar as the reference variable. [c]Voiceless as the reference variable.

*Effect size interpreted for statistical significance ($p < .05$), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding ($p < .05$).

Table 3. Vowel duration linear mixed-effects analysis in Jamaican Creole with age, sex, percentage of language (%language) exposure, %language use, vowel phoneme, and voicing of the following consonant as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	−0.90	0.90	−1.00	.32	.01	—
Sex (female)[a]	11.52	6.37	1.81	.07	.04	—
%Language exposure	0.26	0.30	0.88	.38	.01	—
%Language use	−0.49	0.32	−1.55	.13	.03	—
Vowel phoneme[b]						
a	−52.10	7.31	−7.13	< .001*	.04	Small
aɪ	96.30	8.94	10.77	< .001*	.09	Medium
aʊ	115.15	15.00	7.68	< .001*	.05	Small
ɑ	−7.06	15.91	−0.44	.66	< .001	—
ɛ	−69.20	12.44	−5.55	< .001*	.03	Small
i	14.86	8.84	1.68	.09	< .001	—
iə	20.10	18.41	1.10	.27	< .001	—
ɪ	−75.92	7.88	−9.63	< .001*	.07	Medium
o	−50.06	50.11	−1.00	.32	< .001	—
ɔ	−48.92	9.54	−5.13	< .001*	.02	Small
ɔʊ	79.42	22.94	3.46	< .001*	.01	Small
u	27.20	10.19	2.67	.01*	.01	Small
Voicing of consonant (voiced)[c]	36.18	3.12	11.59	< .001*	.10	Medium

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as reference variable. [b][ʊ] as reference variable. [c]Voiceless as reference variable.

*Effect size interpreted for statistical significance ($p < .05$), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding ($p < .05$).

Manner of articulation and voicing of the consonant following the vowel were significant predictors ($p < .001$) with large effect sizes ($\eta_p^2 = .18$ and $\eta_p^2 = .14$, respectively; see Table 5).

VOT—English

Similarly, in English, the linear mixed-effects analysis for VOT was conducted with VOT as the dependent variable and voicing and POA were included as fixed factors. The linear mixed-effects analysis revealed that the predictor variables accounted for 38.22% of the variance in the VOT values ($R^2_{adj} = .38$; see Table 6). Like VOT in JC, the contextual factors sex, age, %language exposure, and %language use were not significant. Additionally, POA, voicing, and the interaction between POA × Voicing were significant predictors with medium ($\eta_p^2 = .10$), large ($\eta_p^2 = .17$), and small ($\eta_p^2 = .01$) effect sizes, respectively.

Vowel Duration—English

The mixed-effects model for vowel duration was conducted with vowel duration as the dependent variable and vowel and voicing of the consonant following the vowel as covariate fixed variables. The variables accounted for 53.05% of the variance for vowel duration ($R^2_{adj} = .53$). The contextual factor %language use ($p = .036$) and the

Table 4. Whole-word linear mixed-effects analysis in Jamaican Creole with age, sex, percentage of language (%language) exposure, %language use, and manner of articulation as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	−1.98	1.87	−1.06	.29	.01	—
Sex (female)[a]	16.23	13.28	1.22	.23	.02	—
%Language exposure	0.38	0.62	0.62	.54	< .001	—
%Language use	−1.22	0.67	−1.83	.07	.04	—
Manner of articulation[b]						
Affricates	−95.99	18.01	−5.33	< .001*	.02	Small
Nonstrident fricatives	−10.78	9.72	−1.11	.27	< .001	—
Glides	88.58	17.81	4.99	< .001*	.02	Small
Laterals	−7.99	19.81	−0.40	.69	< .001	—
Nasals	53.04	13.36	3.97	< .001*	.01	Small
Stridents	80.58	13.47	5.98	< .001*	.03	Small

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b]Plosives as the reference variable.

*Effect size interpreted for statistical significance ($p < .05$), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding ($p < .05$).

