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Review Article

Children's Consonant Acquisition in 27 Languages: A Cross-Linguistic Review

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Purpose: The aim of this study was to provide a cross-linguistic review of acquisition of consonant phonemes to inform speech-language pathologists' expectations of children's developmental capacity by (a) identifying characteristics of studies of consonant acquisition, (b) describing general principles of consonant acquisition, and (c) providing case studies for English, Japanese, Korean, and Spanish.
Method: A cross-linguistic review was undertaken of 60 articles describing 64 studies of consonant acquisition by 26,007 children from 31 countries in 27 languages: Afrikaans, Arabic, Cantonese, Danish, Dutch, English, French, German, Greek, Haitian Creole, Hebrew, Hungarian, Icelandic, Italian, Jamaican Creole, Japanese, Korean, Malay, Maltese, Mandarin (Putonghua), Portuguese, Setswana (Tswana), Slovenian, Spanish, Swahili, Turkish, and Xhosa.
Results: Most studies were cross-sectional and examined single word production. Combining data from 27 languages, most of the world's consonants were acquired by 5;0 years; months old. By 5;0, children produced at least 93% of consonants correctly. Plosives, nasals, and nonpulmonic consonants (e.g., clicks) were acquired earlier than trills, flaps, fricatives, and affricates. Most labial, pharyngeal, and posterior lingual consonants were acquired earlier than consonants with anterior tongue placement. However, there was an interaction between place and manner where plosives and nasals produced with anterior tongue placement were acquired earlier than anterior trills, fricatives, and affricates.
Conclusions: Children across the world acquire consonants at a young age. Five-year-old children have acquired most consonants within their ambient language; however, individual variability should be considered.
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Children's acquisition of speech involves mastery of the perception and production of consonants, vowels, consonant clusters, tones, prosodic features, and phonological rules of the language(s) they speak, with the outcome of intelligible speech. Mastery of consonants is one of "the most widely used metrics of typical phonological acquisition and of phonological disorder" (Edwards & Beckman, 2008a, p. 937). Since the 1930s (e.g., Poole, 1934; Wellman, Case, Mengert, & Bradbury, 1931), many researchers have documented children's age of acquisition of consonants. In 1972, Sander published an article entitled, "When Are Speech Sounds Learned?", where he graphically summarized two studies of English consonant acquisition (Templin, 1957; Wellman et al., 1931) to describe customary versus mastery production and account for variability between studies. In his famous figure, the shorter bars indicated less variability in the age of acquisition (e.g., /p, m/) and the longer bars indicated greater variability (e.g., /t, s/). His documentation of customary and mastery production of consonants has been cited repeatedly and has been widely used by speech-language pathologists (SLPs) as a summary of English-speaking children's speech acquisition, despite the fact that there have been additional studies of children's acquisition of English published since this time (e.g., Dodd, Holm, Hua, & Crosbie, 2003; Smit, Hand, Freilinger, Bernthal, & Bird, 1990).

In the following decades, two additional summaries of consonant acquisition have been adopted by SLPs: percentage of consonants correct (PCC) and early–middle–late consonants. PCC was originally described by Shriberg and Kwiatkowski (1982) and was calculated by dividing the number of consonants produced correctly by the total number of consonants in a connected speech sample. PCC has been linked to descriptors of severity of involvement for children with speech sound disorders (SSD; e.g., mild, moderate, severe), and the construct has undergone minor modifications over the years (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997; Shriberg, Kwiatkowski, Best, Hengst, & Terselic-Weber, 1986). Since development, PCC and its variants (percentage of vowels correct [PVC] and

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percentage of phonemes correct [PPC]) have been widely used by SLPs to document speech acquisition of typically developing children (e.g., Dodd et al., 2003; Fabiano-Smith & Goldstein, 2010a) and those with SSD (e.g., McLeod, Harrison, McAllister, & McCormack, 2013) to support diagnosis of SSD. The third summary of consonant acquisition was also developed by Shriberg (1993), who grouped the 24 English consonants into early-8, middle-8, and late-8 consonants on the basis of data from 64 children with SSD aged 3–6 years. The early–middle–late construct has been used to describe the speech of typically developing children and children with SSD in English and Spanish (Fabiano-Smith & Goldstein, 2010b; Flipsen, Hammer, & Yost, 2005; Shriberg, Gruber, & Kwiatkowski, 1994) and has been used as a focus of intervention (Bleile, 2017). SLPs frequently use these three constructs (age of acquisition, PCC, and early–middle–late) to describe children's speech acquisition as they work with children in assessment, diagnosis, determination of intervention targets, and decision making regarding successful outcomes of intervention (Bernthal, Bankson, & Flipsen, 2017; McLeod & Baker, 2017).

English is not the first language of a large portion of the world's population (Simons & Fennig, 2018), and most English-dominant countries contain speakers of many different languages (e.g., 20.8% of the U.S. population speaks a language other than English at home, with the second most spoken language being Spanish; Ryan, 2013). Many studies have documented English-speaking SLPs' lack of confidence when providing services to children who speak languages that the SLPs do not speak (Caesar & Kohler, 2007; Guiberson & Atkins, 2012; Kritikos, 2003; Roseberry-McKibbin, Brice, & O'Hanlon, 2005; Williams & McLeod, 2012). In most of these studies, SLPs indicated that they do not have access to relevant research and resources to work effectively in cross-linguistic or multilingual contexts. However, in the case of children's speech acquisition, researchers across the world have been documenting the age of acquisition of consonants for languages other than English for many years. In the past decade, English-language readers have had greater access to normative studies of speech acquisition in a range of languages via books, book chapters, and websites (e.g., Hua & Dodd, 2006; McLeod, 2007, 2010, 2016a). This increase in access to normative studies in languages other than English has answered recent calls to raise the visibility of scientific publications in languages other than English (Meneghini & Packer, 2007) and to answer criticism that much of the research about human behavior comes from western, educated, industrialized, rich, and democratic societies that are not representative of diverse cultures (Henrich, Heine, & Norenzayan, 2010). However, with over 7,000 documented languages in the world (Simons & Fennig, 2018), there will never be available speech acquisition data for every language and dialect. What SLPs need is a comprehensive cross-linguistic review to collate data about consonant acquisition (including age of acquisition, PCC, and early–middle–late constructs) to inform SLPs' expectations of children's acquisition of consonants across the world.

Theoretical Consideration of Consonant Acquisition Across Languages

A number of influential theorists and researchers have drawn on cross-linguistic studies to describe children's speech acquisition (Edwards & Beckman, 2008b; Jakobson, 1941/1968; Locke, 1983; Stokes & Surendran, 2005; Vihman, 1996). Those who considered linguistic universals have focused on the acquisition of features of sounds by looking for generalizations across a large number of children. For example, Jakobson (1941/1968) proposed a structuralist theory of phonological acquisition to describe the order of acquisition of feature classes (e.g., plosives are acquired before fricatives). Jakobson famously stated that "the relative chronological order of phonological acquisitions remains everywhere and at all times the same…the speed of this succession is, in contrast, exceedingly variable and individual…" (p. 46). He argued that the universal properties of sounds contributed to the order and age of acquisition and features were considered to be unmarked (simple, earlier to be acquired) and marked (more complex, later acquired; Jakobson, 1941/1968). Locke (1983) similarly argued that children master phonetic features in a similar sequence in presenting his analysis of studies of English, German, Japanese, Russian, Italian, Arabic, Slovenian, Swedish, Norwegian, and Czech. In contrast, other linguists have challenged the concept of linguistic universals by demonstrating a wide variability between children and insisting on the importance of individual children's acquisition. For example, Ferguson and Farwell (1975) presented a cognitive model of speech acquisition to account for individual variability and argued against writing rules and generalizations. Vihman (1996) also argued for a cognitive model to describe individuals' segmental and prosodic acquisition and proposed a templatic phonology (Vihman & Croft, 2007).

Some researchers have considered children's speech acquisition by combining both general principles and individual capacity. Elbert (1984) reconciled these two seemingly divergent theoretical perspectives by applying them to SLPs' clinical practice. She suggested that SLPs should consider general overarching principles from speech acquisition norms concurrently with viewing individual children as creative learners who are "engaged in highly energetic pursuit of knowledge" (p. 115). The biological account of speech acquisition proposed by Kent (1992) similarly combined both individual capacity and general principles. Kent outlined three broad principles of biological development (variability, reversals and revisions, and excess potential for development) and then described four sets of English consonants differentiated by articulatory complexity by drawing on the work of Sander (1972): Set 1 [p, m, n, w, h], Set 2 [b, d, k, g, f, j], Set 3 [t, ɹ, l, ŋ], and Set 4 [s, z, ʃ, ʒ, ʧ, ʤ, v, θ, ð]. Each set was described regarding the motoric adjustments required to articulate each sound; for example, Set 4 requires adjustment of tongue place and configuration to produce fricatives. More recently, the emergence approach to speech acquisition has been described by Davis and Bedore (2013) combining both general principles and individual

capacity by outlining how children's intrinsic capacities (perception, production, and cognitive) and interaction capacities (joint attention, turn-taking, and intention reading) intersect with the extrinsic context (ambient phonology and sociocultural influences). Combining both general principles and individual capacity is particularly important for children who learn to speak more than one language, especially because there are limited normative data regarding multilingual speech acquisition, and researchers are confounded by the need to account for differences in the age of exposure, level of proficiency, and use of each language for individual children.

To date, description of general principles of consonant acquisition has been undertaken in three ways: consonants within one language (e.g., Kent, 1992; Sander, 1972), features across languages (e.g., plosives develop before fricatives; Jakobson, 1941/1968; Locke, 1983), or consonants across languages (e.g., Edwards, Beckman, & Munson, 2015; McLeod & Singh, 2009). With recent availability of consonant acquisition data across a wide range of languages, it is possible to expand our knowledge of general principles of consonant acquisition across languages. It is important to consider the consonant phoneme (contrastive speech sound within a language) as the unit of analysis rather than the phone (speech sound) or allophone (variations of phonemes) when undertaking a cross-linguistic review of consonant acquisition to provide generalizable information regarding similarities and differences between languages. A large-scale review is required to provide an overview of patterns of consonant phoneme acquisition across languages and general cross-linguistic patterns that could be applicable to languages not already studied.

Aims

The motivation for the current research was to inform SLPs' expectations of cross-linguistic consonant acquisition. Specifically, the aims of this review were to (a) identify and describe studies of consonant acquisition across languages; (b) provide general principles regarding the age of acquisition of consonant phonemes, PCC, early–middle–late consonants, and manner and place characteristics across languages; and (c) consider the application of these general principles to four languages as case studies: English, Korean, Japanese, and Spanish.

Method

A systematic literature search was undertaken, and a scoping review framework (Colquhoun et al., 2014) was used to examine a broad range of literature and synthesize cross-linguistic knowledge about children's acquisition of consonant phonemes.

Search Strategy

Source 1

Thirteen databases were searched to identify the full range of published literature describing children's speech sound acquisition (Cambridge Journals Online; Cochrane; EBSCO Host; Google Scholar; The Scholarly Journal Archive [JSTOR]; Linguistics, Language, and Behavior Abstracts; Medline; Oxford Journals; PsycInfo; PubMed; Sage Journals; Springer Link; and Wiley Online Library). Four search terms were used across all databases—"children" AND "consonant" AND "acquisition" OR "development"—and 1,684 citations were located. Duplicates of citations were identified and removed, leaving 623 unique citations.

Source 2

The first author collated a database of studies of children's speech acquisition over 10+ years from journal articles and by attending conference presentations, visiting speech-language pathology clinics around the world, and contacting colleagues who work in different countries and speak languages other than English. In addition, authors of chapters in the *International Guide to Speech Acquisition* (McLeod, 2007) were asked to document speech acquisition studies that were developed for the languages they were writing about, and these were included in the review. Forty relevant unique articles were located that were not found during the database search (Source 1).

Source 3

Members of the International Expert Panel on Multilingual Children's Speech (McLeod, Verdon, & IEPMCS, 2017) were provided with the list of articles from Sources 1 and 2 and were invited to send additional articles to the authors. Five relevant additional articles were found.

A list of all articles is found on the Multilingual Children's Speech website (McLeod, 2016b).

Inclusion and Exclusion Criteria

The second author examined titles and abstracts of the 668 articles to determine whether they met the following criteria: (a) describe singleton consonant acquisition (n = 474 excluded); (b) present research data (n = 5 excluded); (c) describe typical speech and language development (n = 33 excluded); (d) be a journal article, book chapter, or dissertation (n = 13 excluded); and (e) describe 10 or more participants (n = 19 excluded). Exclusion of articles was hierarchical. After these inclusion criteria were applied, 124 articles remained.

