AJSLP

Review Article

Children's English Consonant Acquisition in the United States: A Review

Kathryn Crowe[a,b] and Sharynne McLeod[a]

Purpose: Speech-language pathologists' clinical decision making and consideration of eligibility for services rely on quality evidence, including information about consonant acquisition (developmental norms). The purpose of this review article is to describe the typical age and pattern of acquisition of English consonants by children in the United States.
Method: Data were identified from published journal articles and assessments reporting English consonant acquisition by typically developing children living in the United States. Sources were identified through searching 11 electronic databases, review articles, the Buros database, and contacting experts. Data describing studies, participants, methodology, and age of consonant acquisition were extracted.
Results: Fifteen studies (six articles and nine assessments) were included, reporting consonant acquisition of 18,907 children acquiring English in the United States. These cross-sectional studies primarily used single-word elicitation. Most consonants were acquired by 5;0 (years;months). The consonants /b, n, m, p, h, w, d/ were acquired by 2;0–2;11; /g, k, f, t, ŋ, j/ were acquired by 3;0–3;11; /v, ʤ, s, ʧ, l, ʃ, z/ were acquired by 4;0–4;11; /ɹ, ð, ʒ/ were acquired by 5;0–5;11; and /θ/ was acquired by 6;0–6;11 (ordered by mean age of acquisition, 90% criterion). Variation was evident across studies resulting from different assessments, criteria, and cohorts of children.
Conclusions: These findings echo the cross-linguistic findings of McLeod and Crowe (2018) across 27 languages that children had acquired most consonants by 5;0. On average, all plosives, nasals, and glides were acquired by 3;11; all affricates were acquired by 4;11; all liquids were acquired by 5;11; and all fricatives were acquired by 6;11 (90% criterion). As speech-language pathologists apply this information to clinical decision making and eligibility decisions, synthesis of knowledge from multiple sources is recommended.

Typical consonant acquisition or developmental norms are a common benchmark used in speech-language pathology assessments and diagnosis, in selection of intervention targets, and to consider eligibility for services for children with speech sound disorders (SSDs; Ireland & Conrad, 2016; Ireland et al., 2020; McLeod & Baker, 2014; Porter & Hodson, 2001; Rvachew & Nowak, 2001; Skahan et al., 2007; Stewart & Weybright, 1980; Storkel, 2019a). Mastery of consonants has been described as one of "the most widely used metrics of typical phonological acquisition and of phonological disorder" (Edwards & Beckman, 2008, p. 937). Consonant acquisition has held a key position in speech-language pathologists' (SLPs) decision making for children with SSDs, even though the ability to speak encompasses a broad range of skills: "perception, articulation/motor production…phonological representation of speech segments (consonants and vowels), phonotactics (syllable and word shapes), and prosody (lexical and grammatical tones, rhythm, stress, and intonation)…intelligibility and acceptability" (McLeod et al., 2013). Recently, Storkel (2019a) encouraged SLPs and policy makers to consider going beyond the use of developmental norms when considering eligibility for services. This requires SLPs to consider children's capacity and performance within their environment, encompassing speech production (e.g., consonants, vowels, consonant clusters, polysyllables, stress relevant to their ambient language; Farquharson, 2019; Storkel, 2019a), speech perception (Rvachew et al., 1999), a comprehensive independent and relational analysis (Fabiano-Smith, 2019; McLeod & Baker, 2017; McLeod et al., 2017), intelligibility (McLeod, 2020; McLeod et al., 2012), stimulability (Powell & Miccio, 1996), phonological awareness, spelling, reading (Gillon, 2004; Farquharson, 2019), academic and social impact (Krueger, 2019), as well as insights from children themselves (McCormack et al., 2019) and significant others in their lives (McCormack et al., 2010; McLeod, 2004).

[a]Charles Sturt University, Bathurst, New South Wales, Australia
[b]University of Iceland, Reykjavik
Correspondence to Sharynne McLeod: smcleod@csu.edu.au

Editor-in-Chief: Julie Barkmeier-Kraemer
Editor: Mary K. Fagan
Received October 24, 2019
Revision received February 7, 2020
Accepted May 2, 2020
https://doi.org/10.1044/2020_AJSLP-19-00168

Disclosure: The authors have declared that no competing interests existed at the time of publication.

SLPs' evidence-based practice relies on rigorous and up-to-date information. Quality evidence regarding typical consonant acquisition is essential because SLPs often use this evidence in assessment, diagnosis, intervention, and decision making regarding eligibility for services (Ireland & Conrad, 2016; McLeod & Baker, 2014; Porter & Hodson, 2001; Rvachew & Nowak, 2001; Storkel, 2019a). For example, Ireland and Conrad (2016) quoted one U.S. state as including the following requirement in their eligibility for services: "Two or more phonemic errors not expected at the child's age" (p. 80). Within the United States, four sources of information about consonant acquisition are frequently used: the review by Sander (1972), journal articles about consonant acquisition (e.g., Smit et al., 1990), commercially available assessments (e.g., Goldman & Fristoe, 2015), and the work of Shriberg and colleagues documenting the percentage of consonants correct (PCC) and the early-8, middle-8, late-8 consonants of children with SSDs (Shriberg, 1993; Shriberg & Kwiatkowski, 1982). Each of these four sources of information are described below, including considerations about participant selection, methods for obtaining speech samples, and data analysis (cf. Smit, 1986).

First, Sander (1972) described "customary" versus "mastery" production of English consonants based on research from Wellman et al. (1931) and Templin (1957). Sander defined customary production as "that point when a child is producing a sound correctly more often than [s]he is misarticulating or omitting it" (p. 56), quantified as "where the combined test average at the various word positions exceeds 50%" (p. 60). He defined mastery production as when a child "produces the sound correctly at three different [word] positions" (p. 56). He included a now-famous figure of consonant acquisition ranging from 50% to 90% production for children from ages < 2 to > 8 years where some consonants had less variability in the age of acquisition (e.g., /p, m, h, n, w, b, f, j/ had the shortest bars) and others had greater variability (e.g., /s/ had the longest bar). Kent (1992) reanalyzed the study of Sander (1972) to categorize articulatory complexity of English consonants into four sets describing the least (Set 1) to most (Set 4) complex groups: 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]. He concluded based on these data that fricatives and affricates were the most complex English consonants to articulate.

Second, since the review by Sander (1972), there have been a few large-scale studies of consonant acquisition in the United States, the most cited being by Smit et al. (1990). Smit and colleagues considered the acquisition of consonants and consonant clusters by 997 children aged 3–9 years in the Iowa–Nebraska region. They reported the percentage of responses considered to be "acceptable" for each consonant (word-initial and word-final) and consonant cluster (word-initial), graphed the trajectory of acquisition for males and females by age, and provided a summary based on "75% levels of acquisition" (p. 788). Smit later reanalyzed the participants' productions of consonants (Smit, 1993a) and consonant clusters (Smit, 1993b) quantifying common, occasional, and rare errors. She indicated that the most common errors for word-initial /ɹ/[1] were [w], derhotacization, and labialization, whereas the most common errors for word-initial /s/ were [t] or [d], dentalization, lateralization, and postalveolar productions.

Third, in the United States, there are many assessments targeting children's production of consonants (reviewed by Eisenberg & Hitchcock, 2010; Flipsen & Ogiela, 2015; Kirk & Vigeland, 2014; Macrae, 2017; McCauley & Strand, 2008; McCauley & Swisher, 1984). The assessment manuals typically include information about standardization of the assessment and data regarding typical consonant acquisition; however, there has been criticism of the rigor of standardization for some assessments (Fabiano-Smith, 2019; Friberg, 2010; Kirk & Vigeland, 2014).

Finally, two metrics created by Shriberg and colleagues for describing children with SSDs have been adopted within SLPs' descriptions of consonant acquisition: PCC and early–middle–late consonants (Shriberg, 1993; Shriberg et al., 1997a). PCC was created as a "procedure for assessing severity of involvement" (Shriberg & Kwiatkowski, 1982, p. 256). Shriberg (1993) analyzed data from 64 English-speaking children with SSDs aged 3–6 years to indicate that early-8 consonants were /m, b, j, n, w, d, p, h/, middle-8 consonants were /t, ŋ, k, g, f, v, ʧ, ʤ/, and late-8 consonants were /ʃ, θ, s, z, ð, l, ɹ, ʒ/. Within the United States and throughout the world, the PCC and early-, middle-, and late-consonant metrics have been used to describe typical speech acquisition (e.g., Fabiano-Smith & Goldstein, 2010; McLeod & Crowe, 2018; Nelson & Bauer, 1991).

Recently, a large-scale review of the age of acquisition of consonants was undertaken for 27 languages across 31 countries from 64 studies reporting on a total of 26,007 children (McLeod & Crowe, 2018). The motivation for that cross-linguistic study was to consider the age and pattern of the acquisition of different consonants that were inclusive of a diverse range of languages. The outcome of the review was that, across studies and languages, most consonants were reported to be acquired by the age of 5;0 (years;months); however, variation existed across consonants and languages. Generally, plosives, nasals, and nonpulmonic consonants were acquired earlier than trills, flaps, fricatives, and affricates. PCC was investigated in 15 studies of 12 languages with children, on average, achieving a PCC of 93.80 by 5;0. As part of the review, case studies were presented for the four languages with the greatest number of studies: English (15 studies), Spanish (four studies), Japanese (four studies), and Korean (four studies). The analysis of studies of English consonant acquisition included studies from the following countries: Australia, Malaysia, Republic of Ireland, South Africa, United Kingdom, and United States.