Table 5. The proportion of vowel to word duration linear mixed-effects analysis in Jamaican Creole with age, sex, percentage of language (%language) exposure, %language use, manner of articulation, and voicing of the following consonant as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	–0.22	0.77	–0.29	.78	< .001	—
Sex (female)[a]	9.36	5.46	1.76	.08	.04	—
%Language exposure	0.15	0.25	0.61	.55	< .001	—
%Language use	–0.03	0.27	–0.01	.92	< .001	—
Manner of articulation[b]						
Affricates	–16.79	13.08	–1.28	.20	< .001	—
Nonstrident fricatives	4.87	6.75	0.72	.48	< .001	—
Glides	–92.58	13.00	–7.12	< .001*	.04	Small
Laterals	–39.11	13.99	–2.80	.01*	.01	Small
Nasals	105.52	9.32	11.32	< .001*	.09	Medium
Stridents	–38.40	9.88	–3.91	< .001*	.01	Medium
Voicing of consonant (voiced)[c]	56.23	3.98	14.14	< .001*	.14	Medium

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b]Plosives as the reference variable. [c]Voiceless as the reference variable.

*Effect size interpreted for statistical significance ($p < .05$), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding ($p < .05$).

covariate factors vowel ($p < .001$) and voicing of the consonant following the vowel ($p < .001$) were significant predictors (see Table 7). The effect size was small for %language use (η_p^2 = .05), large for the vowel phoneme (η_p^2 = .34), and medium for voicing of consonant following the vowel (η_p^2 = .10).

Whole-Word Duration—English

The mixed-effects analysis for whole word included manner of articulation as a fixed factor. The analysis revealed that the predictor variables accounted for 34.60% of the variance in the whole-word measures in English (R^2_{adj} = .35). The %language use was a significant predictor in English with a small effect size (η_p^2 = .05; see Table 8). Manner of articulation was also a significant predictor in English, with a large effect size (η_p^2 = .11).

Vowel-to-Word Proportion—English

The mixed-effects analysis for the proportion of vowel to whole-word duration included manner of articulation and voicing of the consonant after the vowel as covariate fixed factors. The predictor variables accounted for 39.98% of the variance (R^2_{adj} = .40). None of the contextual factors (sex, age, %language exposure, and %language use) were significant predictors. Manner of articulation and voicing of the consonant following the vowel were significant predictors ($p < .001$) with large effect sizes (η_p^2 = .19 and η_p^2 = .14, respectively; see Table 9). As mentioned, post hoc analyses are not reported for the fixed factors of the model because their inclusion in the model was to control variance but was not of primary interest.

Table 6. Voice onset time linear mixed-effects analysis in English with age, sex, percentage of language (%language) exposure, %language use, place of articulation (POA), and voicing as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	–0.23	0.46	–0.50	.62	< .001	—
Sex (female)[a]	–0.02	3.27	–0.01	.99	< .001	—
%Language exposure	0.09	0.17	0.50	.62	< .001	—
%Language use	0.07	0.17	0.42	.68	< .001	—
POA[b]						
Alveolar	18.57	3.41	5.45	< .001*	.04	Small
Bilabial	–26.88	3.30	–8.15	< .001*	.09	Medium
Voicing (voiced)[c]	–0.03	0.003	–11.95	< .001*	.17	Large
POA × Voicing						
Alveolar voiced	5.11	3.41	1.50	< .001*	< .001	Small
Bilabial voiced	–9.10	3.30	–2.76	< .001*	.01	Small

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b]Velar as the reference variable. [c]Voiceless as the reference variable.

*Effect size interpreted for statistical significance ($p < .05$), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding ($p < .05$).

Table 7. Vowel duration linear mixed-effects analysis in English with age, sex, percentage of language (%language) exposure, %language use, vowel phoneme, and voicing of the following consonant as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	−0.89	0.99	−0.92	.36	.01	—
Sex (female)[a]	3.17	7.02	0.44	.66	< .001	—
%Language exposure	−0.26	0.37	−0.72	.47	.01	—
%Language use	0.77	0.36	2.13	.04*	.05	Small
Vowel phoneme[b]						
a	−53.66	12.29	−4.37	< .001*	.02	Small
æ	−37.08	87.36	−0.43	.67	< .001	—
aɪ	79.25	12.93	6.12	< .001*	.03	Small
aʊ	91.62	17.05	5.44	< .001*	.02	Small
ɑ	27.62	18.36	1.50	.14	< .001	—
eɪ	70.18	87.36	0.80	.42	< .001	—
ɛ	−84.87	15.38	−5.47	< .001*	.02	Small
ɛə	2.85	87.34	0.03	.97	< .001	—
ɛɔ	−76.80	62.54	−1.23	.22	< .001	—
i	16.88	13.47	1.24	.21	< .001	—
iə	142.39	28.74	4.96	< .001*	.02	Small
ɪ	−85.24	12.42	−6.88	< .001*	.04	Small
ɔ	−68.54	13.65	−5.04	< .001*	.02	Small
ɔʊ	65.82	24.54	2.68	.01*	.01	Small
u[b]	−9.80	14.47	−0.70	.49	< .001	—
Voicing of following consonant (voiced)[c]	36.54	3.07	11.94	< .001*	.10	Medium

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b][ʊ] as the reference variable. [c]Voiceless as the reference variable.