Next, the entire articles were examined and excluded if (a) the full consonant repertoire of the language was not described (n = 16 excluded), (b) ages and/or consonants were not specified or not presented in a usable form (n = 25 excluded), (c) the only criterion for consonant acquisition was < 75% (n = 11 excluded), (d) data from monolingual and multilingual participants were not presented separately (n = 10 excluded), or (e) data reported within the article were inconsistent between the text, figures, and tables (n = 2 excluded). After the inclusion and exclusion criteria were applied to the articles, 60 articles remained describing 64 studies (some articles described more than one study). For articles where the inclusion/exclusion criteria

were not clearly met, both authors examined and discussed the article until consensus about eligibility was reached.

Procedure

The 60 articles describing 64 unique studies were reviewed, and data were extracted describing article/study characteristics (year and language of publication), participant characteristics (number, age, sex, language/s, dialect, and country), research methods (speech sample type, study design, reliability, sensitivity and specificity, and acquisition criteria), and results (age of consonant acquisition, PCC/PVC/PPC) building on Smit (1986).

The most appropriate International Phonetic Alphabet (IPA; International Phonetic Association, 2015) symbol was selected when non-IPA symbols (e.g., orthographic symbols) were used by reading the entire article and considering additional literature that documented consonants of the language (e.g., International Phonetic Association, 1999; McLeod, 2007). For example, the Linares (1981) article about Spanish described ages of acquisition for "r" and "rr." These were entered in the current study as "r" = /ɾ/ (flap) and "rr" = /r/ (trill). In rare cases, if the non-IPA symbol was unable to be resolved, the consonant was not included.

Data were entered for all consonant phonemes described in each article relevant to each language and dialect. For example, Korean has three ways to distinguish plosives (lenis, fortis, and aspirated) on the basis of voice onset time and vowel onset fundamental frequency. Consequently, there were three Korean contrastive velar plosive phonemes included in the analysis: /k, k*, k^h/ (M. Kim & Pae, 2007). The four Cantonese contrastive velar plosive phonemes, distinguished by aspiration and labialization, were included in the analysis: /k, k^h, k^w, k^{wh}/ (Zee, 1999). In contrast, English has one voiceless velar phoneme /k/ ([k] and [k^h] are allophones and are not contrastive), so /k/ was the only voiceless velar plosive phoneme included in the review for English. Therefore, in the current review, data were entered separately for the phonemes /k, k*, k^h, k^w, k^{wh}/ to represent phonemes across languages and were not combined under /k/. Appendix A provides a list of all consonant phonemes assessed and acquired in each language.

Age-of-acquisition data were extracted from each of the reviewed studies. Typically, participants' age-of-acquisition data were reported in the studies as the minimum age (in years/months) when 75% of the participants had acquired a phoneme and/or when 90% of the participants had acquired a phoneme. If age of acquisition differed across word position or sex of the participants, then the youngest age was recorded. PCC and PVC were recorded in 6-month age intervals. If articles reported these data in 12-month intervals, then data were entered twice at each appropriate 6-month point. If an article was published in a language other than English, the authors used translated data about the article from McLeod (2007), asked the authors of the article (or SLPs) who were fluent in the language to translate specific sections, and/or used Google Translate for short segments (cf. McLeod & Verdon, 2014).

Data Analysis

All data were entered into SPSS Version 23.0 (International Business Machines, 2015) and analyzed in terms of frequency, central tendency (mean and median), and variability (standard deviation and range). The unit of data for analysis was the age of acquisition (in months) for each consonant phoneme, and age of acquisition was categorized as 75%–85% and 90%–100%. Criteria for inclusion within individual studies were not modified but were included in the analysis either in the 75%–85% and/or 90%–100% groups as appropriate. When children in the youngest age group of a study acquired a consonant (75%–85% and/or 90%–100% criteria), the data were included in the analysis, and this was noted. When children in the oldest age group of a study did not acquire a consonant (75%–85% and/or 90%–100% criteria), these data were not included in the analysis but were counted for reporting. For example, in the study of 999 children speaking Afrikaans by Lotter (1974), /s/ and /r/ were not acquired by 113 months old (90% criterion) and so were not included in the data analysis but were reported in Appendix A. Consonant phonemes that were not acquired are reported in the results and Appendix A.

All consonant phonemes were considered in analyses (as described previously), and data are presented in the text and tables. Classification of consonant phonemes into place and manner was based on categories from the IPA (International Phonetic Association, 2015). Because of the large number of consonants described in this article, the graphs contain a subset of consonants, whereas the tables and appendices include all consonants. Consonants presented in graphs are those represented by core, unmodified IPA symbols: consonants (pulmonic), consonants (nonpulmonic), and other symbols. Four case studies are presented for languages that were described in four or more studies: English, Korean, Japanese, and Spanish.

Interrater Reliability

The first author completed reliability checks on data extracted for each of the study characteristics (e.g., country, dialect) and data points for each consonant (e.g., age of acquisition) for seven studies (10.9%). A point-by-point analysis of reliability was conducted, and interrater reliability was 96.7% across all variables and 1,145 data points. Discrepancies were discussed between authors until agreement was reached, and records were amended accordingly.

Results

Description of the Studies

Languages

The 60 articles described 64 studies of children's speech acquisition. Four articles described two separate studies in one article (see Appendix B). For example, Linares (1981) described two studies of Spanish-speaking children with a

cohort in Mexico using the Chihuahua dialect (n = 97) and a separate cohort in the United States using the New Mexico dialect (n = 148). Pearson, Velleman, Bryant, and Charko (2009) described a study of English-speaking children who used General American English (n = 317) and another study of children speaking African American English (n = 537). The 64 studies considered children's speech acquisition in 27 languages: Afrikaans (1), Arabic (3), Cantonese (3), Danish (2), Dutch (2), English (15), French (1), German (1), Greek (2), Haitian Creole (1), Hebrew (1), Hungarian (1), Icelandic (1), Italian (1), Jamaican Creole (1), Japanese (5), Korean (4), Malay (1), Maltese (1), Mandarin (Putonghua; 1), Portuguese (3), Setswana (Tswana; 1), Slovenian (1), Spanish (4), Swahili (1), Turkish (3), and Xhosa (3; see Table 1). Within some languages, multiple dialects were described, although 26 studies did not specify which dialect was studied. Dialects were specified in studies of Afrikaans (Cape Town), Arabic (Jordanian and Kuwaiti), Cantonese (Hong Kong), English (African American, General American, Midwestern American, Australian, British, Cape Town, Irish, and Malay), Dutch (Standard), French (Québécois), Greek (Cypriot), Hebrew (Israeli), Malay (Penang), Mandarin (Putonghua-Beijing), Portuguese (Brazilian), Setswana (SeKwêna), Slovenian (Maribor), and Spanish (Chihuahua, Dominican, Mexican, and New Mexican; see Appendices A and B). Most studies described monolingual children (n = 30, 46.9%), three (4.7%) described multilingual children, eight (12.5%) described first-language speakers (and may have included multilingual children), and 23 (34.8%) did not specify the children's language status.

Countries

The 64 studies described children in 31 countries: Australia (3), Belgium (1), Brazil (3), Canada (1), China (1), Cyprus (1), Denmark (2), Dominican Republic (1), Germany (1), Greece (1), Haiti (1), Hong Kong (3), Hungary (1), Italy (1), Jamaica (1), Japan (5), Jordan (1), Kuwait (2), Malaysia (2), Malta (1), Mexico (1), Iceland (1), Republic of Ireland (1), Slovenia (1), South Africa (6), South Korea (4), the Netherlands (1), Tanzania (1), Turkey (3), the United Kingdom (1), and the United States (10). One study did not specify where the participants lived (see Appendix B).

Languages in Which the Articles Were Published

The 60 articles were originally published in 12 different languages: Afrikaans (1), Chinese (1), Danish (1), English (42), German (1), Greek (1), Hebrew (1), Hungarian (1), Japanese (5), Korean (4), Maltese (1), and Slovenian (1).

Year of Publication

The 60 articles were published between the years 1931 (Wellman et al., 1931) and 2016 (e.g., Másdóttir & Stokes, 2016; M = 1995.22, median = 1999.50, SD = 19.28; see Appendix B).

Description of the Sample

Sample Size

By combining all 64 studies, this review reports on data from 26,007 children. The size of the sample for each of the 64 studies ranged from 10 (Ben-David, 2001; Nakanishi, 1982; Toumi, Gxhilishe, & Matomela, 2001) to 7,602 (Nagy, 1980; M = 406.38, median = 147.50, SD = 1,004.30; see Appendix B).

Demographic Data

The ages of the children in the 64 studies ranged from 5 months (0;5) to 155 months (12;11; see Appendix B). The minimum age examined within a study ranged from 5 to 60 months (M = 28.69 months, median = 28.50 months, SD = 11.52 months). The maximum age studied ranged from 24 to 155 months (M = 73.50 months, median = 72.00 months, SD = 27.93 months). For the 40 studies that provided this information, there were data for 5,244 males and 5,267 females. The number of males and females was unable to be determined for 24 studies.

Description of the Data Collection Techniques

Data Sampling

There were 52 (81.3%) cross-sectional studies, 10 (15.6%) longitudinal studies, and two studies (3.1%) that provided both cross-sectional and longitudinal data.

Data Collection Techniques

There were 45 studies (70.3%) that collected single-word speech samples, 11 (17.2%) that collected connected speech samples, and seven (10.9%) that collected single-word and connected speech samples, and the remaining study (1.6%) collected single words and isolated speech sounds (see Appendix B).

Word Position

Fifty-five (85.9%) studies described acquisition of consonants in the word-initial position, two (3.1%) did not study consonants in this position, and seven (10.9%) did not specify whether they did or not. Forty (62.5%) studies described acquisition of consonants in the within-word position, 11 (17.2%) did not, and 13 (20.3%) did not specify. Forty-two (65.6%) studies described acquisition of consonants in the word-final position, 10 (15.6%) did not, and 12 (18.8%) did not specify. On many occasions, the language being tested mediated the word positions that were tested. For example, consonants rarely occur in the initial or final position of Xhosa, so Mowrer and Burger (1991) only tested consonants in the within-word position.

Additional Data Collected

All 64 (100%) studies described consonant acquisition (because this was the main criterion for inclusion in this review). In addition, 29 (43.9%) also described consonant cluster acquisition, 22 (33.3%) described vowel acquisition, and three (4.5%) described tone acquisition;

Table 1. Mean age of acquisition of pulmonic and nonpulmonic consonant phonemes across 27 languages using the 75%–85% and 90%–100% criteria organized according to age in years.

Criteria	No. of studies		1;10–2;11 (21–35 months)	3;0–3;11 (36–47 months)	4;0–4;11 (48–59 months)	5;0–5;11 (60–71 months)	6;0–6;11 (72–83 months)	7;0–7;6 (84–90 months)
75%–85%	29	Pulmonic	/ʔ, ᵐb, kʷ, ʂ, tʂ, tʂʰ, p*, t*, k*, ʊ, m, ⁿd, ᵑg, n, ɕ, p, b, d, t, q, ɦ, pf, j, w, k, pʰ, c, f, ⁿɻ, tʰ, g, h, tɕʰ, ɣ, ħ, ɦ, tɕ, ŋ, tsʰ, kʰ/	/tˤ, nʷ, ŋʷ, ʁ, ðˤ, s*, sʷ, ʍ, ɮ, lʷ, tsʰʷ, tɕ*, tɬʰ, kxʰʷ, ɲ, ɬ, ʦ, s, l, ʧ, x, χ, ʝ, ʧʰ, ɖ̠, sˤ, ʁ, ʕ, ɾ, ʎ, v, ʃ, z, ç, tʷʰ, kʷʰ, xʷ, ɻ, tɬʷʰ, ʤʷ, ʤ, ʣ, ɹ, ʒ/	/r, ɻ, ð, cʰ/	/tɬ, θ/	/ð̲, s̲/	
75%–85%	3	Nonpulmonic	/pʼ, tʼ, cʼ, kʼ, ɓ, ǀ, ǃ/	/tʷʼ, kʷʼ, tsʷʼ, ǀʰ, ǁʰ, tsʼ, kxʼ, ǁ/	/ǃʰ, ʧʼ/			
90%–100%	37	Pulmonic	/tɕ, tɕʰ, ɻ, ʈʂ, ɬ, c, ʊ, p, m, t/	/pf, n, ʔ, cɕ, tʂʰ, k, ʁ, b, j, ŋ, h, pʰ, ɻ, d, tʰ, ɻʑ, f, cʰ, x, g, w, ɸ, ʂ, ʝ, kʰ, l, ɦ, kʷ, q, ɕ, bː, tːˤʰ, qː, ðˤ, χː, v, ɲ, ʧ/	/ɣ, ʝ, ç, ʤ, ʎ, kʷʰ, ʦ, s, tsʰ, ð, ħ, ɾ, z, ʃ, tˤ/	/ʒ, cç, ɹ, χ, r, θ/	/β/	/ʍ/

Note. Some consonants were only examined in studies using the 75%–85% or 90%–100% criteria, so consonants may appear in one row, but not the other. The consonants within a cell are ordered from earliest to latest acquisition (see Supplemental Material S1 for additional information).

however, these additional data were not analyzed in the current article. Nineteen studies (28.8%) provided information about PCC, eight (12.1%) provided information about PVC, and four (6.1%) provided information about PPC.