The findings of McLeod and Crowe (2018) prompted considerable discussion among clinicians and researchers,

[1]Within the current review article, the symbol /ɹ/ indicates a voiced alveolar approximant (English "r") to differentiate it from /r/ that indicates a voiced trill (trilled "r"; International Phonetic Association, 2018).

particularly around the impact that the "new norms" may have on eligibility and funding of children within U.S. schools (Storkel, 2019a). One particular finding that was discussed frequently by SLPs over social media (e.g., The Informed SLP, 2018) was that English-speaking children's reported age of acquisition of "r" for the 90%–100% criteria was 5;0–5;11 (McLeod & Crowe, 2018), younger than the age reported by Smit et al. (1990; 8;0–8;11). While English consonants share many features across the world, the consonant "r" does differ across countries. For example, "r" is produced in word-initial position in all English dialects; however, it is only produced in word-final position in a few English dialects (e.g., in the United States and Scotland). Within the United States, "r" has been transcribed as the voiced alveolar approximant /ɹ/ (sometimes transcribed as /r/[1]) and the rhotic vowels /ɝ/ and /ɚ/ (e.g., Shriberg et al., 2018). It may be possible that consonant acquisition in the United States may differ from the rest of the world due to differences between word position, transcription, and analysis conventions. Therefore, the motivation for the current review article was to provide a review of age of acquisition information for SLPs working with children acquiring English in the United States in a similar format to data from the cross-linguistic review of consonant acquisition by McLeod and Crowe.

Aims

The aims of this review article were to specifically consider children living in the United States and (a) identify and describe studies of English consonant acquisition, (b) summarize the average age of acquisition of English consonants, and (c) describe the range of age of acquisition for "r."

Method

A systematic literature search using a scoping review framework (Colquhoun et al., 2014) was used to examine literature and synthesize knowledge systematically and rigorously across studies about acquisition of English consonant phonemes by children in the United States. See Table 1 for the final list of 15 studies (journal articles and assessments) included in the review.

Search Strategy

Source 1: Literature

A systematic search of 10 databases was conducted in March 2019. Databases searched were Cochrane Library; EBSCO; Linguistics, Language, and Behavior Abstracts; MEDLINE; Oxford Journals; PsycInfo; PubMed; Sage Journals; The Scholarly Journal Archive; and Wiley Online Library. The search terms children AND consonant AND English AND acquisition OR development were used to search all databases, and searches were limited to abstracts (title/abstract for PubMed). A total of 2,491 citations were located, representing 1,022 unique citations. In addition, a search of Google Scholar using the same search terms was completed in March 2019, yielding 161,000 results. The first 200 results were examined, and no relevant citations were identified in addition to those identified in the systematic database search. Three articles were identified that met the inclusion criteria.

Source 2: Assessments

A list of standardized norm-referenced assessments of English speech sound production (articulation/phonology/speech assessments) that were created/normed in the United States was obtained by examining review articles (Eisenberg & Hitchcock, 2010; Flipsen & Ogiela, 2015; Gubiani et al., 2015; Macrae, 2017; McCauley & Strand, 2008) and the Buros Test Reviews Online (Buros Center for Testing, 2019) under the category of Speech and Hearing. A list of 45 assessments were identified, and 28 were able to be accessed for review.[2] The assessment manuals and score forms were examined for whether they contained usable normative data on the age of consonant acquisition for children in the United States acquiring English and adhered to the inclusion/exclusion criteria below. Four relevant assessments were identified.

Source 3: Expert Knowledge

Clinicians and researchers with expertise in the speech acquisition of children were consulted to identify articles and assessments not identified in through the literature and assessment searches. First, a database of studies of children's speech acquisition collected by McLeod was consulted to identify additional studies (available at https://www.csu.edu.au/research/multilingual-speech/speech-acq-studies). Second, members of the International Expert Panel on Multilingual Children's Speech (McLeod et al., 2017) and experts in the acquisition of American English were e-mailed to ask if they knew of any additional relevant articles or assessments. Three additional articles and five additional assessments describing children's acquisition of English consonants in the United States were identified through these sources.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria from McLeod and Crowe (2018) were adapted and then applied to the review of articles and assessments. Titles and abstracts of articles and assessment manuals were reviewed to determine whether they described English consonant acquisition of children in the United States; presented research data; described typical speech and language development; were published as a journal article, book chapter, or test/assessment; described 10 or more participants; and described the consonant repertoire of English. Additional criteria were applied to assessments, which were required to be articulation and/or phonological assessments for children (as described in the examiners' manual), have been created/normed in the

---

[2]Most of the 17 assessments that were unavailable were: identified by the Buros Center for Testing, published prior to 2000, and out of print.

Table 1. Features of 15 studies describing typical English consonant acquisition in the United States, ordered chronologically.

Author (year)	Source	Assessment abbreviation	Participant location in US	Sample size	Monolingual	Age range (years;months)	Criteria	Data
1. Wellman et al. (1931)	Article	—	IA	240	Mono	2;0–6;11	50%, 75%, 90%	C, CC, V
2. Templin (1957)	Article	—	MN	480	—	3;0–8;0	75%	C, CC, V
3. Prather et al. (1975)	Article	—	WA	147	Mono	1;11–4;0	50%, 75%, 90%	C
4. Arlt & Goodban (1976)	Article	—	IL	240	Mono	3;0–6;0	75%	C
5. Bankson & Bernthal (1990)	Assessment	BBTOP	Northeast, North Central, South, West	1,070	—	3;0–9;11	50%, 75%, 90%	C, CC
6. Smit et al. (1990)	Article	—	IA, NE	997	Mono	3;0–9;0	50%, 75%, 90%	C, CC
7. Fudala (2000)	Assessment	Arizona-3	East, South, Midwest, West	5,515	Mixed[a]	1;6–18;11	90%	C, CC, V
8. Dodd et al. (2006)	Assessment	DEAP	Northeast, South, Midwest ,West	650	—	3;0–8;11	50%, 75%, 90%	C
9. Lowe (2000)	Assessment	ALPHA	IA, IL, MN, PA	1,310	—	3;0–8;11	50%, 75%, 90%	C, CC
10. Pearson et al. (2009)[b]	Article	—	National sample	854	—	4;0–12;11	90%	C, CC
11. Goldman & Fristoe (2015)	Assessment	GFTA-3	Northeast, South, Midwest, West	1,500	Mixed[c]	2;0–21;11	50%, 75%, 90%	C, CC
12. Fudala & Stegall (2017)	Assessment	Arizona-4	Northeast, South, Midwest, West	3,192	Mixed[d]	1;6–21;11	50%, 90%	C, CC, V
13. Bankson & Bernthal (2019)	Assessment	BBTOP-2	North, South, Midwest, West	772	—	3;0–9;11	50%, 75%, 90%	C
14. Glaspey (2019)	Assessment	GDAP	North Central, Northeast, South, West	880	—	3;0–10;11	50%, 75%, 90%	C
15. Woodcock et al. (2019)	Assessment	WCAB	Northeast, South, Midwest, West	1,096	Mono	1;5–103;0	90%	C, CC, V

Note. Em dashes indicate information was not available or unable to be determined. Mono = monolingual; C = consonants; CC = consonant clusters; V = vowels; BBTOP = Bankson–Bernthal Test of Phonology; Arizona = Arizona Articulation Proficiency Scale; DEAP = Diagnostic Evaluation of Articulation and Phonology; ALPHA = Assessment Link Between Phonology and Articulation; GFTA-3 = Goldman-Fristoe Test of Articulation–Third Edition; GDAP = Glaspey Dynamic Assessment of Phonology; WCAB = Woodcock–Camarata Articulation Battery.

[a]In this sample "children were from homes where English was the primary language spoken" (Fudala, 2000, p. 35). [b]The two cohorts were combined (537 primary users of African American English and 317 primary users of Mainstream American English) because "AAE- and MAE-speaking children showed equivalent pronunciation of most MAE singleton consonants…" (Pearson et al., 2009, pp. 238–239). See additional explanation in data analysis. [c]"13% of this sample was bilingual with English their most frequently used language and they spoke and understood English *well* or *very well*" (Goldman & Fristoe, 2015, p. 55). [d]"8% of the sample had a primary language spoken at home that was a language other than English" (Fudala & Stegall, 2017, p. 111).

United States, be standardized assessments, assess production of words (assessments that only included nonwords, imitated sounds, or speech perception tasks were excluded), be commercially published, and be accessible to the authors. If the same speech acquisition data were reported in both a journal article and an assessment manual, the journal article was used. For example, Prather et al. (1975) reported normative data from the Sequenced Inventory of Communication Development (Hedrick et al., 1975) so Prather et al. was included. Studies were excluded when data reported were inconsistent between the text, figures, and tables or presented data that could not be interpreted using the 50%, 75%, or 90% criterion. Within this review article, each reported criterion relates to the definitions used in the studies. Typically, 90% criterion indicates that 90% of the participants produced the consonant correctly.

After applying the inclusion and exclusion criteria to the articles identified in Source 1, the journal article by Poole (1934) was excluded because data were not available using the 50%, 75%, or 90% criteria. Of the 28 available assessments identified in Source 2, 20 were excluded because they did not provide unique normative data regarding age of acquisition of English consonants by children in the United States. One assessment was excluded because it only presented data using the 85% criteria, and three others were excluded due to inconsistencies between the data provided in the tables and the text. Consequently, this review article included six studies published in journal articles and nine assessments (hereafter referred to as studies), for a total of 15 studies (see Table 1).

Procedure

Data were extracted from the 15 eligible studies. Data described study characteristics (year of publication), participant characteristics (number, age, sex, location, language status), research methods (speech sample type, study design, reliability, sensitivity and specificity, acquisition criteria), and results (age of consonant acquisition). Data were entered for the age (months) at which the consonant was considered to have been acquired in each study. Age of consonant acquisition data were extracted in one of two ways. If data for the percentage of children who had acquired each consonant at each age were available in the study, then this was used to determine the age each consonant was acquired by 50%, 75%, and 90% of children. If data for age of acquisition were presented only for predetermined criteria/criterion in the study, these criteria/criterion were used. Where the age of consonant acquisition data were presented separately for subgroups of participants (e.g., males and females) or for different positions (e.g., initial and final position), the youngest age of acquisition was recorded. In some studies, there was no age of acquisition given for a consonant as the children at the oldest age group in the study had not reached the criterion level of accuracy. In such cases, no age of acquisition was recorded, but a note was made as to why these data were unavailable. For example, Prather et al. (1975) examined participants aged between 24 and 48 months and children aged 48 months did not produce /v/, /z/, /θ/, or /ʤ/ at the 75% criterion.