*Effect size interpreted for statistical significance (*p* < .05), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding (*p* < .05).

To allow for some comparison of the children's durational parameters between the two languages, figures and a table are included. Figure 1 illustrates the mean VOT values by voicing and POA. Figure 2 provides a descriptive picture of how vowel duration varied based on the voicing of the following consonant. Table 10 provides the average duration for each vowel. Lastly, Figure 3 graphs whole-word duration based on the manner of articulation and language.

Discussion

Limited normative data regarding the speech characteristics for a wide range of bilingual populations make evaluating bilingual children difficult and put bilingual children at risk for misdiagnosis. This study addressed this clinical problem by acoustically analyzing and characterizing VOT, vowel duration, whole-word duration, and proportion of vowel to

Table 8. Whole-word linear mixed-effects analysis in English with age, sex, percentage of language (%language) exposure, %language use, and manner of articulation as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	−0.44	1.82	−0.24	.81	< .001	—
Sex (female)[a]	14.80	12.85	1.15	.25	.02	—
%Language exposure	−0.88	0.68	−1.31	.20	.02	—
%Language use	1.39	0.66	2.11	.04*	.05	Small
Manner of articulation[b]						
Affricates	−97.63	19.33	−5.05	< .001*	.02	Small
Nonstrident fricatives	−29.94	10.01	−2.99	< .001*	.01	Small
Glides	97.15	19.34	5.02	< .001*	.02	Small
Laterals	8.04	21.95	0.37	.71	< .001	—
Nasals	36.17	14.30	2.53	.01*	.01	Small
Stridents	85.01	14.57	5.84	< .001*	.03	Small

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b]Plosives as the reference variable.

*Effect size interpreted for statistical significance (*p* < .05), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding (*p* < .05).

Table 9. The proportion of vowel to word duration linear mixed-effects analysis in English with age, sex, percentage of language (%language) exposure, %language use, vowel phoneme, and voicing of the following consonant as independent variables.

Variable	Coef.	*SE* Coef.	*t*	*p*	η_p^2	Effect size interpretation
Age	−0.63	0.72	−0.87	.39	.01	—
Sex (female)[a]	0.27	5.08	0.05	.96	< .001	—
%Language exposure	0.13	0.27	0.49	.63	< .001	—
%Language use	0.17	0.26	0.65	.52	.01	—
Manner of articulation[b]						
Affricates	1.64	13.23	0.12	.90	< .001	—
Nonstrident fricatives	12.79	6.54	1.96	.05*	< .001	Small
Glides	−91.84	12.94	−7.10	< .001*	.04	Small
Laterals	−78.46	14.73	−5.33	< .001*	.02	Small
Nasals	107.49	9.31	11.55	< .001*	.10	Medium
Stridents	−34.13	10.34	−3.30	< .001*	.01	Small
Voicing of consonant (voiced)[c]	59.77	4.10	14.58	< .001*	.14	Large

Note. Coef. = coefficient; *SE* Coef. = standard error of the coefficient.

[a]Male as the reference variable. [b]Plosives as the reference variable. [c]Voiceless as the reference variable.

*Effect size interpreted for statistical significance ($p < .05$), an em dash was inserted to indicate there was no effect size calculated due to a nonsignificant finding ($p < .05$).

word in typical 3- to 5-year-old JC-English–speaking bilingual preschoolers. The acoustic methods used in this study can contribute to the development of speech sound metrics for improving the diagnostic accuracy in this population.

Our first RQ aimed to understand if children and adults differed in their patterns of acoustic duration in JC and English. Adults were included to guide our understanding of typical speech acoustic patterns for JC–English speakers. Therefore, differences between children and adults could be interpreted as developmental differences related to maturation and not to disorder. Significant differences between children and adults were found for VOT duration in JC and English, in addition to differences between voiceless and voiced contexts. The differences between voiced and voiceless consonants indicate the ability for children to effectively produce phonemic voicing distinctions (S. A. S. Lee & Iverson, 2017). However, the children presented a larger variance in VOT duration than adults in

Figure 1. Mean voice onset time (VOT) duration in seconds produced by children based on the voicing and place of articulation (POA) in English and Jamaican Creole (JC). CI = confidence interval.