Description of the Data Analysis Techniques

Age-of-Acquisition Criteria

The 64 studies reported the criteria used to document the age of acquisition of consonant phonemes. Fourteen studies reported two criteria (e.g., 75% and 90%), and the remainder reported one criterion. There were 32 studies (41.0%) that used a criterion of 75%, three (3.8%) that used an 80% criterion, one (1.3%) that used an 83% criterion, two (2.6%) that used an 85% criterion, 36 (46.2%) that used a 90% criterion, one that used a 95% criterion (1.3%), and three (3.8%) that used a 100% criterion. Supplemental Material S1 presents summary information about the age of acquisition of consonant phonemes at the 75%–85% and 90%–100% criteria levels across studies. Twenty studies (30.3%) required the consonant to be correct in one word position, five studies (7.6%) required the consonant to be correct in two word positions, and seven (10.6%) required the consonant to be correct in three word positions; however, this information was unable to be determined for 31 (47.0%) studies. It is important to note that accuracy based on word position needs to differ between languages; for example, in Cantonese, only two word (syllable) positions exist and most consonant phonemes are produced in the word-initial position.

Reliability

Twenty-nine (45.3%) studies provided interrater reliability, one (1.6%) provided intrarater reliability, and seven (10.9%) provided interrater and intrarater reliability. For the remaining 27 studies (42.2%), reliability measures were unable to be determined because some articles were not written in English or were published many years before reliability measures were standard practice (e.g., Poole, 1934).

Sensitivity and Specificity

Sensitivity is the proportion of children with SSD identified correctly. Specificity is the proportion of typically developing children not identified as having SSD. No articles described sensitivity or specificity.

Mean Age of Acquisition of Pulmonic Consonant Phonemes Across Languages

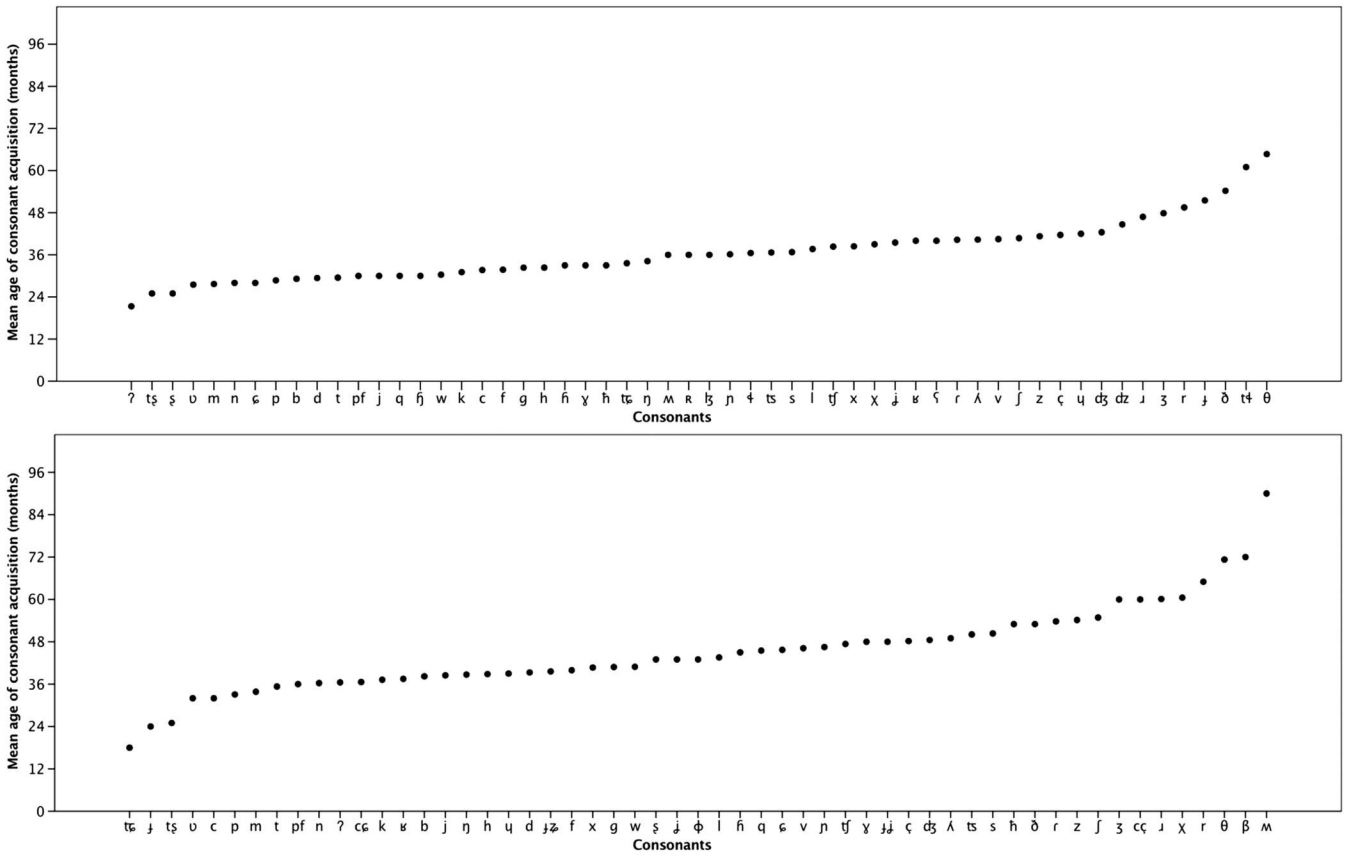
The age of acquisition (mean, median, standard deviation, range, number of studies, and number of languages) for each pulmonic consonant is reported in Supplemental Material S1 and is summarized in Table 1 and Figure 1. Using the 75%–85% criteria (across 29 studies), 40 pulmonic consonant phonemes were acquired at a mean age of between 1;10 and 2;11 years (21–35 months), namely, /ʔ, ᵐb, kʷ, ʂ, tʂ, tʂʰ, p*, t*, k*, ʋ, m, ⁿd, ᵑg, n, ɛ, p, b, d, t, q, ɧ, pf, j, w, k, pʰ, c, f, ⁿɻ, tʰ, g, h, tɕʰ, ɣ, ħ, ɦ, tɕ, ŋ, tsʰ, kʰ/; 44 pulmonic consonant phonemes were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /tˢ, nʷ, ŋʷ, ʁ, ðˢ, s*, sʷ, ʍ, ɮ, lʷ, tsʰʷ, tɕ*, tɬʰ, kxʰʷ, ɲ, ɬ, ʦ, s, l, ʃ, x, χ, j, ʃʰ, ɸ, sˢ, ʁ, ʕ, ɾ, ʎ, v, ʃ, z, ç, tʷʰ, kʷʰ, xʷ, ɥ, tɬʷʰ, ʤʷ, ʤ, ʣ, ɹ, ʒ/; four pulmonic consonant phonemes were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /r, ɻ, ð, cʰ/; two pulmonic consonant phonemes were acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /tɬ, θ/; and two pulmonic consonant phonemes were acquired at a mean age of between 6;0 and 6;11 years (72–83 months), namely, /ð̠, s̠/ (see Table 1 and Supplemental Material S1).

Using the 90%–100% criteria (across 37 studies), 10 pulmonic consonant phonemes were acquired at a mean age of between 1;10 and 2;11 years (21–35 months), namely, /tɕ, tɕʰ, ɻ, tʂ, ɬ, c, ʋ, p, m, t/; 38 pulmonic consonant phonemes were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /pf, n, ʔ, cɛ, tʂʰ, k, ʁ, b, j, ŋ, h, pʰ, ɥ, d, tʰ, ɻz, f, cʰ, x, g, w, ɸ, ʂ, j, kʰ, l, ɦ, kʷ, q, ɛ, bː, tːˢʰ, qː, ðˢ, χː, v, ɲ, ʃʃ/; 15 pulmonic consonant phonemes were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /ɣ, ɻj, ç, ʤ, ʎ, kʷʰ, ʦ, s, tsʰ, ð, ħ, ɾ, z, ʃ, tˢ/; six pulmonic consonant phonemes were acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /ʒ, cç, ɹ, χ, r, θ/; one pulmonic consonant was acquired at a mean age of between 6;0 and 6;11 years (72–83 months), namely, /β/; and one pulmonic consonant was acquired at a mean age of 7;6 years (90 months), namely, /ʍ/ (see Table 1).

Figure 1 demonstrates the mean age of acquisition of consonant phonemes across all languages ordered according to the 75%–85% and 90%–100% criteria. As can be seen, children acquire most of their consonant phonemes by 4 years old, with fewer consonants being acquired between 4 and 7 years old (demonstrated by the steeper gradient). Although the general pattern is that consonant phonemes are acquired by 90%–100% of the children at an older age than 75%–85% of the children, there are some consonants that appear to be acquired earlier by 90%–100% of the children (e.g., /ɻ, ɥ/). This may be an artifact of the different studies, methods, and languages examined. Only 14 of the 64 studies considered acquisition using both the 75%–85% and 90%–100% criteria.

Many consonant phonemes were acquired at a similar age across languages as demonstrated by the standard deviations being less than 12 months in Supplemental Material S1. For example, the voiceless labiodental fricative /f/ was acquired, on average, at 31.76 months old (75%–85% criteria), with a standard deviation of 5.92 months and a range of 18–43 months old, across 33 studies of 18 languages. Similarly, the voiceless palatal fricative /ç/ was acquired, on average, at 48.20 months old (90%–100% criteria), with a standard deviation of 0.45 months and a range of 48–49 months old, across six studies of three languages (German, Greek, and Japanese). There were

Figure 1. Mean age of acquisition of pulmonic consonant phonemes across languages (a) from 29 studies using the 75%–85% criteria and (b) from 37 studies using the 90%–100% criteria. Reprinted with permission from McLeod and Crowe (2018).



also some consonant phonemes that were acquired at similar ages within languages. For example, acquisition of the affricate /tɕ*/ was described in four studies of Korean, and in each of these studies, it was documented as being acquired at 36 months (75%–85% criteria). However, there were some exceptions where the analysis demonstrated wide differences in the age of acquisition between studies. For example, the voiced labiodental fricative /v/ was acquired, on average, at 40.48 months (75%–85% criteria), with a standard deviation of 17.86 months and a range of 20–102 months old, across 25 studies of 14 languages. Similarly, there were wide differences in the age of acquisition for the voiced palatal stop /ɟ/, acquired on average at 51.50 months old (75%–85% criteria) with a standard deviation of 20.60 months and a range of 24–72 months, across four studies of three languages (Greek, Turkish, and Xhosa).

When interpreting these data, it is important to be aware that the youngest and oldest ages of the participants in each study may have contributed to basal and ceiling effects of the data. First, a basal effect may be seen in some studies because the youngest age of the participants in each study may influence the age of acquisition that is reported. Overall, 37.7% of consonant phonemes were documented as acquired by the youngest age of the participants. When considering data from studies that use the 75%–85% criteria, 42.8% (395/922 valid data points) were documented as being acquired at the youngest age of the participants (M = 25.87 months, SD = 9.01 months), and for studies that use the 90%–100% criteria, 32.3% (283/876 data points) were documented as being acquired at the youngest age of the participants (M = 30.00 months, SD = 12.48 months). Therefore, the basal effect of the age of acquisition data reported within studies should be taken into consideration when interpreting children's competence, and it is possible that many consonant phonemes were acquired at an earlier age. Second, a ceiling effect may be seen in some studies. Overall, 11.6% of consonants were documented as not acquired by the oldest age of the participants. When considering data from studies that use the 75%–85% criteria, 8.4% (78/922 data points) were documented as not being acquired at the oldest age of the participants (M = 67.26 months, SD = 21.17 months), and for studies that use the 90%–100% criteria, 14.8% (130/876 data points) were documented as not being acquired at the oldest age of the participants (M = 76.10 months, SD = 30.87 months). Appendix A lists phonemes

not acquired in each language by the participants in the oldest age groups.