Data Analysis

All the data were entered into Statistical Program for the Social Sciences software Version 26.0 (IBM, 2019). Frequency, central tendency (mean and median), and variability (standard deviation and range) of these data were analyzed. Consonants were classified by place and manner based on the International Phonetic Alphabet (International Phonetic Association, 2018). Data from the two cohorts of Pearson et al. (2009) were combined as one study in this review article. Pearson et al. investigated consonant acquisition of 854 children: 537 children who were primary users of African American English (AAE) and 317 children who were primary users of Mainstream American English (MAE). AAE- and MAE-speaking children showed similar pronunciation of consonants and clusters in initial, but not final, position. Furthermore, /ð/ was the consonant that differed most between dialects, prompting Pearson and colleagues (2009) to question whether /ð/ was within the phonemic repertoire of AAE. Therefore, in the current study, the two samples were combined and the age of acquisition was recorded for the word position that demonstrated the earliest acquisition, so /ð/ was recorded using the age of MAE acquisition.

Interrater Reliability

Data were extracted by the first author, and the second author completed reliability checks for five studies (33.3%). Interrater reliability was determined by point-by-point analysis (95.7%, 258 data points). Discrepancies were discussed between authors until agreement was reached and records were amended accordingly.

Results

Description of the Studies

Information on the 15 studies is presented in Table 1. These studies were published between the years 1931 (Wellman et al., 1931) and 2019 (Bankson & Bernthal, 2019; Glaspey, 2019; M = 1993.93, Mdn = 1995.00, SD = 25.86). In total, these 15 studies reported on data from 18,907 participants. The size of samples ranged from 147 (Prather et al., 1975) to 5,515 (Fudala & Stegall, 2017; M = 1,260.47, Mdn = 880.00, SD = 1,387.50). Participants across these studies ranged in age from 1;6 (18 months) to 103 years. The minimum age range examined was from 2;0 to 4;0 (Prather et al., 1975), and the maximum age range examined was from 1;5 to 103 years (Woodcock et al., 2019). The mean minimum age across studies was 30.73 months (Mdn = 36.00, SD = 9.14), and the mean maximum age across studies was 17;4 (M = 208.96 months, Mdn = 119.00, SD = 291.60). Twelve studies provided information on the number of males and females. In all of these studies, there was a similar number of males and females, with the largest difference reported for Pearson et al. (2009; 54.8% females). While all studies examined children in the United States acquiring English, only eight studies (53.3%) specified whether participants were monolingual users of English or not. Five studies stated that their participants were monolingual English speakers, and three studies included speakers that used another language and English. These three studies contained qualifying statements describing multilingual children as being from "homes where English was the primary language spoken" (Fudala, 2000, p. 35), or English was the "most frequently used language" and they "spoke and understood English well or very well" (Goldman & Fristoe, 2015, p. 55), or "8% of the sample had a primary language spoken at home that was a language other than English" (Fudala & Stegall, 2017, p. 111). The language status of speakers was not stated for the remaining seven studies (41.7%).

Description of the Data Collection

All 15 studies used a cross-sectional research design. All collected single-word speech samples, with one also using sentences. Glaspey (2019) collected speech samples in a dynamic hierarchy, including single-word and sentence contexts, but the age of acquisition data used in this review article are based on single-word data. Consonant acquisition in word-initial and word-final position was described in all 15 studies (*n* = 15, 100.0%) and within-word position in four studies (*n* = 4, 26.7%). Singleton consonant data were reported for all studies (*n* = 15, 100.0%), since this was an eligibility criterion. In some studies, the age of acquisition data were also reported for consonant clusters (*n* = 10, 66.7%) and vowels (*n* = 5, 33.3%). No studies provided age-related information about the PCC, the percentage of vowels correct (PVC), and the percentage of phonemes correct (PPC).

Some studies did not sample one or two English consonants. Most often omitted was /ʒ/ (Bankson & Bernthal, 1990, 2019; Fudala, 2000; Fudala & Stegall, 2017; Goldman & Fristoe, 2015; Lowe, 2000; Pearson et al., 2009; Smit et al., 1990). Smit et al. (1990) explained the exclusion of /ʒ/ from their sample, stating it "is rarely used by speakers of Midwestern dialect" (p. 780). Two studies omitted data for /ŋ/ (Bankson & Bernthal, 1990, 2019), although /ŋ/ was elicited in *kangaroo*. One study each omitted the following consonants from their analysis tables: /p/ (Pearson et al., 2009) and /j/ (Arlt & Goodban, 1976). Pearson et al. (2009) included a footnote to indicate that /p/ was omitted in error and Arlt and Goodban (1976) did not elicit /j/ because of infrequent usage. The voiceless labial-velar fricative /ʍ/ "wh" was only considered in four older studies (Arlt & Goodban, 1976; Prather et al., 1975; Templin, 1957; Wellman et al., 1931).

Description of the Data Analysis

Age of Acquisition Criteria

Table 2 presents summary information about the age of acquisition of consonant phonemes at the 50%, 75%, and 90% criteria. Across the 15 studies, 34 sets of data describing consonant acquisition were available with age of acquisition data available for one (*n* = 5, 33.3%), two (*n* = 1, 6.6%), or three (*n* = 9, 60.0%) criteria. Data were available for the following criteria across the 15 studies: 50% (*n* = 10), 75% (*n* = 11), and 90% (*n* = 13).

Transcription Reliability

Six studies (40.0%) provided data on interrater reliability, and none provided intrarater reliability.

Sensitivity and Specificity

Four studies (26.7%) described sensitivity (proportion of children with SSDs identified correctly) or specificity (proportion of typically developing children not identified with SSDs; Dodd et al., 2006; Fudala & Stegall, 2017; Glaspey, 2019; Goldman & Fristoe, 2015), and this information was unable to be identified in 11 studies (73.3%).

Mean Age of Acquisition of Consonant Phonemes

The age of acquisition of each consonant is presented using descriptive statistics (mean, median, standard deviation, range) in Table 2 and summarized in Table 3 and Figure 1. Within each age group, consonants are listed according to the place, manner, and voicing order within the International Phonetic Alphabet (International Phonetic Association, 2018).

50% Criterion

The 50% criterion was used in 10 studies describing a total of 10,772 children. The minimum age of children in these studies ranged from 18 to 36 months, and the maximum age ranged from 48 to 263 months. In total 22 consonant phonemes were acquired at a mean age of between 2;0 and 2;11 (24–35 months): /p, b, t, d, k, ɡ, m, n, ŋ, f, v, s, z, ʃ, ʍ, h, ɹ, j, l, w, ʧ, ʤ/, and three consonant phonemes between 3;0 and 3;11 (36–47 months): /θ, ð, ʒ/ (see Tables 2 and 3).

75% Criterion

The 75% criterion was used in 11 studies describing a total of 8,250 children. The minimum age of children in these studies ranged from 2;0 to 3;0 (24–36 months), and the maximum age ranged from 4;0 to 21;11 (48–263 months). In total, 11 consonant phonemes were acquired at a mean age of between 2;0 and 2;11 (24–35 months; /p, b, t, d, k, ɡ, m, n, f, h, w/), 10 consonant phonemes were acquired between 3;0 and 3;11 (36–47 months; /ŋ, v, s, z, ʃ, ɹ, j, l, ʧ, ʤ/), three consonant phonemes were acquired between 4;0 and 4;11 (48–59 months; /ð, ʒ, ʍ/), and one consonant phoneme was acquired between 5;0 and 5;11 (60–71 months; /θ/; see Tables 2 and 3). Prather et al. (1975) indicated /θ, z, ʍ/ were not achieved by the upper age limit of their study, which was 4;0 (48 months).

90% Criterion

The 90% criterion was used in 13 studies describing a total of 18,187 children. The minimum age of children in these studies ranged from 1;5 to 4;0 (17–48 months), and

Table 2. Average age of acquisition of consonants across 15 studies of children within the United States (*n* = 18,907).