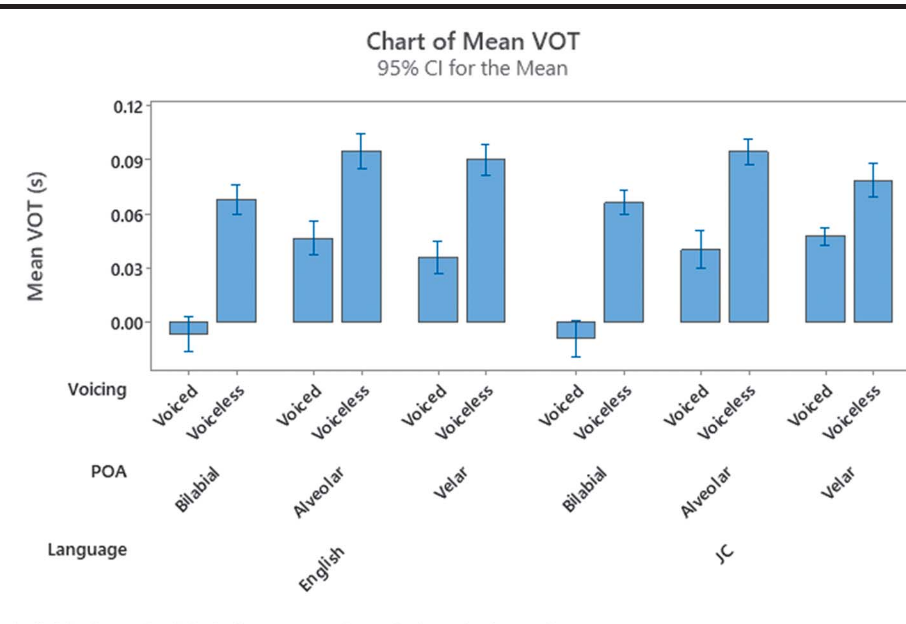
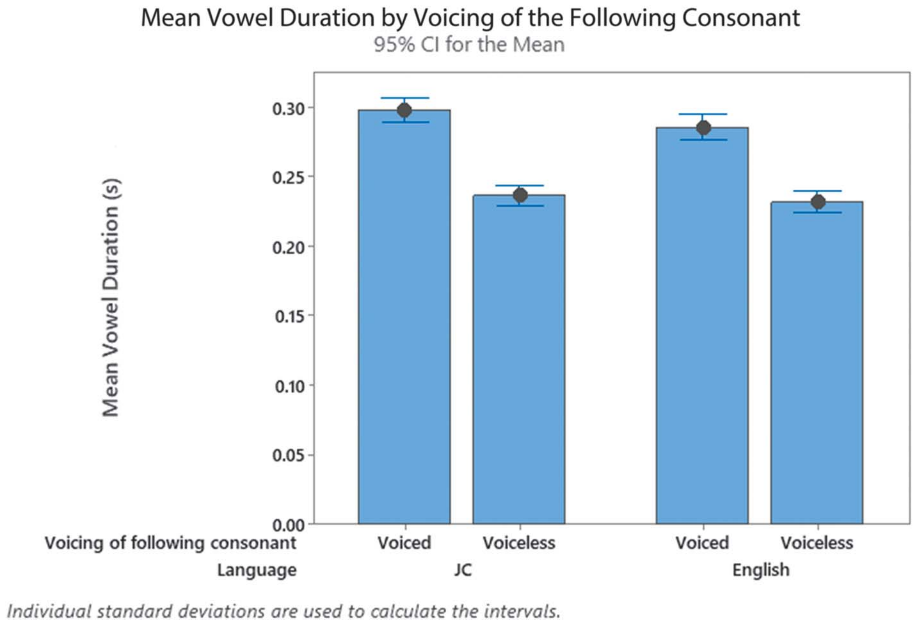


Figure 2. Mean vowel duration in seconds produced by children based on the voicing of the following consonant. CI = confidence interval.



both voiced and voiceless plosives in JC and English (see Table 1). These results are consistent with those of other studies (e.g., Tingley & Allen, 1975; Whiteside & Marshall, 2001; including Korean-English–speaking children: S. A. S. Lee & Iverson, 2012; Korean [Seoul dialect]–speaking children: Kim & Stoel-Gammon, 2009; and Mandarin-speaking children: Yang, 2018), which demonstrated that children's motoric control related to VOT is still developing between the ages of 3 and 5 years. Therefore, we surmise that bilingual preschoolers have established phonemic voicing distinctions but require further maturation to approximate adult patterns.