Mean Age of Acquisition of Nonpulmonic Consonant Phonemes Across Languages

The age of acquisition (mean, median, standard deviation, range, number of studies, and number of languages) for each nonpulmonic consonant is reported in Supplemental Material S1 and is summarized in Table 1. Using the 75%–85% criteria (across three studies of Setswana and Xhosa), seven nonpulmonic consonant phonemes (clicks, implosives, and ejectives) were acquired at a mean age of between 1;10 and 2;11 years (21–35 months), namely, /pʼ, tʼ, cʼ, kʼ, ɓ, ǀ, !/; eight nonpulmonic consonant phonemes were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /t^{w}ʼ, k^{w}ʼ, ts^{w}ʼ, ǀ^{h}, ǁ^{h}, tsʼ, kxʼ, ǁ/; and two nonpulmonic consonant phonemes were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /!^{h}, ʛʼ/ (see Table 1).

Percentage of Accuracy Across Languages

PCC was examined in 15 studies of 12 languages that presented the full repertoire of consonant phonemes for that language: Arabic, Danish, English, French, German, Hungarian, Malay, Portuguese, Setswana, Swahili, Turkish, and Xhosa (see Appendix B). Each of these studies used single-word samples to determine PCC. Eight of these studies examined PCC within six monthly age ranges. All 15 studies examined PCC at 48 months old (4;0), whereas fewer studies examined children aged between 12 months (1;0) and 102 months (8;6). Data from the studies demonstrate that children's PCC steadily increased as children grew older (see Table 2). By 2;0 years, children achieved an average PCC of 63.50, and by 5;0 years, children achieved an average PCC of 93.80. PVC was examined in seven studies of five languages that presented the full repertoire of vowels for that language: Danish, English, Setswana, Swahili, and Xhosa. Again, these data demonstrate that children's PVC increased. By 2;0 years, children achieved an average PVC of 88.20, and by 5;0 years, children achieved an average PVC of 98.02 (see Table 2). PPC was examined in four studies of two languages that presented the full repertoire of consonants and vowels for that language: English and German. By 2;0 years, children achieved an average PPC of 75.51, and by 5;0 years, children achieved an average PPC of 96.92 (see Table 2).

Manner and Place of Articulation

Table 3 and Supplemental Material S2 compare consonants produced using seven different manners of articulation (based on the IPA classification). On average, nasals, plosives, nonpulmonic consonants, approximants, and laterals were acquired earlier than trills, flaps, affricates, and fricatives.

Table 2 and Supplemental Material S3 compare consonants produced at five places of articulation (based on the IPA classification). Overall, consonants produced with the lips (bilabial and labiodental), pharynx (pharyngeal, epiglottal, and glottal), and posterior tongue (palatal, velar, and uvular) were acquired earlier than consonants articulated with the anterior tongue (dental, alveolar, postalveolar, and retroflex). However, the data also indicate an interaction between place and manner. Anterior plosives and nasals (e.g., /t, d, n/) were typically acquired earlier than anterior fricatives (e.g., /s, z, ʃ, ʒ/), liquids (e.g., /l/), trills (e.g., /r/), and affricates (e.g., /ʧ, ʤ/).

Language Case Studies

English Consonant Acquisition

Fourteen articles describing 15 studies reported children's age of acquisition of English consonant phonemes in the following dialects: General American (6), Australian (3), African American (1), Midwestern American (1), British (1), Cape Town (1) Irish (1), and Malaysian (1; see Appendix B). The children were studied in Australia (3), Malaysia (1), Republic of Ireland (1), South Africa (1), the United Kingdom (1), and the United States (8; see Appendix B for the included studies). The articles were published between 1931 and 2014 (M = 1984.00, median = 1990.00, SD = 26.82). The sum of all participants was 7,369, ranging from 60 to 1,756 (M = 491.27, median = 264.00, SD = 512.25). The ages of the children ranged from 23 months (1;11) to 155 months (12;11). There were 1,807 males and 1,904 females within the 10 studies that provided this information. Fourteen studies (93.3%) elicited single-word data, and the remaining study elicited single words and isolated speech sounds. Thirteen (86.7%) studies described acquisition of consonants in the word-initial position, nine (60.0%) described acquisition of consonants in the within-word position, and 13 (86.7%) described acquisition of consonants in the word-final position; however, this information was not available for one study. There were eight studies (47.1%) that used a criterion of 75%, one (5.9%) that used a criterion of 80%, seven (41.2%) that used a criterion of 90%, and one (5.9%) that used a criterion of 100%. Two studies reported both 75% and 90% criteria (McIntosh & Dodd, 2008; Smit et al., 1990). Eleven studies (73.3%) reported interjudge reliability, and no studies reported intrajudge reliability.

Figures 2a and 3 profile the age of acquisition of consonant phonemes across the 15 studies of English-speaking children. Using the 75%–85% criteria (across nine studies), 11 consonants were acquired at a mean age of between 2;0 and 2;11 years (24–35 months), namely, /m, n, h, p, w, d, b, f, k, g, ŋ/; five consonants were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /j, t, s, l, ʃ/; six consonants were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /ʧ, z, ɹ, ʒ, ʤ, v/; one consonant was acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /ð/; and one consonant was acquired at a mean age of between 6;0 and 6;11 years (72–83 months), namely, /θ/ (see Figure 2a). Using the 90%–100% criteria (across

Table 2. Average percentage of consonants correct (PCC), percentage of vowels correct (PVC), and percentage of phonemes correct (PPC) across studies and languages.

Age		PCC				PVC				PPC			
Years; Months	Months	*M*	*SD*	No. of studies	Languages[a]	*M*	*SD*	No. of studies	Languages[a]	*M*	*SD*	No. of studies	Languages[a]
1;0	12	42.80	—	1	tur	—	—	—	—	—	—	—	—
1;6	18	57.38	14.58	3	deu, fra, tur	—	—	—	—	73.95	—	1	deu
2;0	24	63.50	10.00	6	ara, deu, eng, fra, pot, tur	88.20	—	1	eng	75.51	4.67	2	deu, eng
2;6	30	75.12	9.87	7	ara, dan, deu, eng, fra, pot, tur	93.99	1.29	2	dan, eng	84.06	4.74	2	deu, eng
3;0	36	86.39	9.14	14	ara, dan, deu, eng, fra, hun, pot, swa, tsn, tur, xho	94.16	5.72	6	dan, eng, swa, tsn, xho	90.95	6.43	3	deu, eng
3;6	42	88.56	6.76	14	ara, dan, deu, eng, fra, hun, pot, swa, tsn, tur, xho	96.92	2.28	6	dan, eng, swa, tsn, xho	93.43	4.38	3	deu, eng
4;0	48	92.13	6.65	15	ara, dan, deu, eng, fra, hun, msa, pot, swa, tsn, tur, xho	97.79	1.64	6	dan, eng, swa, tsn, xho	95.12	3.82	3	deu, eng
4;6	54	92.12	4.81	14	ara, dan, deu, eng, hun, msa, pot, swa, tsn, tur, xho	98.05	1.34	6	dan, eng, swa, tsn, xho	96.08	2.92	3	deu, eng
5;0	60	93.80	5.10	13	ara, deu, eng, hun, msa, pot, swa, tsn, tur, xho	98.02	0.91	5	eng, swa, tsn, xho	96.92	2.31	3	deu, eng
5;6	66	94.54	3.47	13	ara, deu, eng, hun, msa, pot, swa, tsn, tur, xho	98.23	0.97	5	eng, swa, tsn, xho	97.32	2.34	3	deu, eng
6;0	72	95.12	3.74	10	ara, eng, hun, msa, pot, tur	98.15	1.48	2	eng	97.05	3.03	2	eng
6;6	78	97.01	1.34	7	eng, hun, pot, tur	98.30	1.27	2	eng	97.50	2.40	2	eng
7;0	84	97.76	2.10	6	eng, hun, pot, tur	98.10	—	1	eng	96.60	—	1	eng
7;6	90	98.00	2.25	5	eng, hun, pot, tur	97.40	—	1	eng	95.90	—	1	eng
8;0	96	99.69	0.30	2	hun, tur	—	—	—	—	—	—	—	—
8;6	102	99.69	0.30	2	hun, tur	—	—	—	—	—	—	—	—

Note. Em dashes (—) indicate data not assessed.

[a]Language names use the ISO 639-3:2007 standard abbreviations: ara = Arabic; dan = Danish; deu = German; eng = English; fra = French; hun = Hungarian; msa = Malay; pot = Portuguese; swa = Swahili; tsn = Setswana; tur = Turkish; and xho = Xhosa.

Table 3. Mean age of acquisition of consonant phonemes across 27 languages using the 75%–85% and 90%–100% criteria organized according to age in years, manner, and place.

Variable	Criteria	1;10–2;11 (21–35 months)	3;0–3;11 (36–47 months)	4;0–4;11 (48–59 months)	5;0–5;11 (60–71 months)	6;0–6;11 (72–83 months)	7;0–7;6 (84–90 months)
Manner							
Plosive	75%–85%	/ʔ, ᵐb, kʷ, p*, t*, k*, ⁿd, ᵑg, p, b, d, t, q, k, pʰ, c, ᶮɟ, tʰ, g, kʰ/	/tˤ, tʷʰ, kʷʰ/	/ɟ, cʰ/	—	—	—
	90%–100%	/ɟ, c, p, t/	/ʔ, k, b, pʰ, d, tʰ, cʰ, g, kʰ, kʷ, q, bː, tːˤʰ, qː/	/kʷʰ, tˤ/	—	—	—
Nasal	75%–85%	/m, n, ŋ/	/nʷ, ŋʷ, ɲ/	—	—	—	—
	90%–100%	/m/	/n, ŋ, ɲ/	—	—	—	—
Trill, tap, and flap	75%–85%	—	/ʁ, ɾ/	/r/	—	—	—
	90%–100%	—	—	/ɾ/	/r/	—	—
Fricative	75%–85%	/ʂ, ɕ, ɦ, f, h, ɣ, ħ, ɦ/	/ðˤ, s*, sʷ, ʍ, s, x, χ, ɻ, ɸ, sˤ, ʁ, ʕ, v, ʃ, z, ç, xʷ, ʒ/	/ð/	/θ/	/ð̲, s̲/	—
	90%–100%	—	/ʁ, h, f, x, ɸ, ʂ, ɻ, ɦ, ɕ, ðˤ, χː, v/	/ɣ, ç, s, ð, ħ, z, ʃ/	/ʒ, χ, θ/	/β/	/ʍ/
Approximant and lateral	75%–85%	/ʊ, j, w/	/ɮ, lʷ, ɬ, l, ʎ, ɥ, ɹ/	—	—	—	—
	90%–100%	/ʊ, ɬ/	/j, ɥ, w, l/	/ʎ/	/ɹ/	—	—
Affricate	75%–85%	/tʂ, tʂʰ, pf, tɕʰ, tɕ, tsʰ/	/tsʰʷ, tɕ*, tɬʰ, kxʰʷ, ʧ, ʧʰ, tɬʷʰ, dʒʷ, dʒ, dz/	—	/tɬ/	—	—
	90%–100%	/tɕ, tɕʰ, tʂ/	/pf, cɕ, tʂʰ, ɻʑ, ʧ/	/ɟʝ, dʒ, ʦ, tsʰ/	/cç/	—	—
Nonpulmonic	75%–85%	/p’, t’, c’, k’, ɓ, ǀ, ǃ/	/tʷʼ, kʷʼ, tsʷʼ, ǀʰ, ǁʰ, ts’, kx’, ǁ/	/ǃʰ, ʧʼ/	—	—	—
Place							
Labial (bilabial and labiodental)	75%–85%	/ᵐb, p*, ʊ, m, p, b, pʰ, f, p’, ɓ/	/v/	—	—	—	—
	90%–100%	/ʊ, p, m/	/pf, b, pʰ, f, ɸ, bː, v/	—	—	/β/	—