	50% Criterion[a]				75% Criterion[a]				90% Criterion[a]			
Consonant	***M* (months)**	***SD* (months)**	**Range (months)**	**No. of studies[b]**	***M* (months)**	***SD* (months)**	**Range (months)**	**No. of studies[b]**	***M* (months)**	***SD* (months)**	**Range (months)**	**No. of studies[b]**
Plosives												
p	30.60	7.18	18–36	10	32.73	5.61	24–36	11	33.25	6.94	24–48	12
b	30.60	7.18	18–36	10	32.73	5.61	24–36	11	31.38	7.81	24–48	13
t	31.20	6.20	24–36	10	33.82	7.24	24–48	11	38.54	9.19	24–60	13
d	30.60	7.18	18–36	10	33.09	5.09	24–36	11	35.69	6.68	24–48	13
k	31.20	6.20	24–36	10	33.82	4.85	24–36	11	37.69	7.30	24–48	13
g	31.20	6.20	24–36	10	33.82	4.85	24–36	11	36.77	6.61	24–48	13
Nasals												
m	30.60	7.18	18–36	10	32.73	5.61	24–36	11	33.23	6.66	24–48	13
n	30.60	7.18	18–36	10	32.73	5.61	24–36	11	33.08	7.42	24–48	13
ŋ	30.00	6.41	24–36	8	36.67	12.17	24–66	9	40.30	10.75	24–55	10
Fricatives												
f	31.20	6.20	24–36	10	33.82	4.85	24–36	11	38.31	6.26	24–48	13
v	32.80	5.27	24–36	10	42.73	11.64	30–72	11	50.83	10.77	36–66	12
θ	46.00	7.66	36–60	10	64.20	4.94	60–72	10	77.00	7.44	72–96	10
ð	41.80	4.94	36–48	10	56.73	7.28	48–72	11	69.00	11.33	54–96	12
s	32.40	5.80	24–36	10	38.55	10.00	24–60	11	51.33	16.32	24–84	12
z	33.40	5.97	24–42	10	44.40	17.02	24–84	10	56.82	14.28	30–84	11
ʃ	32.40	5.80	24–36	10	41.27	10.21	24–60	11	55.00	10.50	36–72	12
ʒ	37.00	8.25	28–48	4	54.00	16.54	36–84	6	70.67	12.22	60–84	3
ʍ	32.00	5.66	28–36	2	48.00	16.97	36–60	2	—	—	—	0
h	30.60	7.18	18–36	10	32.73	5.61	24–36	11	35.00	6.95	24–48	13
Approximants, laterals												
ɹ	35.40	7.18	24–48	10	47.64	13.02	24–66	11	66.58	18.62	30–96	12
j	33.00	5.10	24–36	10	39.60	7.59	24–48	10	45.77	10.96	30–60	13
l	33.20	5.01	24–36	10	40.91	7.97	24–48	11	53.75	10.43	24–60	12
w	30.60	7.18	18–36	10	32.73	5.61	24–36	11	35.23	6.76	24–48	13
Affricates												
ʧ	34.20	4.05	24–36	10	41.64	8.71	24–54	11	53.50	10.69	36–72	12
ʤ	34.20	4.05	24–36	10	41.27	8.68	24–54	11	51.00	11.82	36–72	13

Note. Em dashes indicate not acquired by the oldest child in the study, not assessed, or no variability.

[a]Each reported criterion relates to the definitions used in each of the 15 studies. Typically, 90% criterion indicates that 90% of the participants produced the consonant correctly.
[b]The number of studies varies because of whether the consonant was included in the study or whether it was not acquired by children in the oldest age group examined in the study.

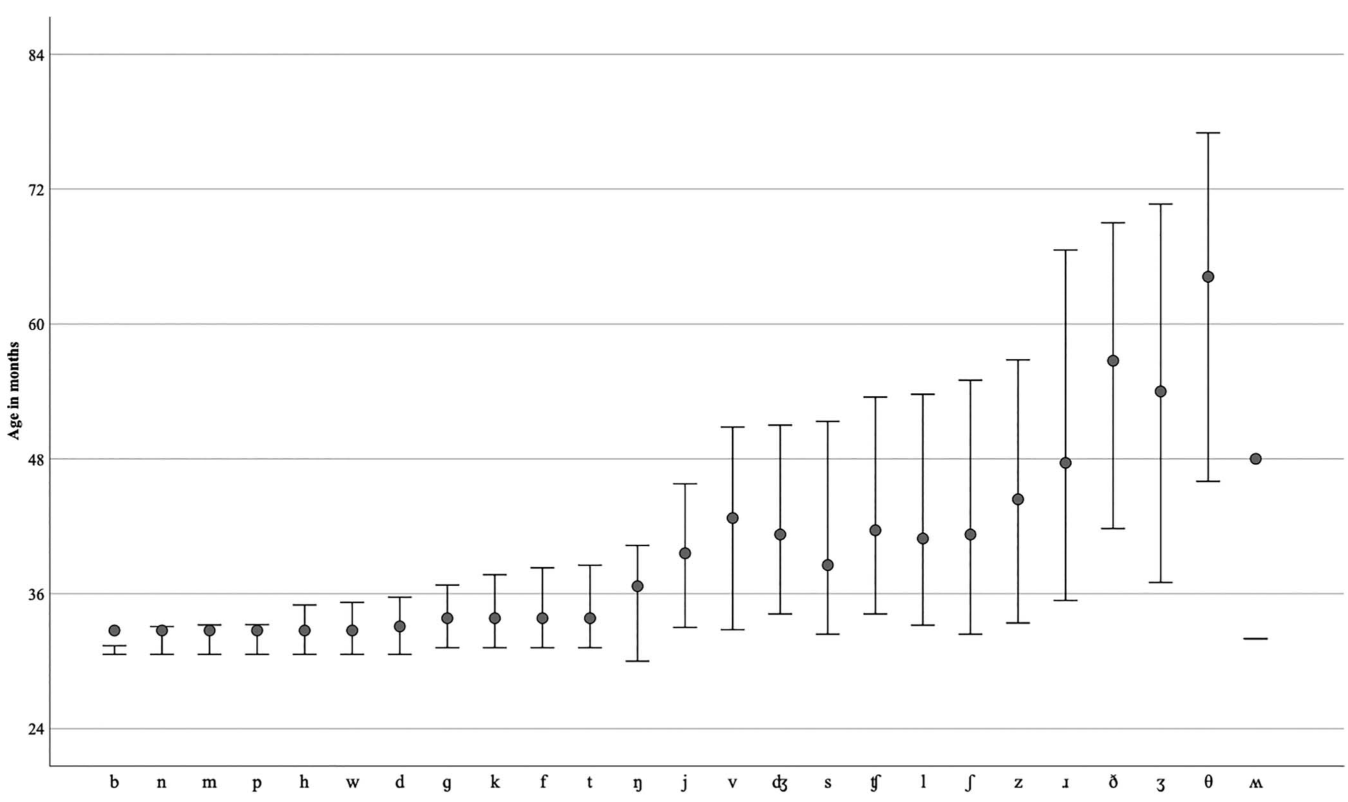
Table 3. Mean age of consonant acquisition for English-speaking children within the United States and children across the world organized according to age in years.

No. of studies/Age	United States sample[a]			Global sample[a]		
	50%	75%	90%	50%[b]	75%–85%	90%–100%
No. of studies at each criterion	8	9	10	5	9	8
2;0–2;11 (24–35 months)	/p, b, t, d, k, g, m, n, ŋ, f, v, s, z, ʃ, ʍ, h, ɹ, j, l, w, ʧ, ʤ/	/p, b, t, d, k, g, m, n, f, h, w/	/p, b, d, m, n, h, w/	/p, b, d, t, k, g, m, n, f, s, ʃ, h, j, w/	/p, b, d, k, g, m, n, ŋ, f, h, w/	/p/
3;0–3;11 (36–47 months)	/θ, ð, ʒ/	/ŋ, v, s, z, ʃ, ɹ, j, l, ʧ, ʤ/	/t, k, g, ŋ, f, j/	/ŋ, v, z, ð, ʒ, ʍ, ɹ, l, ʧ, ʤ/	/t, s, ʃ, j, l/	/b, t, d, k, g, m, n, ŋ, f, h, j, w/
4;0–4;11 (48–59 months)		/ð, ʒ, ʍ/	/v, s, z, ʃ, l, ʧ, ʤ/	/θ/	/v, z, ʒ, ɹ, ʧ, ʤ/	/v, s, z, ʃ, l, ʧ, ʤ/
5;0–5;11 (60–71 months)		/θ/	/ð, ʒ, ɹ/		/ð/	/ð, ʒ, ɹ/
6;0–6;11 (72–83 months)			/θ/		/θ/	/θ/

Note. The United States sample is based on 15 studies of 18,907 children analyzed in the current study. The global sample is based on 15 studies of 7,369 analyzed in the study of McLeod and Crowe (2018).

[a]The order of consonants within age groups was based on International Phonetic Alphabet (2018) organization of place, voice, and manner to assist comparison across studies. Six articles were analyzed in both studies of McLeod and Crowe (2018) and the current study. [b]Data for the 50% criterion were not reported in the study of McLeod and Crowe (2018) but were analyzed for the current review article.

Figure 1. Mean age of acquisition of consonant phonemes across studies of English-speaking children from the United States (n = 18,907) at 50% criterion (low bar), 75% criterion (circle), and 90% criterion (high bar). Consonants are ordered according to mean age of acquisition at the 90% criterion. At the 75% criterion, Prather et al. (1975) indicated /θ, z, ʍ/ were not achieved by 4;0 (48 months). At the 90% criterion, Bankson and Bernthal (1990) indicated that /θ, ɹ/ were not achieved by 6;11 (83 months), Prather et al. indicated that /θ, ð, v, z, ʃ, ʒ, ʍ, l, ʧ/ were not achieved by 4;0 (48 months), and Wellman et al. (1931) indicated that /θ, s, z, ʒ, ʍ/ were not achieved by 6;11 (83 months). Copyright © 2020 Crowe and McLeod. Reprinted with permission.



the maximum age ranged from 4;0 to 103 years (48–1,236 months). Seven consonant phonemes were acquired at a mean age of between 2;0 and 2;11 (24–35 months; /p, b, d, m, n, h, w/), six consonant phonemes were acquired between 3;0 and 3;11 (36–47 months; /t, k, ɡ, ŋ, f, j/), seven consonant phonemes were acquired between 4;0 and 4;11 (48–59 months; /v, s, z, ʃ, l, ʧ, ʤ/), three consonant phonemes were acquired between 5;0 and 5;11 (60–71 months; /ð, ʒ, ɹ/), and one consonant phoneme was acquired between 6;0 and 6;11 (72–83 months; /θ/; see Table 3). There were three studies that reported ceiling ages for the 90% criterion. Bankson and Bernthal (1990) indicated that /θ, ɹ/ were not achieved by 9;11 (119 months). Prather et al. (1975) indicated that /θ, ð, v, z, ʃ, ʒ, ʍ, l, ʧ/ were not achieved by 4;0 (48 months). Wellman et al. (1931) indicated that /θ, s, z, ʒ, ʍ/ were not achieved by 6;11 (83 months).