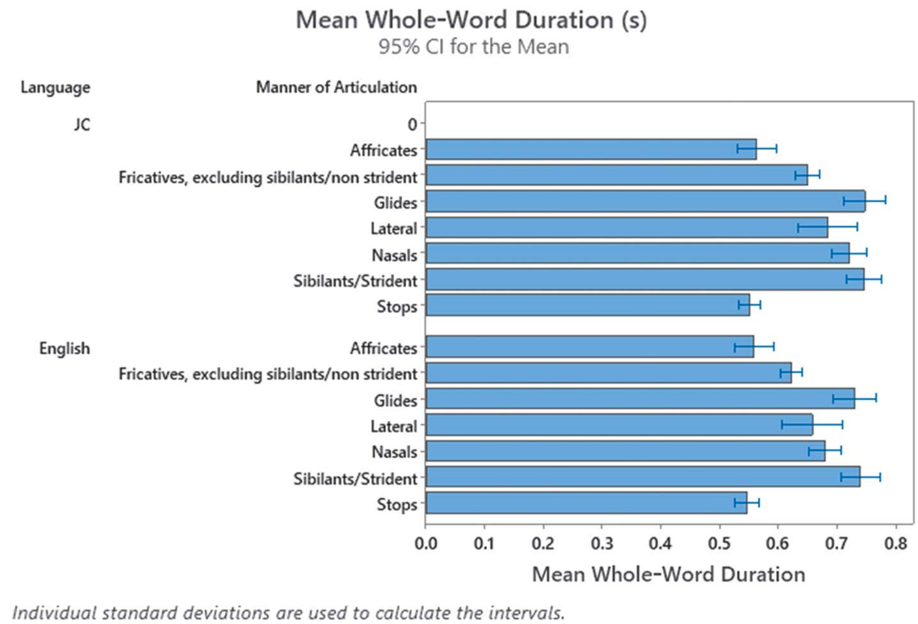
Table 10. Children's average vowel duration in milliseconds in Jamaican Creole (JC) and English.

Vowel phoneme	JC		English	
	n	Mean duration	*n*	Mean duration
aʊ	39	395	47	378
aɪ	140	376	171	365
ɔʊ	15	359	16	352
u	100	307	91	276
iə	25	230	11	429
i	173	294	151	303
ɑ	34	272	36	314
ɔ	116	231	119	217
ɛɔ	—	—	2	209
ʊ	87	230	77	205
o	3	229	—	—
a	303	227	290	233
ɛ	62	210	73	202
ɪ	213	204	249	201
æ	—	—	1	249

Note. Em dashes (—) indicate no response for phoneme.

Similar characteristics, such as the distinction between voiced and voiceless plosives (Nakai & Scobbie, 2016), is commonplace among languages (Cho & Ladefoged, 1999) and thus was expected. However, the range of acceptable VOT durations vary depending on the spoken language (Lisker & Abramson, 1964) and can change across languages or may share similar features. For example, JC adult speakers in this study consistently exhibited prevoicing for voiced plosives. This pattern contrasts with that documented in the prior literature for some speakers of American English (Lisker & Abramson, 1964). That said, this characteristic observed in JC adult speakers may be more in line with speakers of certain dialects of American English (Ryalls et al., 1997). Our current study showed a large amount of variation in voiced plosive productions for children in both English and JC, with inconsistent prevoicing patterns. The large variance in the children's voiced VOT duration may illustrate articulatory and vocal maturation patterns or cross-linguistic influence. For voiced plosives, prevoicing requires more advanced muscular control (mainly needed for complex velopharyngeal closure and sustaining appropriate transglottal pressure during laryngeal closure) than is needed when producing a voiced plosive with a short positive VOT, which require maintaining complete velopharyngeal closure (Auzou et al., 2000; Kewley-Port & Preston, 1974). VOT voicing contrast requires the coordination of different systems (e.g., articulatory, phonatory, and respiratory), which include the abduction and adduction of vocal folds, constriction and closure of the velopharyngeal port, closure and opening of the lips, oral pressure build-up and release,

Figure 3. Mean whole-word duration in seconds produced by children based on the initial consonant's manner of articulation in Jamaican Creole (JC) and English. CI = confidence interval.



and lowering of the mandible (Moore, 2004). The time of acquisition for prevoicing has been inconsistently reported in monolingual children (Kehoe & Kannathasan, 2021). Some studies with bilingual child participants have documented patterns of voicing transfer from one language to another, showed delays in acquiring prevoicing, or did not demonstrate possible cross-linguistic patterns (Kehoe & Kannathasan, 2021). Additionally, it has been proposed that the later acquisition of prevoicing is attributed to learning strategies by children (Kim & Stoel-Gammon, 2009). These may be reasons that the children in this study have not yet mastered the prevoicing skill that other children have been reported to have mastered (e.g., 4-year-old English-speaking children; Barton & Macken, 1980).