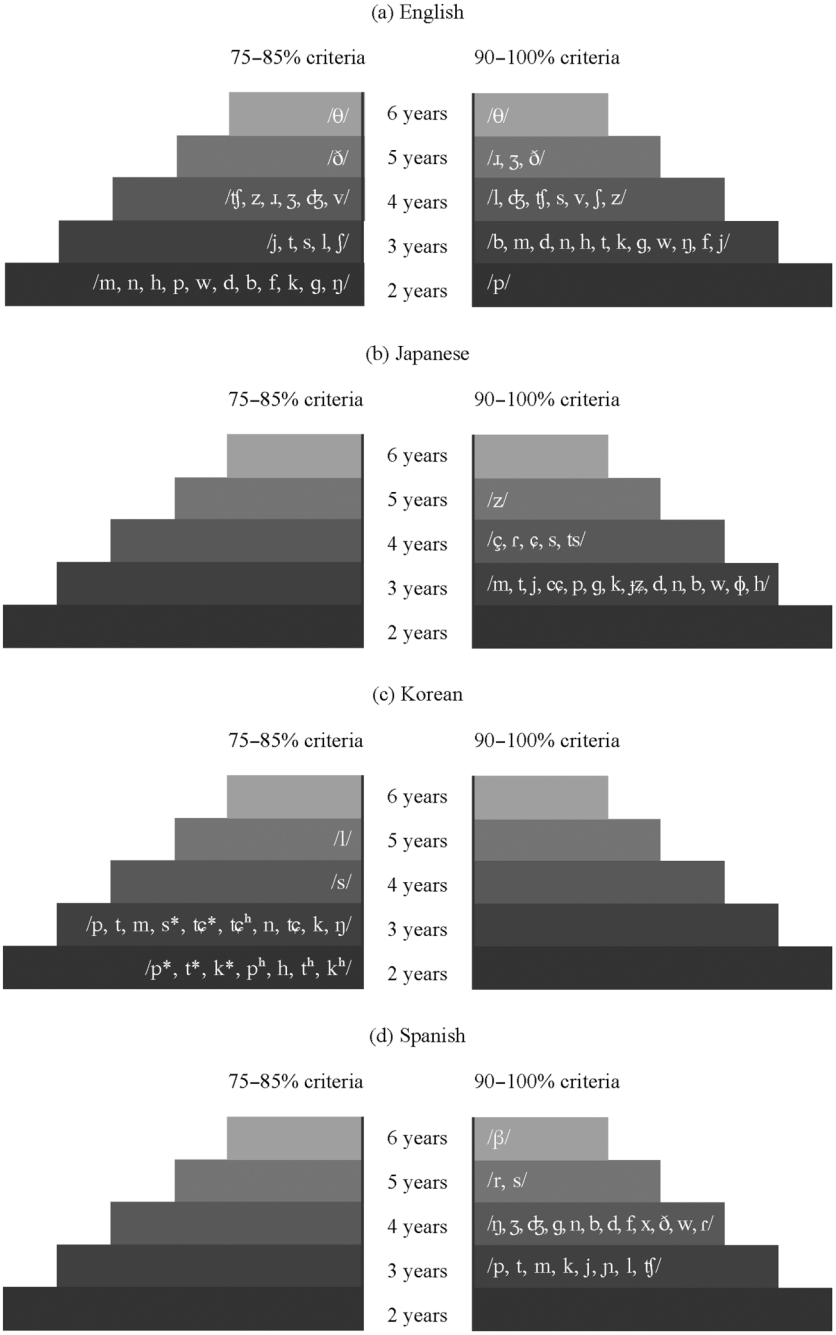
(*table continues*)

Table 3. *(Continued).*

Variable	Criteria	1;10–2;11 (21–35 months)	3;0–3;11 (36–47 months)	4;0–4;11 (48–59 months)	5;0–5;11 (60–71 months)	6;0–6;11 (72–83 months)	7;0–7;6 (84–90 months)
Anterior tongue (dental, alveolar, postalveolar, and retroflex)	75%–85%	/ʂ, tʂ, tʂʰ, tˣ, ⁿd, n, d, t, tʰ, tsʰ, tʼ, l, !/	/sˣ, ɮ, tɬʰ, ɬ, ɬs, s, l, tʃ, tʃʰ, ɖ, ɾ, ʃ, z, dʒ, ʣ, ɹ, ʒ, lʰ, llʰ, ts', ll/	/r, ð, !ʰ, tʃʼ/	/tɬ, θ/	/ð̲, s̲/	—
	90%–100%	/tʂ, c, t/	/n, tʂʰ, d, tʰ, ʂ, l, tʃ/	/dʒ, ɬs, s, tsʰ, ð, ɾ, z, ʃ, tʕ/	/ʒ, ɹ, r, θ/	—	—
Posterior tongue (palatal, velar, and uvular)	75%–85%	/kˣ, q, j, k, c, g, ɣ, ŋ, kʰ, cʼ, kʼ/	/ʁ, ɲ, x, χ, ʝ, ʁ, ʕ, ʎ, ç, kx'/	/ɟ, cʰ/	—	—	—
	90%–100%	/ɟ, c/	/k, ʁ, j, ŋ, cʰ, x, g, ʝ, kʰ, q, qː, χː, ɲ/	/ɣ, ɟ̲, ç/	/cç, χ/	—	—
Pharynx (pharyngeal, epiglottal, and glottal)	75%–85%	/ʔ, h, ɦ, ɦ/	/ʕ/	—	—	—	—
	90%–100%	—	/ʔ, h, ɦ/	/ɦ/	—	—	—
Dual place	75%–85%	/kʷ, ⁿg, ɕ, ɧ, w, ⁿɟ, tɕʰ, tɕ/	/tʕ, nʷ, ŋʷ, ðʕ, sʷ, ʍ, ɮ, lʷ, tsʰʷ, tɕˣ, kxʰʷ, sʕ, tʷʰ, kʷʰ, xʷ, ɻ, tɬʷʰ, dʒʷ, tʷ', kʷ', tsʷ'/	—	—	—	—
	90%–100%	/tɕ, tɕʰ, ɬ/	/cɕ, ɻ, ɟʑ, w, kʷ, ɕ, tːʕʰ, ðʕ/	/ɟ̲, kʷʰ, tʕ/	—	—	/ʍ/

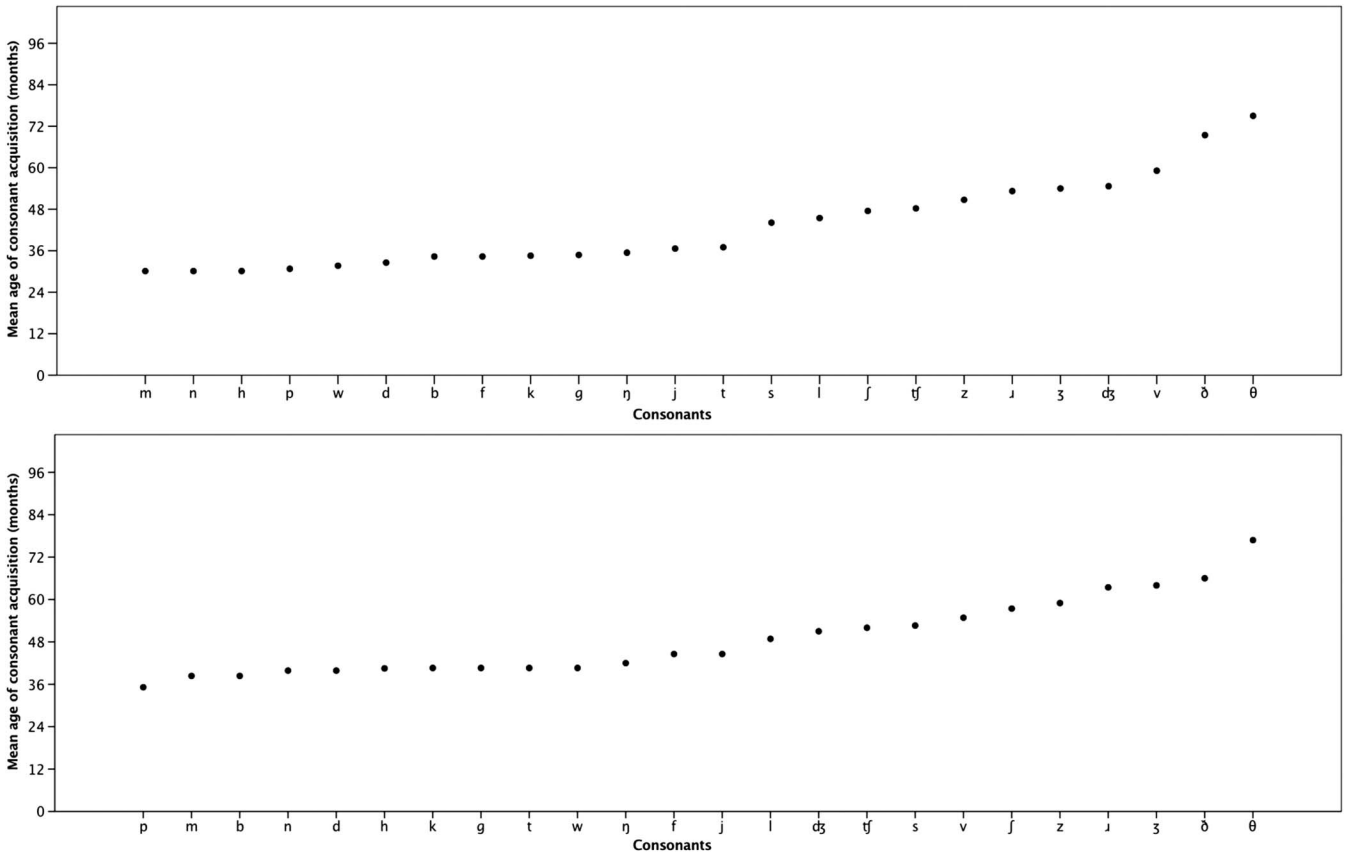
Note. Em dashes (—) indicate that there were no data available for consonants for this criterion. Some consonants were only examined in studies using the 75%–85% or 90%–100% criteria, so consonants may appear in one row, but not the other. The consonants within a cell are ordered from earliest to latest acquisition (see Supplemental Material S1 for additional information).

Figure 2. Mean age of acquisition of consonant phonemes organized according to age in years for (a) English across 15 studies using the 75%–85% and 90%–100% criteria, (b) Japanese across five studies using the 90%–100% criteria, (c) Korean across four studies using the 75%–85% criteria, and (d) Spanish across four studies using the 90%–100% criteria. Reprinted with permission from McLeod and Crowe (2018).



eight studies), one consonant was acquired at a mean age of between 2;0 and 2;11 years (24–35 months), namely, /p/; 12 consonants were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /b, m, d, n, h, t, k, g, w, ŋ, f, j/; seven consonants were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /l, ʤ, ʧ, s, v, ʃ, z/; three consonants were acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /ɹ, ʒ, ð/; and one consonant was acquired at a mean age of between 6;0 and 6;11 years (72–83 months), namely, /θ/ (see Figure 2a). Using the 90%–100% criteria across eight studies of typical speech acquisition,

Figure 3. Mean age of acquisition of consonants for English-speaking children (a) from nine studies using the 75%–85% criteria and (b) from eight studies using the 90%–100% criteria. Reprinted with permission from McLeod and Crowe (2018).



the following English consonants could be classified accordingly:

- Early (2;0–3;11): /p, b, m, d, n, h, t, k, g, w, ŋ, f, j/
- Middle (4;0–4;11): /l, ʤ, ʧ, s, v, ʃ, z/
- Late (5;0–6;11): /ɹ, ʒ, ð, θ/

Across the 15 studies of English consonants, nasals, plosives, and laterals typically were acquired earlier than most affricates and fricatives. English consonants produced with the lips, pharynx, and posterior tongue typically were acquired earlier than consonants articulated with the anterior tongue; however, there was an interaction between place and manner, with anterior plosives and nasals being acquired earlier than anterior fricatives and affricates.

Japanese Consonant Acquisition

Five articles describing four studies reported the age of acquisition of Japanese consonant phonemes in Japan (see Appendix B). The articles were published between 1967 and 1982 (M = 1971.40, median = 1970.50, SD = 6.66). The sum of all participants was 2,299, ranging from 10 to 1,689 (M = 486.40, median = 300.00, SD = 767.37). The ages of the children ranged from 12 months (1;0) to 83 months (6;9). All five studies (100.0%) elicited single-word data. All five studies (100.0%) described acquisition of consonants in the word-initial position. Four studies used a criterion of 90%, and one used a criterion of 100%. The use of interjudge and intrajudge reliability was unable to be determined.