Using the 90% criteria across 10 studies of typical speech acquisition, the following English consonants could be classified as (ordered by mean age of acquisition):

- early 13 (2;0–3;11) = /b, n, m, p, h, w, d, ɡ, k, f, t, ŋ, j/ (all plosives, nasals and glides);
- middle 7 (4;0–4;11) = /v, ʤ, s, ʧ, l, ʃ, z/; and
- late 4 (5;0–6;11) = /ɹ, ð, ʒ, θ/.

The age range of participants in these studies created basal and ceiling effects; therefore, these mean ages of acquisition are conservative (i.e., could be lower). To elaborate, a basal effect was observed when children achieved a criterion at the youngest age group examined in a study. For example, Pearson et al. (2009) indicated that all consonants investigated in their study were acquired by their youngest participants (4;0) at the 90% criterion, with the exception of /θ/ and /ð/. Similarly, Goldman and Fristoe (2015) indicated that /p, b, t, d, k, ɡ, m, n, ŋ, f, s, l/ were acquired by their youngest participants at (2;0) at the 90% criterion. Therefore, consonant phonemes may have been acquired at earlier ages than reported. Furthermore, ceiling effects were observed where children had not acquired a consonant to the required accuracy criteria at the oldest age group examined in a study. Ceiling effects were observed for three studies (Bankson & Bernthal, 1990; Prather et al., 1975; Wellman et al., 1931).

Mean Age of Acquisition of "r"

The age of acquisition of /ɹ/ across studies was examined in detail using descriptive statistics (mean, median, standard deviation, range) and is summarized in Table 4 and Figure 2. Table 2 shows that, in this review article, /ɹ/ has the largest standard deviation of any of the English consonants at the 90% criterion (M = 66.58, SD = 18.62, range: 30–96 months). It is important to note that many studies only reported acquisition of /ɹ/ (frequently using the symbol /r/) in word-initial position and described "r" in word-final position as being produced as the vowels /ɝ/ and/or /ɚ/ (e.g., Bankson & Bernthal, 1990; Smit et al., 1990), whereas other studies examined /ɹ/ in both word-initial and word-final position (e.g., Pearson et al., 2009; Wellman et al., 1931).

50% Criterion

The 50% criterion was used in 10 studies describing acquisition of "r" by a total of 10,772 children at a mean age of 2;11 (35.40 months). Mean age of acquisition was 2;0 (two studies), 3;0 (six studies), 3;6 (one study), and 4;0 (one study). In four (50.0%) of these studies, /ɹ/ was reported to be acquired (50% criterion) at the youngest age of children assessed in the study: 2;0 (Goldman & Fristoe, 2015; Prather et al., 1975) and 3;0 (Bankson & Bernthal, 1990; Dodd et al., 2006; Glaspey, 2019; Lowe, 2000). No studies showed a ceiling effect.

75% Criterion

The 75% criterion was used in 11 studies describing acquisition of "r" by a total of 8,250 children at a mean age of 3;11 (47.64 months). Mean age of acquisition was 2;0 (one study), 2;8 (one study), 3;0 (one study), 3;6 (one study), 4;0 (one study), 4;6 (two studies), 5;0 (one study), and 5;6 (one study). In two (22.2%) of these studies, /ɹ/ was reported to be acquired (75% criterion) at the youngest age of children assessed in the study: 2;0 (Goldman & Fristoe, 2015) and 3;0 (Bankson & Bernthal, 1990). No studies showed a ceiling effect.

90% Criterion

The 90% criterion was used in 13 studies describing acquisition of "r" by a total of 18,187 children at a mean age of 5;6 (66.58 months). Mean age of acquisition was 2;6 (one study), 3;4 (one study), 4;0 (one study), 5;6 (one study), 6;0 (two studies), 6;6 (one study), 7;0 (one study), and 8;0 (one study). Only one study reported that /ɹ/ was acquired at the youngest age of children assessed in the study (Pearson et al., 2009). One study showed a ceiling effect, with /ɹ/ being acquired by 89% of 6-year-old children (i.e., the oldest age group; Bankson & Bernthal, 1990, p. 15).

Discussion

This review article presents the largest review of English consonant acquisition in the United States describing 15 studies (articles and assessments) of consonant acquisition by 18,907 children and demonstrates that most consonants were acquired by 5 years of age (see Table 3). The studies included in the review adhered to stringent inclusion and exclusion criteria.

Age of Acquisition of Consonants

Children acquiring English in the United States have, on average, acquired all but four consonants by 5;0 (see Table 3). On average, all plosives, nasals, and glides were acquired by 3;11; all affricates were acquired by 4;11; all liquids were acquired by 5;11; and all fricatives were acquired by 6;11 (90% criterion). The overall results are therefore similar to the acquisition of English within 15 studies from

Table 4. Studies reporting the age of acquisition of "r" according to the 50%, 75%, and 90% criteria ordered chronologically.

Author (year)	Article/ Assessment	Participant location (US states)	Sample size	Assessed age (years;months)	50% Criterion (M_{age})[a]	75% Criterion (M_{age})[a]	90% Criterion (M_{age})[a]
1. Wellman et al. (1931)	Article	IA	240	2;0–6;11	3;0	4;0	6;0
2. Templin (1957)	Article	MN	480	3;0–8;0	—	3;6	—
3. Prather et al. (1975)	Article	WA	147	1;11–4;0	2;0	2;8	3;4
4. Arlt & Goodban (1976)	Article	IL	240	3;0–6;0	—	5;0	—
5. Bankson & Bernthal (1990)	B-BTOP	Northeast, North Central, South, West	1,070	3;0–9;11	3;0	3;0	—
6. Smit et al. (1990)	Article	IA, NE	997	3;0–9;0	3;6	5;6	8;0
7. Fudala (2000)	Arizona-3	East, South, Midwest, West	5,515	1;6–18;11	—	—	6;0
8. Dodd et al. (2006)	DEAP	Northeast, South, Midwest, West	650	3;0–8;11	3;0	4;6	5;6
9. Lowe (2000)	ALPHA	IA, IL, MN, PA	1,310	3;0–8;11	3;0	4;6	6;6
10. Pearson et al. (2009)	Article	National sample	854	4;0–12;11	—	—	4;0
11. Goldman & Fristoe (2015)	GFTA-3	Northeast, South, Midwest, West	1,500	2;0–21;11	2;0	2;0	2;6
12. Fudala & Stegall (2017)	Arizona-4	Northeast, South, Midwest, West	3,192	1;6–21;11	3;0	—	7;0
13. Bankson & Bernthal (2019)	BBTOP-2	North, South, Midwest, West	772	3;0–9;11	4;0	5;0	6;0
14. Glaspey (2019)	GDAP	North Central, Northeast, South, West	880	3;0–10;11	3;0	4;0	6;0
15. Woodcock et al. (2019)	WCAB	Northeast, South, Midwest, West	1,096	1;5–103;0	—	—	5;9

Note. Em dashes indicate information was not available or unable to be determined. BBTOP = Bankson–Bernthal Test of Phonology; Arizona = Arizona Articulation Proficiency Scale; DEAP = Diagnostic Evaluation of Articulation and Phonology; ALPHA = Assessment Link Between Phonology and Articulation; GFTA-3 = Goldman-Fristoe Test of Articulation–Third Edition; GDAP = Glaspey Dynamic Assessment of Phonology; WCAB = Woodcock–Camarata Articulation Battery.

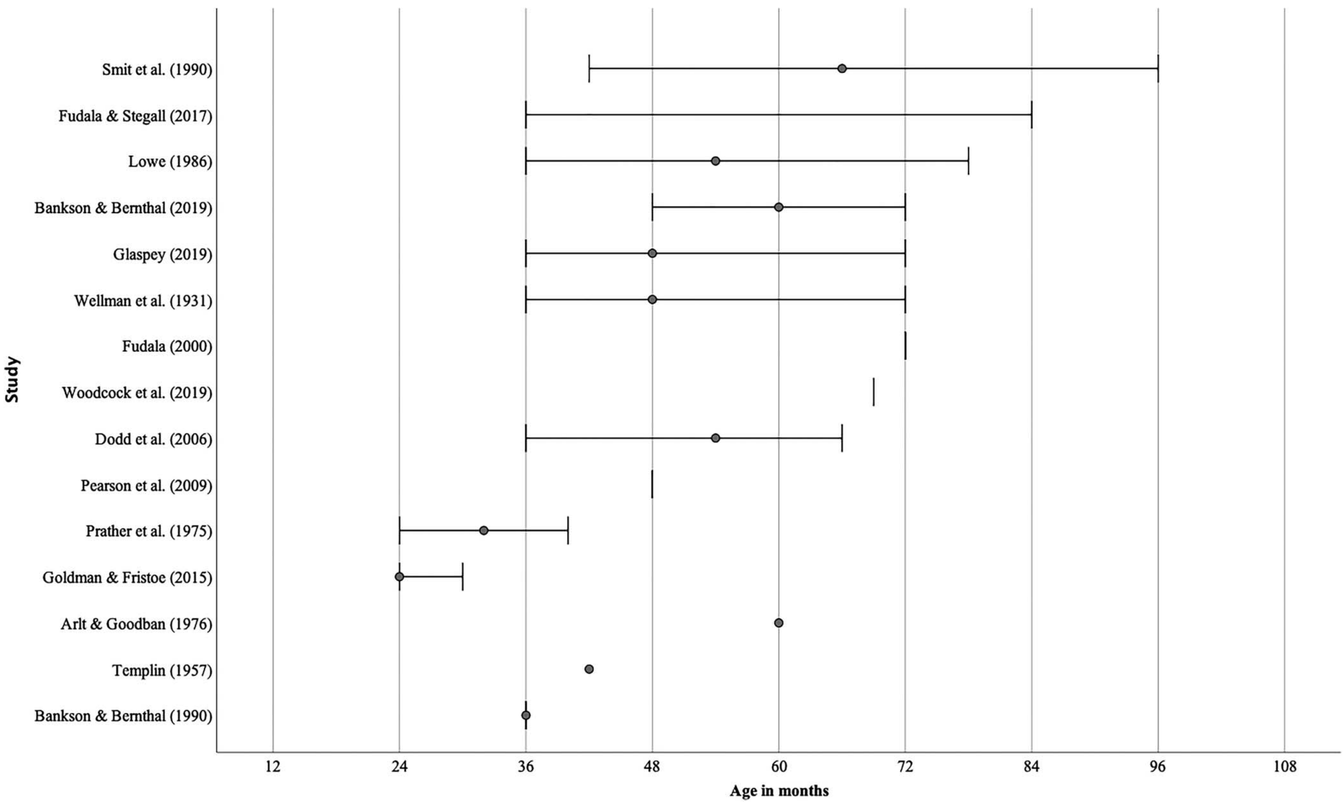
[a]Each reported criterion relates to the definitions used in each of the 15 studies. Typically, 90% criterion indicates that 90% of the participants produced the consonant correctly.