Previous literature has suggested that young monolingual speakers of English demonstrate greater variability with "voiceless" VOT (Lowenstein & Nittrouer, 2008), leading to a large range of productions that often overlap with established voiced VOT ranges (Whiteside & Marshall, 2001; Zlatin & Koenigsknecht, 1976). In this study, we also observed a large range of voiceless VOT productions for children across both JC and English, in which some children produced prevoicing VOT for voiceless plosives. Prevoicing was determined by any voicing prior to the release burst, whether the participants paused in voicing during prevoicing was not tracked for our sample. Our findings demonstrate maturational trends in the mastery of voiceless VOT, as demonstrated by higher variability in voiced VOT. This trend is also expected in monolingual children (Lowenstein & Nittrouer, 2008). However, more work is needed in this area and would be valuable to better understand developmental trajectories across both populations that may be considered universal and for language-specific trends (Kim & Stoel-Gammon, 2009).

Additional evidence that children within this age range are developing speech motor refinement was found through differences between children's and adults' whole-word and vowel duration. Specifically, nearly 58% of the words in JC and English showed differences. The observed differences in whole-word duration can signal difficulties in producing some phonemes in specific phonotactic conditions for children in this age range (e.g., later developing) due to the necessary motoric coordination and precision. For example, many of the words with significant differences between child and adult productions contained fricatives in word-final position (i.e., fish, this, legs, and house). Fricatives are generally acquired later in childhood and involve advanced articulatory coordination (Namasivayam et al., 2020). Some words also included consonant clusters in the final position (i.e., socks, legs). Although consonant clusters in the final position have been found to be acquired early in childhood for some populations (e.g., typically developing English-speaking monolingual children), individual variability remains frequent (see McLeod et al., 2001). Variability in child participants' production of consonant clusters may have impacted the significant differences found from the adults' productions. Lastly, the nonsignificant effect sizes point to a difference between adults and children for variable vowel duration, whole-word duration, and proportion of vowel to word duration. However, the sample sizes for both adult and child groups may have not been large enough to demonstrate significance. The difference between the groups may be best explored with larger sample sizes to understand its true significance.

The second RQ investigated whether children's acoustic duration patterns aligned between JC and English. It is of interest to determine the presence of cross-linguistic effects because language systems may interact differently in diverse, bilingual profiles (e.g., acceleration, delay, and transfer; Paradis & Genesee, 1996). We found few statistically significant differences between the durational characteristics of JC and English. For the differences found (e.g., vowel duration of [mun]), the duration was longer in JC than in English. Our data also showed that the vowel-to-word-duration proportions were similar for both languages. Phonologically, it seems possible to interpret that these results suggest similar trajectory patterns or language "rules" (e.g., sonority-based patterns) in JC and English for these bilingual speakers. Another possibility is a strong cross-linguistic interaction between the languages for these bilingual speakers.

A possible explanation for not finding many differences between the languages may be that features of the post-Creole continuum result in similar durational patterns or motor control maturation trajectories in both languages. The continuum allows for shared production features, especially if speakers prefer using acceptable productions toward the "middle" of the continuum. Cross-linguistic effects can be observed through overlapping durational patterns across languages. S. A. S. Lee and Iverson (2012) discussed a similar finding in one of their simultaneous bilingual groups, suggesting that their similar (albeit not merged) speech productions across languages may be due to less exposure/experience to their second spoken language. Furthermore, in sharing a similar motor schema, JC–English speakers do not need to broadly distinguish duration to abide by both languages' linguistic parameters.