Figure 2b profiles the age of acquisition across the five studies of Japanese-speaking children. Using the 90%–100% criteria (across five studies), no consonants were acquired at a mean age of between 2;0 and 2;11 years; (24–35 months; although this age group was studied by Nakanishi, 1982); 14 consonants were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /m, t, j, cɕ, p, g, k, ʝz, d, n, b, w, ɸ, h/; five consonants were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /ç, ɾ, ɕ, s, ts/; and one consonant was acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /z/ (see Figure 2b). Using the 90%–100% criteria across five studies of typical speech acquisition, the following Japanese consonants could be classified accordingly:

- Early (3;0–3;11): /m, t, j, cɕ, p, g, k, ʝz, d, n, b, w, ɸ, h/

- Middle (4;0–4;11): /ç, ɾ, ɕ, s, ts/
- Late (5;0–5;11): /z/

Across the five studies of Japanese consonants, nasals, plosives, and approximants typically were acquired earlier than flaps and most fricatives. Japanese consonants produced with the lips, pharynx, and posterior tongue typically were acquired earlier than consonants articulated with the anterior tongue; however, there was an interaction between place and manner.

Korean Consonant Acquisition

Four articles describing four studies reported the age of acquisition of Korean consonant phonemes in South Korea (see Appendix B). The articles were published between 1986 and 2005 (M = 1995.5, median = 1995.5, SD = 7.77). The sum of all participants was 845, ranging from 150 to 320 (M = 211.25, median = 187.50, SD = 79.20). The ages of the children ranged from 5 months (0;5) to 76 months (6;3). All four studies (100.0%) elicited single-word data and used a criterion of 75%. The word position and use of interjudge and intrajudge reliability were unable to be determined.

Figure 2c profiles the age of acquisition across the four studies of Korean-speaking children. Using the 75% criterion (across four studies), six consonants were acquired at a mean age of between 2;0 and 2;11 years (24–35 months), namely, /t*, k*, p^h, h, t^h, k^h/; 10 consonants were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /p, t, m, s*, tɕ*, $tɕ^h$, n, tɕ, k, ŋ/; one consonant was acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /s/; and one consonant was acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /l/ (see Figure 2c). Using the 75% criterion across four studies of typical speech acquisition, the following Korean consonants could be classified accordingly:

- Early (2;0–2;11): /t*, k*, p^h, h, t^h, k^h/
- Middle (3;0–3;11): /p, t, m, s*, tɕ*, $tɕ^h$, n, tɕ, k, ŋ/
- Late (4;0–4;11): /s, l/

Across the four studies of Korean consonants, nasals, plosives, and affricates typically were acquired earlier than the lateral and the fricative /s/. Korean consonants produced with the lips, pharynx, and posterior tongue typically were acquired earlier than consonants articulated with the anterior tongue; however, there was an interaction between place and manner.

Spanish Consonant Acquisition

Three articles describing four studies reported the age of acquisition of Spanish consonant phonemes in the following dialects: Dominican (1), New Mexican (1), Mexican (1), and Chihuahua (1; see Appendix B). The children were studied in the Dominican Republic (1), Mexico (1), and the United States (2). The articles were published between 1981 and 1987 (M = 1983.50, median = 1983.00, SD = 3.00). The sum of all participants was 420, ranging from 55 to 148 (M = 105.00, median = 108.50, SD = 39.32). The ages of the children ranged from 23 months (1;11) to 107 months (8;9). One study documented the male-to-female ratio (67 males and 53 females). All four studies (100.0%) elicited single-word data. All four studies (100.0%) described acquisition of consonants in the word-initial, within-word, and word-final positions. All four studies were reported in the current study using a criterion of 90%.[1] One study (25.0%) reported interjudge reliability.

Figure 2d profiles the age of acquisition across the four studies of Spanish-speaking children. Using the 90% criterion (across four studies), no consonants were acquired at a mean age of between 2;0 and 2;11 years (24–35 months; although this age group was studied by De la Fuenta, 1985); eight consonants were acquired at a mean age of between 3;0 and 3;11 years (36–47 months), namely, /p, t, m, k, j, ɲ, l, ʧ/; 12 consonants were acquired at a mean age of between 4;0 and 4;11 years (48–59 months), namely, /ŋ, ʒ, ʤ, g, n, b, d, f, x, ð, w, ɾ/; two consonants were acquired at a mean age of between 5;0 and 5;11 years (60–71 months), namely, /r, s/; and one consonant was acquired at a mean age of between 6;0 and 6;11 year (72–83 months), namely, /β/ (see Figure 2d). Using the 90% criterion across four studies of typical speech acquisition, the following Spanish consonants could be classified accordingly:

- Early (3;0–3;11): /p, t, m, k, j, ɲ, l, ʧ/
- Middle (4;0–4;11): /ŋ, ʒ, ʤ, g, n, b, d, f, x, ð, w, ɾ/
- Late (5;0–6;11): /r, s, β/

Across the four studies of Spanish consonants, nasals, plosives, approximants, and laterals typically were acquired earlier than flaps and some fricatives. Spanish consonants produced with the pharynx and posterior tongue typically were acquired earlier than consonants articulated with the anterior tongue; however, there was an interaction between place and manner where anterior plosives and nasals were acquired earlier than anterior fricatives and trills.

Discussion

This article presents the world's largest analysis of consonant acquisition data to date: 60 articles describing 64 studies of consonant acquisition in 27 languages by 26,007 children from 31 countries. Most of the 64 studies of consonant acquisition reported cross-sectional data (81.3%) and elicited single-word speech samples (70.3%). Most described acquisition of consonant phonemes in the word-initial position (85.9%), with fewer describing the word-final position (65.6%) and the within-word position (62.5%). Although all described consonant acquisition, some also described consonant cluster acquisition (43.9%), vowel acquisition (33.3%), and tone acquisition (4.5%). Other studies that exclusively reported data for the acquisition of consonant clusters, vowels, and/or tones were not

[1]Acevedo (1993) provided the percentage of correct production of consonants by each age group.

included in the current review (e.g., McLeod, van Doorn, & Reed, 2001). Some studies included PCC (28.8%), PVC (12.1%), and/or PPC (6.1%). Just over half included interjudge and/or intrajudge reliability measures (58.8%).

This article provides an overview of patterns of acquisition in 27 languages, across four case studies (English, Japanese, Korean, and Spanish), as well as general cross-linguistic patterns that could be applicable to working with a child with a language background that is not represented in the review. General principles of development were generated by considering consonant phonemes as the unit of analysis (rather than language). On average, almost all of the world's consonants were acquired by children's fifth birthdays (see Table 1). Most consonants and vowels were produced correctly by 5;0 years: 93.80 PCC (across 15 studies of 12 languages), 98.02 PVC (across seven studies of five languages), and 96.92 PPC (across four studies of two languages; see Table 2). On average, plosives, nasals, and nonpulmonic consonants (e.g., clicks) were acquired earlier than trills, flaps, fricatives, and affricates. Most labial (bilabial and labiodental), pharyngeal (pharyngeal, epiglottal, and glottal), and posterior lingual (palatal, velar, and uvular) consonants were acquired earlier than those using an anterior lingual placement (dental, alveolar, postalveolar, and retroflex); however, there was an interaction between place and manner. Nasal consonants were among the earliest to develop, and plosives (stops) were acquired earlier than fricatives. Approximant/lateral (liquid) consonants did not always precede fricatives. When individual languages were considered as case studies, the general principles of development were upheld; however, specific consonants not acquired by 5;0 differed slightly. Consonants that were not acquired by 5;0 years were /ɹ, ʒ, ð, θ/ (90%–100% criteria) across 15 studies of English consonants, /z/ (90%–100% criteria) across five studies of Japanese consonants, /s, l/ (75% criterion) across four studies of Korean consonants, and /r, s, β/ (90% criterion) across four studies of Spanish consonants.

In this study, the summarized acquisition of the 24 English consonants did not neatly fall into the early-8, middle-8, and late-8 consonants outlined by Shriberg (1993). Instead, Figures 2a and 3 depict a steady increase in acquisition for most consonants (early–middle), with four consonants, namely, /ɹ, ʒ, ð, θ/, being acquired last. Three of these consonants were included in the late consonants described by Shriberg, namely, /ɹ, ð, θ/, and the fourth consonant, /ʒ/, was excluded from Shriberg's analysis. The other consonants included in Shriberg's late-developing consonants were /ʃ, s, z/, but the current study indicates that these were acquired, on average, at a younger age. It is important to note that Shriberg's work was based on children with SSD, and the current study examined children with typically developing speech. The summarized acquisition of the Spanish consonants in Figure 2c did not neatly fall into the early, middle, and late consonants outlined by Fabiano-Smith and Goldstein (2010b) for eight monolingual Spanish-speaking children. The latest consonants to be acquired according to Fabiano-Smith and Goldstein (2010b) were /l, ð, r, ɾ/, whereas the latest consonants to be acquired according to the compilation of studies in the current article were /r, s, β/. These findings highlight the importance of combining general principles from the current study with individual data that are relevant to children in specific contexts (and dialects). The results from the current study should be used as general guidance, and SLPs are encouraged to source specific studies regarding children who speak the dialect and language within their communities (McLeod, 2016b).

Theoretical Implications

Children's consonant acquisition is a key feature of children's overall development, enabling them to perceive and produce intelligible speech and interact with members of society. The results of the current study support elements of the emergence approach to speech acquisition (Davis & Bedore, 2013) that describes how children's intrinsic capacities (e.g., children's production skills) intersect with the extrinsic context (e.g., the ambient phonology). The results of the current study can be interpreted to demonstrate that children master some categories of phonemes (manner/place) using a similar pattern of acquisition across languages, providing some support for theorists such as Locke (1983) and Jakobson (1941/1968). However, the wide range and large standard deviations in the acquisition of some individual phonemes also provide support for individual variability and the cognitive model of speech acquisition by theorists such as Ferguson and Farwell (1975) and Vihman (1996). The current study upholds some (but not all) of the principles of markedness (cf. Jakobson, 1941/1968) and the biological account of speech acquisition proposed by Kent (1992). The influence of functional load, phonetic frequency, and phonotactic probability was unable to be examined because of the lack of language-specific data for many of the languages studied (cf. Edwards & Beckman, 2008b; Ingram, 2012; Stokes & Surendran, 2005). Although the current study supported elements of the emergence approach to speech acquisition (Davis & Bedore, 2013), to comprehensively test this functionalist model of speech acquisition, future research should incorporate (a) children's production, perception, and cognition skills; (b) children's interaction capacities; (c) the extrinsic context including adults' ambient phonology and sociocultural influences; (d) the influence of phonetic complexity, functional load, phonetic frequency, and phonotactic probability; and (e) comparison of data from monolingual and multilingual children, keeping in mind Elbert's (1984) assertion that children are creative learners who are "engaged in highly energetic pursuit of knowledge" (p. 115). To do this, researchers could consider undertaking cross-sectional and longitudinal studies of both languages of multilingual speakers, gathering a range of data (single words, nonwords, and connected speech) from children who were typically developing and with SSD, such as those documented in the comprehensive study undertaken by Albrecht (2017) to consider German-Turkish–speaking children's speech acquisition.

Clinical Implications

Children's consonant acquisition and accuracy are the main indicators used by SLPs to measure children's speech maturity and intelligibility. The current article draws together a large body of literature on consonant acquisition from across the world and adds to the information available to support SLPs' work with children who speak a range of languages. The article provides guidance to support SLPs' expectations of cross-linguistic consonant acquisition, including for languages where there are no data currently available. The current article provides a preliminary resource regarding consonant acquisition for nearly 7,000 languages that do not have speech acquisition data. In the current article, the traditional library database search only identified 25% (15/60) of the articles. To identify articles about consonant acquisition, SLPs need to access additional resources. Recently, international research collaborations have increased cross-linguistic access and knowledge about children's speech acquisition, assessment, and intervention. For example, the International Expert Panel on Multilingual Children's Speech (46 researchers who had worked in 43 countries using 27 languages) produced a tutorial to support SLPs to assess children's speech in a language that they do not speak (McLeod et al., 2017). The tutorial outlined a range of additional resources for SLPs including a review of 30 speech assessments in 19 languages (McLeod & Verdon, 2014), the Multilingual Children's Speech website (McLeod, 2016a) that provides resources in over 60 languages, and the crosslinguisticprojectmaterials website (Bernhardt & Stemberger, 2016) that provides assessments and analyses to support SLPs' cross-linguistic service provision. When SLPs are reading articles about consonant acquisition, particularly those that were published before the availability of typesetting of IPA symbols, additional resources including the IPA (International Phonetic Association, 1999, 2015) are required to decode some orthographic symbols within articles.