across the world presented by McLeod and Crowe (2018; see Table 3). Where differences occur, this is usually because children in the United States were reported to use English consonants at a mean age that was younger than in the study of McLeod and Crowe. Using the 90% criterion across eight studies of typical speech acquisition, the 24 English consonants were not classified as early-8, middle-8 or late-8 consonants as per Shriberg (1993). Instead, they were classified as early-13 /b, p, n, m, d, h, w, t, k, g, f, ŋ, j/, middle-7 /v, ʤ, l, ʧ, s, ʃ, z/, and late-4 /ʒ, ɹ, ð, θ/ consonants (see Table 5). However, there were many similarities in the general order of acquisition between these studies. Shriberg's early-8 consonants were within the early-13 consonants listed in the current study; similarly, the late-4 consonants from the current study were within Shriberg's late-8 group of consonants.

By summarizing data across 15 studies of 18,907 children, this review article presents an updated account of typical consonant acquisition that may seem contradictory to current (entrenched) beliefs in the United States about typical consonant acquisition (e.g., Sander, 1972; The Informed SLP, 2018). These updated consonant acquisition data may be used to inform decision making during speech-language pathology assessments and eligibility for speech intervention in U.S. schools (Ireland et al., 2020; Storkel, 2019a, 2019b). The youngest age of participants in half of the studies in the current review was 3;0 (36 months); consequently, it is possible that some consonants may be acquired earlier than this review suggests. Indeed, many studies specifically considering consonant acquisition of typically developing 2-year-old children show their seemingly precocious capacity compared with current benchmarks (McLeod et al., 2001; Nelson & Bauer, 1991; Stoel-Gammon, 1985, 1987; Watson & Terrell, 2012), and many international studies of speech acquisition include data from 2-year-olds (McLeod & Crowe, 2018). New studies of children's speech acquisition should consider eliciting data from children at 2 years of age or younger (if possible).

Two consonants, /ɹ/ and /s/, had the largest variability in age ranges across the studies with a standard deviation of approximately 20 months at the 90% criterion (see Table 2). Within the United States, the consonants /ɹ/ and /s/ are commonly reported as "residual errors" and "common clinical distortions" for children with persistent SSDs (e.g., Karlsson et al., 2002; Shriberg et al., 1997b). These consonants also are common intervention targets (e.g., Farquharson, 2019; Smit, 1993a) and have received attention from many speech researchers in the United States (e.g., Preston et al., 2019). Table 4 demonstrates that the Smit et al. (1990) study had the latest age of acquisition for /ɹ/ in this review. In her in-depth analysis of typical speech acquisition data, Smit (Smit 1993a; Smit et al., 1990) presented tables and figures demonstrating the range of

Figure 2. Mean age of /ɹ/ acquisition across studies of English-speaking children from the United States (n = 18,907) at 50% criterion (low bar), 75% criterion (circle), and 90% criterion (high bar). Studies are ordered according to mean age of acquisition at the 90% criterion. Bankson and Bernthal (1990) indicated that /ɹ/ was achieved at 3;0 (36 months) for the 50% and 75% criteria; however, it was not achieved at the 90% criterion by 9;11 (119 months). Copyright © 2020 Crowe and McLeod. Reprinted with permission.



error types across ages for /ɹ/ and /s/. Smit (1993a) presented a clear explanation for the changing error pattern for the consonant /s/: It was frequently stopped (produced as [t, d]) when the children were younger, produced as a dentalized /s/ or postalveolar consonant when older, sometimes lateralized, and was impacted by the loss of the upper incisors (dentition). However, she indicated "Analysis of error data provided no ready explanation for… the relatively late acquisition of /r/" (Smit et al., 1990, p. 794; referring to the English "r"). The current authors hypothesize that one contributing factor to the later age of acquisition for "r" in Smit et al. (1990) may have been the rigor in their definition of correct production of "r" and the inclusion of phonetic descriptions for "word-initial /r/ errors: … [w], derhoticized, labialized, derhoticized-labialized" (Smit, 1993a, p. 537).

Table 5. Comparison of order of English consonant acquisition for typical and atypical speech.

Source	Participant sample	Country	Early sounds	Middle sounds	Late sounds
Shriberg (1993) (n = 63)	Atyical speech acquisition	United States	/m, b, j, n, w, d, p, h/	/t, ŋ, k, g, f, v, ʧ, ʤ/	/ʃ, θ, s, z, ð, l, ɹ, ʒ/
McLeod & Crowe (2018) (n = 7,369)	Typical speech acquisition[a]	Australia, Malaysia, Republic of Ireland, South Africa, United Kingdom, United States	/p, b, m, d, n, h, t, k, g, w, ŋ, f, j/	/l, ʤ, ʧ, s, v, ʃ, z/	/ɹ, ʒ, ð, θ/
Current study (n = 18,907)	Typical speech acquisition[a]	United States	/b, p, n, m, d, h, w, t, k, g, f, ŋ, j/	/v, ʤ, l, ʧ, s, ʃ, z/	/ʒ, ɹ, ð, θ/

Note. Consonants are listed in order of age of acquisition from youngest to oldest.

[a]Based on studies reporting 90% criterion.

Features of Studies of English Consonant Acquisition in the United States

As with other studies conducted in countries across the world (McLeod & Crowe, 2018), these studies of English consonant acquisition in the United States typically reported cross-sectional data (100.0%) and elicited single words (91.7%). In addition to consonant acquisition, some included consonant cluster acquisition (86.7%) and vowel acquisition (33.3%). The studies of English consonant acquisition in the United States reported interrater reliability in less than half of the studies (40.0%), and sensitivity and specificity measures were rarely reported (26.7%). Suggested recommendations for undertaking and reviewing studies reporting age of acquisition of consonants are provided in Appendix C of McLeod and Crowe (2018) and include considerations regarding demographics, age range, stimuli, consonant acquisition data, analysis, and documentation.

None of the studies from the current review of typical English consonant acquisition in the United States included data regarding PCC, PVC, and PPC; in contrast, these data have been included in studies of many other English-speaking countries and other languages (e.g., Arabic, Danish, German, French, Hungarian, Malay, Portuguese, Swahili, Setswana, Turkish, and Xhosa, as reported in McLeod & Crowe, 2018). The foundational work on PCC in the United States by Shriberg and colleagues (Shriberg & Kwiatkowski, 1982; Shriberg et al., 1997a, 1997b) was based on children with SSDs, not typically developing children. While smaller scale studies of typically developing Spanish–English children's PCC have been undertaken in the United States (e.g., Bunta et al., 2009; Fabiano-Smith & Goldstein, 2010), there is a need for large-scale data from typically developing children regarding PCC and other summary measures (e.g., Ingram & Ingram, 2001).

One surprising finding from undertaking this research was the difficulty in locating recent studies of English consonant acquisition for children living in the United States. Originally, the search strategy was restricted to published articles and chapters, corresponding with the strategy from McLeod and Crowe (2018). However, this revealed only two large-scale studies in the past 30 years that met the inclusion and exclusion criteria (Pearson et al., 2009; Smit et al., 1990) and other historical studies. The search strategy was broadened after the realization that, in the United States, many studies of consonant acquisition are contained within assessment manuals. With this broader search strategy, an additional eight assessments published in the past 20 years (plus Bankson & Bernthal, 1990) were added to the analysis. When considering eligible assessments, some were unable to be accessed because they were no longer published; however, many others were excluded due to the lack of unique standardization data or inconsistencies in data presentation. These limitations regarding rigor corroborate findings from other review articles regarding the inadequacy of psychometric properties for some standardized speech assessments (Fabiano-Smith, 2019; Friberg, 2010; Kirk & Vigeland, 2014; McLeod & Verdon, 2014).

Clinical Implications

It is important to remember that "the approach to determining what is normal and what is not normal needs to reflect a variety of measures with normative data for target speech sounds being just one piece of the diagnostic puzzle" (Storkel, 2019a, p. 68). There are three considerations based on Storkel's quote. First, the current review is an attempt to make information about "normative data for target speech sounds" as comprehensive and accurate as possible. Second, average age of acquisition data need to be interpreted related to the context of every individual child; that is, "to determine acceptable acquisition by thinking as an anthropologist within the community that you are working" (McLeod & Baker, 2017, p. 178). Third, age of acquisition data are not enough for clinical decision making or to determine eligibility for services. As mentioned in the introduction to this review article, a "richer representation of development" (Storkel, 2019a, p. 67) requires SLPs to consider children's speech production, perception, comprehensive independent and relational analysis, intelligibility, stimulability, phonological awareness, spelling, reading, academic and social impact, as well as insights from children and significant others in their lives. A tutorial outlining recommendations for assessing children's speech using this richer representation of development was created by an international panel of 46 experts (McLeod et al., 2017) and can be applied to working with children who speak any language.