The third RQ sought to examine the presence of a relationship between preschoolers' contextual factors (age, sex, language exposure, and language use) and their acoustic patterns of durations in JC and in English. This question incorporated some personal contextual factors informed by the ICF-CY framework (WHO, 2007). Results in both languages determined that age, sex, and %language exposure were not significant variables in the mixed-effects models for each acoustic parameter (VOT, vowel, and whole-word duration). However, %language use was found to be a significant predictor in vowel and whole-word duration in English. Our model showed that for every increase in %language use, we may find an 8-ms difference in whole-word duration. This suggests that a 10% increase in language use could result in an 80-ms increase in whole-word duration. This duration difference could likely be due to lengthened vowel duration and could be perceived auditorily. Depending on the vowel, the increased vowel length could align more with values expected in Jamaican, American, or British English. For example, e.g., /a, ɑ, u:/ were found to be longer in child speakers of American English, whereas /i:/ was longer in child speakers of Jamaican English (Coy & Watson, 2020).

Additionally, although differences in duration can be expected by age and sex in older populations, significant differences were not found in our sample. Although this result was unexpected, it is consistent with those of other studies that suggest that some age ranges (Jacewicz et al., 2011) and sex (S. Lee et al., 1999; Whiteside & Marshall, 2001) may not be significant variables in children's durational patterns, such as vowel duration. The possibility exists that these variables would have more significant implications in a larger sample size consisting of a wider age range. It should be noted that %language use was a significant predictor for vowel and whole-word duration in English. However, it had a small effect size, and thus, not only is its relationship with vowel and whole-word duration limited, but its clinical relevance may also be minimal.

In addition to analyzing relationships between contextual factors and durational measures, this RQ also allowed us to analyze the preschoolers' durational characteristics in each language separately (see Figures 1, 2, and 3). It also allowed some comparison with other studies. However, it should be noted that direct comparison is difficult due to differences in methodology. For example, House (1961) described the [ɪ] [ɛ] [ʊ] [ʌ] vowels in English as having the shortest average duration. Although their data were collected from nonsense utterances and only by adult male speakers, we also found [ɪ], [ɛ], and [ʊ] had the shortest duration in English for our sample of preschoolers. Our sample did not produce the vowel [ʌ] in English or JC. In JC, preschoolers produced [ɪ] and [ɛ] with the shortest duration. However, [ʊ] was not among the shortest produced vowels and was produced longer than in English, indicating that [ʊ] is lengthened in JC.

A subgroup of the participants in the 5-year-old age range in this study was compared with a same-age participant group from the Khattab (2000) study. This comparison allowed us to determine that the JC–English bilingual participants aged 5;0–5;6 from this study produced voiceless plosives (/p/: 63 ms, /t/: 79 ms, /k/: 78 ms), similar to a 5;5 monolingual English speaker's values described by Khattab (2000; /p/: 52 ms, /t/: 75 ms /k/: 62 ms). However, the voiced plosive values produced by JC–English bilingual participants aged 5;0–5;6 from this study were noticeably different (/b/: −21 ms, /d/: 51 ms, /g/: 39 ms) than the speaker from the Khattab (2000) study (/b/: −5 ms, /d/: 9 ms, /g/: 17 ms). Particularly the /b/, which was produced within a prevoicing range by the participants in this study.

As previously mentioned, our results indicate prevoicing is a typical acoustic feature of the post-Creole continuum.

This study provided an opportunity to advance the knowledge base of durational patterns in this bilingual context. Our results provide insight as to what may be typical of JC-English–speaking preschoolers. First, that JC-English–speaking bilingual children aged 3–5 years may have mastered voicing distinction for plosive consonants. Nevertheless, they continue to develop vocal and articulatory systems that need precise time coordination for productions, and therefore, their durational values have not entirely approximated that of adults. Second, the duration characteristics are produced similarly across languages. This can indicate shared motor control trajectories. Third, the contextual factor of %language use was a significant predictor of the children's vowel and whole-word duration in English. However, other contextual factors of age, sex, and language exposure did not significantly impact children's durational values in either JC or English. Furthermore, linguistic–motor interactions were observed, such as the duration of a vowel being affected by the voicing of the consonant that follows it (e.g., the significant statistical effect found for vowel and voicing of the following consonant for vowel duration). These durational patterns are a foundation for establishing normative acoustic data for this understudied bilingual typology. Additionally, we found similar acoustic patterns across languages in children and adults. These were important findings that supported the conceptual premise of cross-linguistic transfer, or to an interaction between languages, for these bilingual speakers as evidenced in acoustic patterns.