In the recent tutorial published to support SLPs to assess children's speech in language(s) not spoken by the SLPs (McLeod et al., 2017), elements of comprehensive and respectful assessments are described. One recommendation was to seek, where appropriate, typical speech acquisition data for the language(s) assessed. However, when typical speech acquisition data are unavailable or the data context/dialect is not appropriate, data from the current cross-linguistic review can be used to provide preliminary data to be compared with data from a family-member contrastive analysis (McLeod et al., 2017). Age of acquisition, PCC, and early–middle–late data from the current study can be used to inform SLPs' expectations of children's acquisition of consonants across the world. General principles to be gleaned from the current study are that most of the world's consonant phonemes are acquired (on average) by the time children are 5 years old, and, by this time, over 90% of consonants within words are produced correctly. Generally, the latest groups of consonants to be acquired are consonants that use the anterior tongue, particularly trills, flaps, affricates, and fricatives. This knowledge can be used to inform SLPs' expectations of children's developmental capacity and decision making regarding the need for intervention. A scenario using this knowledge could be that an SLP was asked to assess a 5-year-old child who spoke Hmong, a language that, to date, does not have a published study of consonant acquisition data available in English. Working with an interpreter, a speech sample was obtained that included a number of examples of each consonant phoneme. The child's parent also produced the same words, and the child's productions were compared using a family-member contrastive analysis, generating a list of phonemes that were not produced in an adultlike way, and by calculating the PCC. In the current scenario, the parents were concerned about their child's speech and had indicated that he was sometimes intelligible on the Intelligibility in Context Scale: Hmong (McLeod, Harrison, & McCormack, 2012). The child produced approximately 50% of consonants correct (whereas, in the current study, 5-year-old children had an average PCC of 93). The child had difficulty producing most types of consonants, including plosives and nasals (identified in the current study as being acquired early). Consequently, the child was referred for intervention to work with the parent and interpreter on accuracy of Hmong consonant production to increase his intelligibility in Hmong.

Limitations

Although this study presents an inclusive and diverse cross-linguistic view of children's consonant acquisition, there are a number of limitations that influence the findings. First, the mean age of acquisition as the primary data source can be influenced by the number of studies, the number of languages, the maximum and minimum ages studied, the elicited words, the criteria reported, the individual variability resulting in large standard deviations of scores (especially when there are small sample sizes), and the era of the studies (some were conducted > 50 years ago, so different theoretical and methodological conventions influenced data collection and analyses). The maximum and minimum ages studied influenced the age of acquisition; as mentioned in the results, data from 8.4% of the studies (75%–85% criteria) and 14.8% of the studies (90–100% criteria) were not included in the analysis because the consonants were not acquired by participants who were of the oldest ages in the study. As a result, Appendix A and Supplemental Material S1 provide additional data (standard deviation, range, number of studies, and languages studied) to assist with the interpretation of data.

Most data included in the current article report monolingual consonant acquisition, with a few reporting acquisition of consonants in children's first language or other languages of multilingual children (see Appendix B). Therefore, the summary data contained within this article cannot be extrapolated to all multilingual children's consonant acquisition. Within the world's literature, there are fewer

studies of multilingual consonant acquisition than monolingual consonant acquisition, so disambiguating acquisition of consonant phonemes within multilingual children's languages and examining transfer of features from one language to another is challenging (see Hambly, Wren, McLeod, & Roulstone, 2013). However, there are some examples of carefully controlled studies of children's acquisition in more than one language that can provide a model for future studies (e.g., Albrecht, 2017; Fabiano-Smith & Goldstein, 2010a, 2010b).

Finally, most articles were published in English or had summary data available in English, presenting a limitation of the study because there may have been other studies that were not included because they were unable to be located with search strategies by English speakers. Although the current article increases the visibility of some scientific publications in languages other than English (Meneghini & Packer, 2007), it is likely that more articles could have been included in the review if the authors could search using non-Latin script (e.g., Chinese electronic databases were used by Li & To, 2017). In addition, although every attempt was made to collate data from the studies available in languages other than English, some information (e.g., reliability) could not be translated in all cases.

Future Research

During the collation and analysis of data in the current study, the authors developed guidelines to inform future researchers' reporting of data and to facilitate comparisons across studies of children's consonant acquisition (see Appendix C). These guidelines address reporting of demographic data, determining the age range of participants, selection of stimuli, reporting of consonant acquisition data, analysis, and documentation. The psychometric guidelines provided by McCauley and Swisher (1984) for creating norm-referenced assessments could supplement the guidelines in Appendix C.

Conclusion

This cross-linguistic review of 64 studies of 27 languages describes children's acquisition of consonant phonemes. By 5;0 years, most consonants were acquired and children were producing over 90% of consonants correctly. SLPs can draw upon these general principles as milestones of adultlike speech production but also should acknowledge children's individual speech acquisition journeys as a creative process.

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Appendix A (p. 1 of 2)

Consonants Assessed and Acquired in the Studies of 27 Languages

Language assessed (ISO[a])	No. studies	Age range assessed (months)	Plosives	Nasals	Trills, taps, and flaps	Fricatives	Lateral fricatives	Approximants and laterals	Affricates	Clicks	Implosives	Ejectives
Afrikaans (afr)	1	36–114	/p, b, t, d, k, g/	/m, n, ŋ/	/(r)/	/f, v, (s), z, ʃ, x, ɦ/	—	/j, l/	—	—	—	—
Arabic (ara)	3	16–76	/p, b, bː, t, tˤ, tːʰ, (t̪), d, (dˤ), (d̪), k, g, q, qː, ʔ/	/m, n, (ŋ)/	/r, (rː), ɾ/	/f, (v), θ, ð, ðˤ, (ð̪, s, sˤ, s̪, (sː), z, (zˤ), ʃ, (ʒ), x, (ɣ), χ, χː, ʁ, ħ, ʕ, h/	—	/j, l, w, ɥ/	/ʧ, ʤ/	—	—	—
Cantonese (yue)	3	24–148	/p, pʰ, t, tʰ, k, kʰ, kʷ, kʷʰ/	/m, n, ŋ/	—	/f, s, h/	—	/j, l, w/	/ts, tsʰ/	—	—	—
Danish (dan)	2	24–71	/p, b, t, d, k, g/	/m, n, ŋ/	—	/f, v, ð, s, ɕ, ʁ, h/	—	/j, l, w/	—	—	—	—
Dutch (nld)	2	15–48	/p, b, t, d, (c), k, (g)/	/m, n, (ɲ), (ŋ)/	/r/	/f, v, s, (z), (ʃ), (ʒ), (ɣ), χ, h/	—	/ʊ, (ɹ), j, l, (w)/	/(ʧ), (ʤ)/	—	—	—
English (eng)	15	23–155	/p, b, t, d, k, g/	/m, n, ŋ/	—	/f, v, θ, ð, s, z, ʃ, ʒ, ʍ, h/	—	/ɹ, j, l w/	/ʧ, ʤ/	—	—	—
French (fra)	1	20–53	/p, b, t, d, k, g/	/m, n, ŋ/	—	/f, v, z, ʃ, ʒ, ʁ/	—	/j, l, w, ɥ/	—	—	—	—
German (deu)	1	18–71	/p, b, t, d, k, g/	/m, n, ŋ/	—	/f, v, s, z, ʃ, ç, x, ʁ, h/	—	/j, l/	/pf, ʦ/	—	—	—
Greek (ell)	2	24–54	/p, pʰ, ᵐb, t, tʰ, d, ⁿd, c, (cʰ), ɟ, ᶮɟ, k, kʰ, kʷ, g, ᵑg/	/m, n, ɲ, (ŋ)/	/r/	/f, v, θ, ð, s, z, (ʃ), (ʒ), ç, j̟, x, ɣ/	—	/l, ʎ/	/ʦ, ʣ, (ʧ), (ʤ)/	—	—	—
Haitian Creole (hat)	1	24–51	/p, b, t, d, k, (g)/	/m, n, (ɲ), (ŋ)/	—	/f, v, s, z, ʃ, ʒ, ʁ/	—	/j, l, w, ɥ/	/(ʧ), ʤ/	—	—	—
Hebrew (heb)	1	10–42	/p, b, t, d, k, g/	/m, n/	—	/f, v, s, z, ʃ, (ʒ), x, (h)/	—	/j, l/	/ʦ, ʧ, (ʤ)/	—	—	—
Hungarian (hun)	1	36–96	/p, b, t, d, k, g/	/m, n, ɲ/	/r/	/f, v, s, z, ʃ, ʒ, h/	—	/j, l/	/ʦ, ʧ, cç, ɟ͡ʝ/	—	—	—
Icelandic (isl)	1	28–40	/p, pʰ, t, tʰ, c, cʰ, k, kʰ/	/m, n, (n̥)/	/(r), (r̥)/	/f, (θ), ð̥, s, ç, h/	—	/ʊ, j, (ɯ̥), l, (l̥)/	—	—	—	—
Italian (ita)	1	18–27	/p, b, t, d, k, (g)/	/m, n/	/(r)/	/(f), (v), (s)/	—	/(ɹ), l/	/(ʧ), (ʤ)/	—	—	—

Appendix A (p. 2 of 2)

Consonants Assessed and Acquired in the Studies of 27 Languages

Language assessed (ISO[a])	No. studies	Age range assessed (months)	Plosives	Nasals	Trills, taps, and flaps	Fricatives	Lateral fricatives	Approximants and laterals	Affricates	Clicks	Implosives	Ejectives
Jamaican Creole (jam)	1	12–54	/p, b, t, d, k, g/	/m, n, ŋ/	—	/f, v, (θ), (ð), s, z, ʃ, (ʒ), (h)/	—	/ɹ, j, l, w/	/ʧ, ʤ/	—	—	—
Japanese (jpn)	5	12–83	/p, b, t, d, k, g/	/m, n/	/ɾ/	/ɸ, s, z, ç, ɕ, h/	—	/j, w/	/ʦ, cɕ, ɟʑ/	—	—	—
Korean (kor)	4	5–85	/p, p*, pʰ, t, t*, tʰ, k, k*, kʰ/	/m, n, ŋ/	—	/s, s*, h/	—	/l/	/tɕ, tɕ*, tɕʰ/	—	—	—
Malay (msa)	1	48–77	/p, b, t, d, k, g, ʔ/	/m, n, ɲ, ŋ/	—	/s, h/	—	/ɹ, j, l, w/	/ʧ, ʤ/	—	—	—
Maltese (mlt)	1	24–42	/p, b, t, d, k, g, ʔ/	/m, n/	—	/f, v, s, ʃ, h/	—	/ɹ, j, l, w/	/ʧ, ʤ/	—	—	—
Mandarin (Putonghua; cmn)	1	18–54	/p, pʰ, t, tʰ, k, kʰ/	/m, n/	—	/f, s, ʂ, ɕ, x/	—	/ɹ, l/	/ʦ, tsʰ, tʂ, tʂʰ, tɕ, tɕʰ/	—	—	—
Portuguese (pot)	3	24–95	/p, b, t, d, k, g/	/m, n, ɲ/	/r, ʁ, ɾ/	/f, v, θ, ð, s, z, ʃ, ʒ, x/	—	/l, ʎ/	/ʧ, ʤ/	—	—	—
Setswana (Tswana; tsn)	1	36–71	/pʰ, b, tʰ, tʷʰ, d, kʰ, kʷʰ/	/m, n, nʷ, ɲ, ŋ, ŋʷ/	/(r), (rʷ)/	/f, s, sʷ, x, xʷ, h/	—	/j, l, lʷ, w/	/tsʰ, tsʰʷ, tɬʰ, tɬʷʰ, ʧʰ, ʤ, ʤʷ, kxʰʷ/	—	—	/p’, t’, tʷ’, k’, kʷ’, ts’, tsʷ’/
Slovenian (slv)	1	29–67	/p, b, t, d, k, g/	/m, n/	/(r)/	/f, v, (s), (z), (ʃ), (ʒ), x/	—	/j, l/	/(ʦ), (ʧ)/	—	—	—
Spanish (spa)	4	23–107	/p, b, t, d, k, g/	/m, n, ɲ, ŋ/	/r, ɾ/	/β, f, ð, s, ʒ, x/	—	/j, l, w/	/ʧ, ʤ/	—	—	—
Swahili (swa)	1	36–71	/p, b, t, d, k, g/	/m, n, ɲ, ŋ/	/r/	/f, v, θ, ð, s, z, ʃ, h/	—	/j, l, w/	/ʧ/	—	—	—
Turkish (tur)	3	12–107	/p, b, t, d, c, ɟ, k, g/	/m, n/	/r/	/f, v, s, z, ʃ, ʒ, ɣ, h/	—	/ʊ, j, l, ɬ/	/ʧ, ʤ/	—	—	—
Xhosa (xho)	3	12–72	/p, pʰ, b, t, tʰ, d, cʰ, ɟ, k, kʰ, g/	/m, n, ɲ, ŋ/	/r/	/f, v, s, z, ʃ, x, ɣ, ɦ, h/	/ɬ, ɮ/	/j, l, w/	/ʦʰ, ʣ, tɬ, ʧ, ʧʰ, ʤ/	/ǀ, ǀʰ, ǃ, ǃʰ, ǁ, ǁʰ/	/ɓ/	/p’, t’, c’, k’, ts’, ʧ’, kx’/

Note. This appendix includes all consonant phonemes that were assessed in the reviewed studies; however, consonants may vary between dialects of each language. Consonants in parentheses were assessed but not acquired by participants in any of the reviewed studies in that language. This appendix provides the context for data in Supplemental Material S1.