Limitations

This review limited the number of studies by using strict inclusion and exclusion criteria but was also broad by not imposing a limit on the age of included studies. Therefore, over the past 90 years, there have been theoretical and methodological changes in the field, as well as changes in the dialect and demography of young children acquiring American English that may have influenced the variability of the results. The calculation of the average age of acquisition for the 50%, 75%, and 90% criteria should be interpreted by considering maximum and minimum ages examined in each study (see Table 1), the standard deviations for each consonant indicating the level of variability (see Table 2), and the impact of the choice of words included in the stimuli lists, definition of mastery, and the impact that theoretical and methodological changes in the field may have had on study findings. The reported data are conservative (i.e., reporting younger ages) due to the impact of basal and ceiling scores and the decision to report the youngest age of acquisition when data were presented for subgroups of participants or in different word positions.

Future Research

Future large-scale studies of English consonant acquisition in the United States should consider eliciting data from children at 2 years of age or younger and include additional metrics such as PCC, PVC, PPC, and whole word measures (Ingram & Ingram, 2001; Shriberg et al., 1997a, 1997b). Studies should also address children's bidialectal and multilingual speech acquisition, since 20.8% of the U.S. population speaks a language other than English at home (Ryan, 2013). For example, a journal article describing a large-scale study of Spanish-English–speaking children's acquisition of both English and Spanish in the United States is long overdue.

Conclusion

This review article presents a comprehensive review of 15 studies that met strict inclusion and exclusion criteria that described English consonant acquisition by 18,907 children living in the United States. On average, 13 consonants (including all plosives, nasals, and glides) were acquired between 2;0 and 3;11 (/p, b, t, d, k, ɡ, m, n, ŋ, f, h, j, w/), seven additional consonants were acquired between 4;0 and 4;11 (/v, s, z, ʃ, l, ʧ, ʤ/), and the remaining four consonants were acquired between 5;0 and 6;11 (/ð, ʒ, ɹ, θ/; 90% criterion; see Table 5). These findings echo the cross-linguistic findings of McLeod and Crowe (2018) across 27 languages that most consonants were acquired by 5;0. These data inform SLPs' clinical decision making and consideration of eligibility for services to support best practice to enhance children's communicative competence.

Acknowledgments

This research was supported by Australian Research Council Discovery Grant DP180102848, awarded to the first author. The authors acknowledge support from the Faculty of Arts and Education, Charles Sturt University, Australia, and the Schools of Health Sciences and Education at the University of Iceland, Iceland. We thank our U.S. colleagues Kelly Farquharson, Holly Storkel, Marie Ireland, A. Lynn Williams, Rebecca J. McCauley, Peter Flipsen Jr., and Jonathan L. Preston for identifying data sources and/or providing helpful insights on this review article.

References

*Articles included in review.

*__Arlt, P. B., & Goodban, M. T.__ (1976). A comparative study of articulation acquisition as based on a study of 240 normals, aged three to six. *Language, Speech, and Hearing Services in Schools, 7*(3), 173–180. https://doi.org/10.1044/0161-1461.0703.173

*__Bankson, N. W., & Bernthal, J. E.__ (1990). *Bankson–Bernthal Test of Phonology*. Pro-Ed.

*__Bankson, N. W., & Bernthal, J. E.__ (2019). *Bankson–Bernthal Test of Phonology–Second Edition*. Pro-Ed.

Bunta, F., Fabiano-Smith, L., Goldstein, B., & Ingram, D. (2009). Phonological whole-word measures in 3-year-old bilingual children and their age-matched monolingual peers. *Clinical Linguistics & Phonetics, 23*(2), 156–175. https://doi.org/10.1080/02699200802603058

Buros Center for Testing. (2019). *Test reviews online*. University of Nebraska–Lincoln. https://marketplace.unl.edu/buros/

Colquhoun, H. L., Levac, D., O'Brien, K. K., Straus, S., Tricco, A. C., Perrier, L., Kastner, M., & Moher, D. (2014). Scoping reviews: Time for clarity in definition, methods, and reporting. *Journal of Clinical Epidemiology, 67*(12), 1291–1294. https://doi.org/10.1016/j.jclinepi.2014.03.013

*__Dodd, B. J., Hua, Z., Crosbie, S., Holm, A., & Ozanne, A.__ (2006). *Diagnostic Evaluation of Articulation and Phonology*. Pearson.

Edwards, J., & Beckman, M. E. (2008). Methodological questions in studying consonant acquisition. *Clinical Linguistics & Phonetics, 22*(12), 937–956. https://doi.org/10.1080/02699200802330223

Eisenberg, S. L., & Hitchcock, E. R. (2010). Using standardized tests to inventory consonant and vowel production: A comparison of 11 tests of articulation and phonology. *Language, Speech, and Hearing Services in Schools, 41*(4), 488–503. https://doi.org/10.1044/0161-1461(2009/08-0125)

Fabiano-Smith, L. (2019). Standardized tests and the diagnosis of speech sound disorders. *Perspectives of the ASHA Special Interest Groups, 4*(1), 58–66. https://doi.org/10.1044/2018_PERS-SIG1-2018-0018

Fabiano-Smith, L., & Goldstein, B. A. (2010). Early-, middle-, and late-developing sounds in monolingual and bilingual children: An exploratory investigation. *American Journal of Speech-Language Pathology, 19*(1), 66–77. https://doi.org/10.1044/1058-0360(2009/08-0036)

Farquharson, K. (2019). It might not be "just artic": The case for the single sound error. *Perspectives of the ASHA Special Interest Groups, 4*(1), 76–84. https://doi.org/10.1044/2018_PERS-SIG1-2018-0019

Flipsen, P., Jr., & Ogiela, D. A. (2015). Psychometric characteristics of single-word tests of children's speech sound production. *Language, Speech, and Hearing Services in Schools, 46*(2), 166–178. https://doi.org/10.1044/2015_LSHSS-14-0055

Friberg, J. C. (2010). Considerations for test selection: How do validity and reliability impact diagnostic decisions? *Child Language Teaching and Therapy, 26*(1), 77–92. https://doi.org/10.1177/0265659009349972

*__Fudala, J. B.__ (2000). *Arizona Articulation Proficiency Scale–Third Edition (Arizona-3)*. Western Psychological Services.

*__Fudala, J. B., & Stegall, S.__ (2017). *Arizona Articulation and Phonology Scale–Fourth Revision (Arizona-4)*. Western Psychological Services.

Gillon, G. T. (2004). *Phonological awareness: From research to practice*. Guildford Press.

*__Glaspey, A. M.__ (2019). *Glaspey Dynamic Assessment of Phonology*. Academic Therapy Publications.

*__Goldman, R., & Fristoe, M.__ (2015). *Goldman-Fristoe Test of Articulation–Third Edition*. Pearson Clinical.

Gubiani, M. B., Pagliarin, K. C., & Keske-Soares, M. (2015). Tools for the assessment of childhood apraxia of speech [Instrumentos para avaliação de apraxia de fala infantil]. *CoDAS: Communication Disorders, Audiology and Swallowing, 27*(6), 610–615. https://doi.org/10.1590/2317-1782/20152014152

Hedrick, D. L., Prather, E. M., & Tobin, A. R. (1975). *Sequenced Inventory of Communication Development (SICD)*. University of Washington Press.

IBM. (2019). *Statistical Program for the Social Sciences (Version 26.0.0)*.

Ingram, D., & Ingram, K. D. (2001). A whole-word approach to phonological analysis and intervention. *Language, Speech, and Hearing Services in Schools, 32*(4), 271–283. https://doi.org/10.1044/0161-1461(2001/024)

International Phonetic Association. (2018). *The International Phonetic Alphabet (revised to 2018)*. https://www.internationalphoneticassociation.org/IPAcharts/IPA_Doulos_2018_full.pdf

Ireland, M., & Conrad, B. J. (2016). Evaluation and eligibility for speech-language services in schools. *Perspectives of the ASHA*