Limitations and Future Directions

The findings reported in this research are subject to at least four limitations. First, it was beyond the scope of this research to use different parameters to acoustically analyze the speech samples (e.g., F2 and F3 describe the tongue position in the oral cavity and useful for describing vowels; Neel, 2010), which could enrich the current acoustic normative. Measuring and accounting for the participants' speaking rate would also be beneficial as it can impact the duration of segments, such as vowels (Coy & Watson, 2020). This study followed the protocol of a larger study (Jamaican Creole Language Project) that involved previously established measures and single-word responses. Repetitions of segments, including vowels, could enhance the description of acoustic characteristics and account for individual variability (Vorperian & Kent, 2007). This study included word response criteria that excluded phonemes such as the vowel /e/ and consonants in labiodental, interdental, palatal, and glottal POA. Future studies should therefore expand the phonemes assessed and include their repetition. Second, although simultaneous bilinguals are representative of the Jamaican demographic population, it would be of value to include other bilingual typologies (e.g., sequential bilinguals), which would expand the generalizability of the results. Third, adults did not undergo formal hearing or language assessments for inclusion in this study. Although self-reported, formal hearing screening would be beneficial because hearing loss can impact the duration parameters measured (e.g., VOT voicing distinction). Future work might also include increasing the number of participants, especially other age ranges, such as a larger 3-year-old range, and more male adults, in the sample. Although the 4- and 5-year-old sample was relatively balanced, the sample of 3-year-old children was small and may have impacted the age analysis. Cisgender female adult anatomy (i.e., laryngeal and vocal tract) is closer in similarity to children's than cisgender males. Therefore, including more males would be helpful to explore whether their inclusion would impact the overall durational values observed and other results. It should also be noted that although the demographic questionnaires allowed for information to be written, a binary female/male option was included and, therefore, did not likely measure possible differences in participants' gender groups (Johnson et al., 2009). Additionally, the nonsignificant medium and large effect sizes observed may have been influenced by the smaller adult sample size (RQ1), and therefore, an increase in the adult sample size could result in significant differences not found in this study. Fourth, a pertinent progression following the characterization of typical acoustic patterns would be to include children who present with SSD characteristics. This comparison could lead to distinguishing atypical patterns of speech sound productions in this population and improving the diagnostic accuracy of SSDs.

Clinical Implications and Conclusions

This study provides an innovative approach to categorizing speech sound productions in an understudied bilingual population. The findings can provide practical and theoretical support for understanding the impact of contextual factors (i.e., sex, age, language exposure, and use) for this bilingual population and their speech development. Findings may also be relevant to other bilingual populations and typologies such as simultaneous bilingual speakers of language pairings with a shared linguistic foundation or Creole languages.

The inclusion of acoustic duration measures and analyses contributes to understanding articulatory and vocal motor patterns of preschool-age JC-English–speaking bilingual children. This study's characterization of durational patterns is not exhaustive; however, it is an initial step in developing speech acoustic models. Acoustic analyses are beneficial when working with bilingual children because they offer a more objective description of speech than traditional perceptual measures. It should be recognized that, for acoustic analysis to be clinically feasible, a more timely and automatic recognition system may be needed.

The subtle differences found in this sample of preschoolers are important to understand, especially in their bilingual environment. The possibility of transfer between JC and English in Jamaican speakers has important clinical implications (see Karem & Washington, 2021). Previous findings demonstrated increased variability in lexical production in these speakers as measured using acoustic means (León et al., 2022). We now know that we may also expect minimal acoustic distinction in duration features in bilingual speakers using either JC or English. Although part of typical bilingual development, differences in speech production compared with monolingual speech patterns may be misinterpreted as characteristic of SSD and thus lead to misdiagnosis (Hambly et al., 2013). This observation gives credence to the importance of establishing normative data from large data sets and comparing speech skills to bilingual data sets, when possible, instead of solely monolingual skills.

Although significant effects were not found for the %language exposure, it should be remembered that bilingualism is fluid. Bilingual status has been shown to change over time, depending on the exposure of the two languages (McLeod et al., 2017). It is important to gain information on the language environment for a holistic and thorough understanding of bilingual children's speech skills and utilize culturally responsive approaches (i.e., adult participants from the same linguistic community) to inform their speech patterns.

This study presented duration characteristics that can serve as a foundation for normative data in JC-English–speaking preschoolers. This is important because it can lead to the adaptation of clinical assessment methods to match the expectations of typical speakers from this population and reduce bilingual misdiagnosis. It is also important clinically because it can support SLPs' understanding of how post-Creole characteristics may be reflected in other languages, such as lengthening vowels or other segments.

Data Availability Statement

The data sets generated and analyzed during this study are not publicly available due to privacy and ethical concerns. For more information, please contact the corresponding author.

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