[a]Language names use the International Organization for Standardization (ISO) 639-3:2007 standard abbreviations.

Appendix B (p. 1 of 2)

Features of 60 Articles (64 Studies) Describing Typical Speech Acquisition in 27 Languages

Language assessed	Dialect	Author (year)	Country of data collection	Sample size	Monolingual/ multilingual	Age range	Design	SW/CS/I	Age of acquisition data	Percentage correct reported
Afrikaans	Cape Town	Lotter (1974)	South Africa	999	First	36–114	Cr	SW	C, CC	—
Arabic	Jordanian	Amayreh & Dyson (1998)	Jordan	180	Mono	24–76	Cr	SW	C	PCC
	Kuwaiti	Alquattan (2015)	Kuwait	70	Mono	16–43	Cr	CS	C, CC	PCC[a]
	Kuwaiti	Ayyad et al. (2016)	Kuwait	80	Mono	46–62	Cr	SW	C, CC, V	—
Cantonese	Hong Kong	Cheung (1990)	Hong Kong	155	—	25–72	Cr	SW	C, V	—
	Hong Kong	So & Dodd (1995)	Hong Kong	268	Mono	24–71	Cr	SW, CS	C, V, T	—
	Hong Kong	To et al. (2013)	Hong Kong	1,726	First	18–148	Cr	SW	C, V, T	—
Danish	—	Clausen & Fox-Boyer (2011)	Denmark	80	Mono	24–71	Cr	SW	C	—
	—	Clausen & Fox-Boyer (2017)	Denmark	443	Mono	30–59	Cr	SW	C, CC, V	PCC, PVC
Dutch	Standard	Beers (1995)	The Netherlands	90	Mono	15–48	Cr	CS	C	—
	Standard	Van Severen (2013)	Belgium	30	Mono	6–24	L	CS	C	—
English	American	Arlt & Goodban (1976)	United States	240	Mono	36–72	Cr	SW	C, CC, V	—
	Australian	Chirlian & Sharpley (1982)	Australia	1,375	Mono	24–108	Cr	SW	C	—
	British	Dodd et al. (2003)	United Kingdom	684	Mono	36–83	Cr	SW, I	C, CC, V	PCC, PVC, PPC
	Australian	Kilminster & Laird (1978)	Australia	1,756	Mono	35–109	Cr	SW	C	—
	Australian	McIntosh & Dodd (2008)	Australia	62	—	25–35	L	SW	C, CC	PCC, PVC, PPC
	African American	Pearson et al. (2009)	United States	537	Mono	48–155	Cr	CS	C, CC	—
	American (Mainstream)	Pearson et al. (2009)	United States	317	Mono	48–155	Cr	CS	C, CC	—
	American	Poole (1934)	United States	140	—	42–90	Cr	SW	C	—
	American (General)	Prather et al. (1975)	United States	147	Mono	23–48	Cr	SW	C	—
	American (Standard Midwestern dialect)	Smit et al. (1990)	United States	997	Mono	36–108	Cr	SW	C, CC	—
	American (General)	Templin (1957)	United States	480	—	36–96	Cr	SW	C, CC, V	—
	American (General)	Wellman et al. (1931)	United States	240	Mono	24–83	Cr	SW	C, CC, V	—
	Cape Town, South African	Mowrer & Burger (1991)[b]	South Africa	70	Mono	30–72	Cr	SW	C	—
	Irish	Monaghan (2014)	Republic of Ireland	60	Mono	36–71	Cr	SW	C	PCC[a]
	Malay	Phoon (2010)	Malaysia	264	Multi	36–95	Cr	SW	C, CC, V	PCC, PVC, PPC
French	Québécois	MacLeod et al. (2011)	Canada	156	Mono	20–53	Cr	SW	C, CC, V	PCC
German	—	Fox & Dodd (1999)[c]	Germany	177	—	18–71	Cr	SW	C, CC, V	PCC, PVC[a], PPC
Greek	—	Papadopoulou (2000)	Greece	34	—	43–54	Cr	SW	C, CC, V	—
	Cypriot	Petinou & Theodorou (2016)	Cyprus	14	First	24–36	L	CS	C	—
Haitian Creole	—	Archer et al. (2013)[d]	Haiti	12	Mono	24–51	Cr	SW	C, CC	—
Hebrew	Israeli	Ben-David (2001)	—	10	—	10–42	L	SW, CS	C, CC, V	—
Hungarian	—	Nagy (1980)	Hungary	7,602	—	36–96	Cr	SW, CS	C, V	PCC
Icelandic	—	Másdóttir & Stokes (2016)	Iceland	28	Mono	28–40	L	SW, CS	C	—
Italian	—	Zmarich & Bonifacio (2005)	Italy	13	Mono	18–27	L	CS	C, CC	—
Jamaican Creole	—	Meade (2001)	Jamaica	24	Multi	12–54	L	CS	C, CC, V	—

Appendix B (p. 2 of 2)

Features of 60 Articles (64 Studies) Describing Typical Speech Acquisition in 27 Languages

Language assessed	Dialect	Author (year)	Country of data collection	Sample size	Monolingual/ multilingual	Age range	Design	SW/CS/I	Age of acquisition data	Percentage correct reported
Japanese	—	Nakanishi (1982)	Japan	10	—	12–48	L	SW	C, V	—
	—	Nakanishi et al. (1972)	Japan	1,689	—	48–83	Cr	SW	C	—
	—	Noda et al. (1969)	Japan	466	—	24–78	Cr	SW	C	—
	—	Sakauchi (1967)	Japan	134	—	34–56	Cr	SW	C, CC	—
	—	Takagi & Yasuda (1967)	Japan	133	—	42–72	Cr	SW	C	—
Korean	—	M. Kim & Pae (2005)	South Korea	220	—	30–76	Cr	SW	C, CC	PCC[a]
	—	Y. Kim (1996)	South Korea	155	—	24–72	Cr	SW	C	—
	—	Oum (1986)	South Korea	150	—	36–60	Cr	SW	C	—
	—	Pae (1995)	South Korea	320	—	5–85	Cr	CS	C	—
Malay	Penang	Phoon et al. (2014)	Malaysia	326	First	48–77	Cr	SW	C	PCC
Maltese	—	Grech (1998)	Malta	21	—	24–42	L	SW, CS	C, CC, V	—
Mandarin (Putonghua)	Beijing	Hua & Dodd (2000)	China	129	Mono	18–54	Cr	SW, CS	C, V, T	—
Portuguese	Brazilian	Salviano Santini (1995)	Brazil	192	Mono	24–82	Cr	SW	C, CC	PCC
	Brazilian	Silva et al. (2012)	Brazil	240	—	36–95	Cr	SW	C	PCC
			Brazil	240	—	36–95	Cr	SW	C	PCC
Setswana (Tswana)	SeKwêna	Mahura & Pascoe (2016)	South Africa	36	First	36–71	Cr	SW	C, V	PCC, PVC
Slovenian	Maribor	Marin (2013)	Slovenia	70	—	29–67	Cr	SW	C, CC	—
Spanish	Dominican	De la Fuenta (1985)	Dominican Republic	55	Mono	23–77	Cr	SW	C	—
	Mexican	Jimenez (1987)	United States	120	First	36–67	Cr	SW	C	—
	Mexican (Chihuahua)	Linares (1981)	Mexico	97	Mono	36–83	Cr	SW	C	—
	New Mexico	Linares (1981)	United States	148	Mono	60–107	Cr	SW	C	—
Swahili	—	Gangji et al. (2014)	Tanzania	24	First	36–71	Cr	SW	C, CC, V	PCC, PVC
Turkish	—	Topbaş (1997)	Turkey	22	—	12–36	Cr, L	CS	C, CC	—
	—	Topbaş & Yavaş (2006)	Turkey	665	Mono	12–107	Cr, L	SW, CS	C, CC	PCC
	—	Yalcinkaya et al. (2010)	Turkey	753	—	12–83	Cr	SW	C	—
Xhosa	—	Maphalala et al. (2014)	South Africa	24	First	36–72	Cr	SW	C	PCC, PVC
	Cape Town, South African	Mowrer & Burger (1991)[b]	South Africa	70	Mono	30–72	Cr	SW	C	—
	—	Toumi et al. (2001)	South Africa	10	Mono	12–36	L	CS	C, V	—

Note. Em dashes (—) indicate that information was not available or unable to be determined. First = first-language speaker; Cr = cross-sectional; SW = single word; C = consonants; CC = consonant clusters; Mono = monolingual; PCC = percentage of consonants correct; CS = connected speech; V = vowels; T = tones; PVC = percentage of vowels correct; L = longitudinal; I = isolation; PPC = percentage of phonemes correct; Multi = multilingual.

[a]An overall PCC/PVC score was unavailable for inclusion in the current article. [b]Mowrer and Burger (1991) included two studies describing English and Xhosa. [c]Additional information about Fox and Dodd (1999) is provided in Fox-Boyer (2016) and Fox-Boyer and Schäfer (2015). [d]Portions of this thesis subsequently have been published as Archer, J., Champion, T., Tyrone, M. E., & Walters, S. (2018). Phonological development of monolingual Haitian Creole–speaking preschool children. *Communication Disorders Quarterly, 39*(3), 426–437.

Appendix C

Recommendations for Studies Reporting Age of Acquisition of Consonants

Demographic information

Report

- Language and dialect spoken by the participants
- Country (and region) where the data were collected
- Monolingual, first language, or multilingual status of the participants and what additional language(s) were spoken
- Number of males versus females in each age group (and overall)
- Socioeconomic status of participants
- Hearing, cognitive, and developmental status of the participants
- Whether the sample only includes typically developing children with no reported speech and language difficulties or is a population sample (Peña, Spaulding, & Plante, 2006)

Age range

- Ensure the minimum and maximum age of the participants captures children's acquisition (i.e., eliminate basal and ceiling effects as much as possible).
- Document age of acquisition in six monthly intervals.

Stimuli

- Include a table of the consonants within the language and dialect to describe place, manner, and voicing characteristics (e.g., formatted similarly to the International Phonetic Alphabet chart).
- Examine all of the consonants within the inventory of the language and dialect.
- Elicit consonants within single words (or connected speech), not in isolation.
- Elicit at least two productions of the consonant in each syllable and/or word position relevant to the language.
- Report the percentage of words that were elicited spontaneously (cf. imitated).
- Consider the phonotactic and prosodic features of the stimuli (e.g., monosyllabic vs. polysyllabic words, stress patterns) and the range of vowels, consonant clusters, and tones (if appropriate).

Consonant acquisition data

Report

- Consonants using symbols from the International Phonetic Alphabet
- Phonotactic constraints on the data: Which consonants were elicited in word-initial, within-word, and word-final contexts?
- Decision making regarding the accuracy of specific consonants; for example, describe whether distorted consonants and allophonic variants were considered to be correct or incorrect.

Analysis and documentation

- Report the criteria used to determine age of acquisition (e.g., correct in three word positions).
- Analyze data according to 75% and 90% criteria to be able to be compared with previous studies.
- Include a list of consonants that were not acquired by children in the oldest age group in the study.
- Include percentage of consonants, vowels, tones (if appropriate), and phonemes correct.
- Report interjudge and intrajudge reliability.