Special Interest Groups, 1(16), 78–90. https://doi.org/10.1044/persp1.SIG16.78
Ireland, M., McLeod, S., Farquharson, K., & Crowe, K. (2020). *Evaluating children in U.S. public schools with speech sound disorders: Considering federal and state laws, guidance, and research. Topics in Language Disorders*. https://doi.org/10.1097/TLD.0000000000000226
Karlsson, H. B., Shriberg, L. D., Flipsen, P., Jr., & McSweeny, J. L. (2002). Acoustic phenotypes for speech-genetics studies: Towards an acoustic marker for residual /s/ distortions. *Clinical Linguistics & Phonetics, 16*(6), 403–424. https://doi.org/10.1080/02699200210128954
Kent, R. D. (1992). The biology of phonological development. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 65–90). York Press.
Kirk, C., & Vigeland, L. (2014). A psychometric review of norm-referenced tests used to assess phonological error patterns. *Language, Speech, and Hearing Services in Schools, 45*(4), 365–377. https://doi.org/10.1044/2014_LSHSS-13-0053
Krueger, B. I. (2019). Eligibility and speech sound disorders: Assessment of social impact. *Perspectives of the ASHA Special Interest Groups, 4*(1), 85–90. https://doi.org/10.1044/2018_PERS-SIG1-2018-0016
*__Lowe, R. J.__ (2000). *Assessment Link Between Phonology and Articulation–Revised*. ALPHA Speech & Language Resources.
Macrae, T. (2017). Stimulus characteristics of single-word tests of children's speech sound production. *Language, Speech, and Hearing Services in Schools, 48*(4), 219–233. https://doi.org/10.1044/2017_LSHSS-16-0050
McCauley, R. J., & Strand, E. A. (2008). A review of standardized tests of nonverbal oral and speech motor performance in children. *American Journal of Speech-Language Pathology, 17*(1), 81–91. https://doi.org/10.1044/1058-0360(2008/007)
McCauley, R. J., & Swisher, L. (1984). Psychometric review of language and articulation tests for preschool children. *Journal of Speech and Hearing Disorders, 49*(1), 34–42. https://doi.org/10.1044/jshd.4901.34
McCormack, J., McLeod, S., & Crowe, K. (2019). What do children with speech sound disorders think about their talking? *Seminars in Speech and Language, 40*(02), 94–104. https://doi.org/10.1055/s-0039-1677760
McCormack, J., McLeod, S., McAllister, L., & Harrison, L. J. (2010). My speech problem, your listening problem, and my frustration: The experience of living with childhood speech impairment. *Language, Speech, and Hearing Services in Schools, 41*(4), 379–392. https://doi.org/10.1044/0161-1461(2009/08-0129)
McLeod, S. (2004). Speech pathologists' application of the ICF to children with speech impairment. *International Journal of Speech-Language Pathology, 6*(1), 75–81. https://doi.org/10.1080/14417040410001669516
McLeod, S. (2020). Intelligibility in Context Scale: Cross-linguistic use, validity, and reliability. *Speech, Language and Hearing, 23*(1), 9–16. https://doi.org/10.1080/2050571X.2020.1718837
McLeod, S., & Baker, E. (2014). Speech-language pathologists' practices regarding assessment, analysis, target selection, intervention, and service delivery for children with speech sound disorders. *Clinical Linguistics & Phonetics, 28*(7–8), 508–531. https://doi.org/10.3109/02699206.2014.926994
McLeod, S., & Baker, E. (2017). *Children's speech: An evidence-based approach to assessment and intervention*. Pearson Education.
McLeod, S., & Crowe, K. (2018). Children's consonant acquisition in 27 languages: A cross-linguistic review. *American Journal of Speech-Language Pathology, 27*(4), 1546–1571. https://doi.org/10.1044/2018_AJSLP-17-0100
McLeod, S., Harrison, L. J., & McCormack, J. (2012). The Intelligibility in Context Scale: Validity and reliability of a subjective rating measure. *Journal of Speech, Language, and Hearing Research, 55*(2), 648–656. https://doi.org/10.1044/1092-4388(2011/10-0130)
McLeod, S., & Verdon, S. (2014). A review of 30 speech assessments in 19 languages other than English. *American Journal of Speech-Language Pathology, 23*(4), 708–723. https://doi.org/10.1044/2014_AJSLP-13-0066
McLeod, S., van Doorn, J., & Reed, V. A. (2001). Consonant cluster development in two-year-olds: General trends and individual difference. *Journal of Speech, Language, and Hearing Research, 44*(5), 1144–1171. https://doi.org/10.1044/1092-4388(2001/090)
McLeod, S., Verdon, S., Bowen, C., & International Expert Panel on Multilingual Children's Speech. (2013). International aspirations for speech-language pathologists' practice with multilingual children with speech sound disorders: Development of a position paper. *Journal of Communication Disorders, 46*(4), 375–387. https://doi.org/10.1016/j.jcomdis.2013.04.003
McLeod, S., Verdon, S., & International Expert Panel on Multilingual Children's Speech. (2017). Tutorial: Speech assessment for multilingual children who do not speak the same language(s) as the speech-language pathologist. *American Journal of Speech-Language Pathology, 26*(3), 691–708. https://doi.org/10.1044/2017_AJSLP-15-0161
Nelson, L. K., & Bauer, H. R. (1991). Speech and language production at age 2. *Journal of Speech and Hearing Research, 34*(4), 879–892. https://doi.org/10.1044/jshr.3404.879
*__Pearson, B. Z., Velleman, S. L., Bryant, T. J., & Charko, T.__ (2009). Phonological milestones for African American English–speaking1 children learning mainstream American English as a second dialect. *Language, Speech, and Hearing Services in Schools, 40*(3), 229–244. https://doi.org/10.1044/0161-1461(2008/08-0064)
Poole, I. (1934). The genetic development of consonant sounds in the speech of children. *The Elementary English Review, 11*, 159–161.
Porter, J. H., & Hodson, B. W. (2001). Collaborating to obtain phonological acquisition data for local schools. *Language, Speech, and Hearing Services in Schools, 32*(3), 165–171. https://doi.org/10.1044/0161-1461%282001/015%29
Powell, T. W., & Miccio, A. W. (1996). Stimulability: A useful clinical tool. *Journal of Communication Disorders, 29*(4), 237–253. https://doi.org/10.1016/0021-9924(96)00012-3
*__Prather, E. M., Hedrick, D. L., & Kern, C. A.__ (1975). Articulation development in children aged two to four years. *Journal of Speech and Hearing Disorders, 40*(2), 179–191. https://doi.org/10.1044/jshd.4002.179
Preston, J. L., McCabe, P., Tiede, M., & Whalen, D. H. (2019). Tongue shapes for rhotics in school-age children with and without residual speech errors. *Clinical Linguistics & Phonetics, 33*(4), 334–348. https://doi.org/10.1080/02699206.2018.1517190
Rvachew, S., & Nowak, M. (2001). The effect of target-selection strategy on phonological learning. *Journal of Speech, Language, and Hearing Research, 44*(3), 610–623. https://doi.org/10.1044/1092-4388(2001/050)
Rvachew, S., Rafaat, S., & Martin, M. (1999). Stimulability, speech perception skills, and the treatment of phonological disorders. *American Journal of Speech-Language Pathology, 8*(1), 33–43. https://doi.org/10.1044/1058-0360.0801.33

Ryan, C. (2013). *Language use in the United States: 2011*. U.S. Census Bureau.
Sander, E. K. (1972). When are speech sounds learned? *Journal of Speech and Hearing Disorders, 37*(1), 55–63. https://doi.org/10.1044/jshd.3701.55
Shriberg, L. D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech and Hearing Research, 36*(1), 105–140. https://doi.org/10.1044/jshr.3601.105
Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., & Wilson, D. L. (1997a). The percentage of consonants correct (PCC) metric: Extensions and reliability data. *Journal of Speech, Language, and Hearing Research, 40*(4), 708–722. https://doi.org/10.1044/jslhr.4004.708
Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., & Wilson, D. L. (1997b). The Speech Disorders Classification System (SDCS): Extensions and lifespan reference data. *Journal of Speech, Language, and Hearing Research, 40*(4), 723–740. https://doi.org/10.1044/jslhr.4004.723
Shriberg, L. D., Kent, R. D., McAllister, T., & Preston, J. L. (2018). *Clinical phonetics* (5th ed.). Pearson.
Shriberg, L. D., & Kwiatkowski, J. (1982). Phonological disorders III: A procedure for assessing severity of involvement. *Journal of Speech and Hearing Disorders, 47*(3), 256–270. https://doi.org/10.1044/jshd.4703.256
Skahan, S. M., Watson, M., & Lof, G. L. (2007). Speech-language pathologists' assessment practices for children with suspected speech sound disorders: Results of a national survey. *American Journal of Speech-Language Pathology, 16*(3), 246–259. https://doi.org/10.1044/1058-0360(2007/029)
Smit, A. B. (1986). Ages of speech sound acquisition: Comparisons and critiques of several normative studies. *Language, Speech, and Hearing Services in Schools, 17*(3), 175–186. https://doi.org/10.1044/0161-1461.1703.175
Smit, A. B. (1993a). Phonologic error distributions in the Iowa–Nebraska articulation norms project: Consonant singletons. *Journal of Speech and Hearing Research, 36*(3), 533–547. https://doi.org/10.1044/jshr.3603.533
Smit, A. B. (1993b). Phonologic error distributions in the Iowa–Nebraska articulation norms project: Word-initial consonant clusters. *Journal of Speech and Hearing Research, 36*(5), 931–947. https://doi.org/10.1044/jshr.3605.931
*__Smit, A. B., Hand, L., Freilinger, J. J., Bernthal, J. E., & Bird, A.__ (1990). The Iowa Articulation Norms Project and its Nebraska replication. *Journal of Speech and Hearing Disorders, 55*(4), 779–798. https://doi.org/10.1044/jshd.5504.779
Stewart, S. R., & Weybright, G. (1980). Articulation norms used by practicing speech-language pathologists in Oregon. *Journal of Speech and Hearing Disorders, 45*(1), 103–111. https://doi.org/10.1044/jshd.4501.103
Stoel-Gammon, C. (1985). Phonetic inventories, 15–24 months: A longitudinal study. *Journal of Speech and Hearing Research, 28*(4), 505–512. http://doi.org/10.1044/jshr.2804.505
Stoel-Gammon, C. (1987). Phonological skills of 2-year-olds. *Language, Speech, and Hearing Services in Schools, 18*(4), 323–329. http://doi.org/10.1044/0161-1461.1804.323
Storkel, H. L. (2019a). Using developmental norms for speech sounds as a means of determining treatment eligibility in schools. *Perspectives of the ASHA Special Interest Groups, 4*(1), 67–75. https://doi.org/10.1044/2018_PERS-SIG1-2018-0014
Storkel, H. L. (2019b). Clinical forum prologue: Speech sound disorders in schools: Who qualifies? *Perspectives of the ASHA Special Interest Groups, 4*(1), 56–57. https://doi.org/10.1044/2018_PERS-SIG1-2018-0025
*__Templin, M. C.__ (1957). *Certain language skills in children: Their development and interrelationships*. University of Minnesota, The Institute of Child Welfare.
The Informed SLP. (2018, December, 30). *That one time a journal article on speech sounds broke the SLP Internet* [Blog post]. https://www.theinformedslp.com/how-to/that-one-time-a-journal-article-on-speech-sound-norms-broke-the-slp-internet
Watson, M. M., & Terrell, P. (2012). Longitudinal changes in phonological whole-word measures in 2-year-olds. *International Journal of Speech-Language Pathology, 14*(4), 351–362. https://doi.org/10.3109/17549507.2012.663936
*__Wellman, B., Case, I., Mengert, I., & Bradbury, D.__ (1931). Speech sounds by young children. *University of Iowa Studies: Child Welfare*, *5*(2), 82.
*__Woodcock, R. W., Camarata, S., & Camarata, M.__ (2019). *Woodcock–Camarata Articulation Battery (WCAB)*. Schoolhouse Educational Services.