Abstract:

Purpose

This article examines the need for increased research into the prelinguistic trajectory of childhood apraxia of speech (CAS). We discuss the significant gains made in the early identification of disorders such as autism spectrum disorder (ASD), Fragile X syndrome, and Rett syndrome that have resulted through the study of early (i.e., prelinguistic) developmental behaviours of infants and toddlers at-risk for these disorders. We suggest that notable gains in understanding CAS could be made by increasing investigative focus on infants and toddlers later diagnosed with CAS or who are at-risk for it (i.e., have an older sibling diagnosed with the disorder).

Conclusion

Currently, there are few studies to guide clinical decision making for infants and toddlers who may have CAS. To address this gap, we present a call to action with recommendations for researchers and clinicians. We recommend more retrospective investigative designs be conducted, inclusive of retrospective parent questionnaires and retrospective home-video analysis, as well as prospective longitudinal studies of at-risk infants. We suggest that studies not be limited to exploring an affected infant’s vocal output, but that efforts be made to acquire a broad view of an affected infant’s early developmental trajectory (e.g., social skills, eye gaze, and imitative skills). A more comprehensive understanding of CAS will guide clinicians not only in identification of the disorder, but will inform treatment decisions as well.

Response to Reviewers:

To: Dr. Peter Meulenbroek and Reviewers
We are grateful for the careful review and additional comments for improving our manuscript “The Need for Increased Study of Infants and Toddlers Later Diagnosed with Childhood Apraxia of Speech.” In the space below, we have identified the reviewers’ comments and provided our response. We look forward to hearing additional feedback.
Sincerely,
Megan Overby and Chantelle Highman
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I would just change "developmental trajectory" to "early developmental" trajectory on line 82 page 4.

RESPONSE: Corrected.
We respectfully submit the attached manuscript, The Need for Increased Study of Infants and Toddlers Later Diagnosed with Childhood Apraxia of Speech, for review and possible publication in the SIG 2 Neurogenic Communication Disorders division of the ASHA Perspectives journal. We confirm that this work has not been published, or is under consideration for publication, elsewhere. The purpose of this viewpoint article is to examine the importance of clinical research with infants and toddlers later diagnosed with childhood apraxia of speech (CAS). We review the substantial gains made in the early identification of autism spectrum disorder (ASD) via retrospective and prospective study of infants and toddlers at risk for the disorder and suggest that similar gains could be possible in early identification of CAS with an energized research focus on infants and toddlers at risk for CAS. We expect this topic to be of interest to the readership of the journal.

We have tried to adhere to the guidelines provided in Instructions for Authors. The current word count for the manuscript is 4485, inclusive of the abstract, text, and references.

Thank you for your consideration. We look forward to your response and comments.

Sincerely,

Megan Overby and Chantelle Highman
The Need for Increased Study of Infants and Toddlers Later Diagnosed with Childhood Apraxia of Speech

Megan Overby and Chantelle Highman

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Author Note

Conflict of Interest Statement: We have no known conflicts of interest to disclose.

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Phone: 402-960-2828
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Purpose: This article examines the need for increased research into the prelinguistic trajectory of childhood apraxia of speech (CAS). We discuss the significant gains made in the early identification of disorders such as autism spectrum disorder (ASD), Fragile X syndrome, and Rett syndrome that have resulted through the study of early (i.e., prelinguistic) developmental behaviors of infants and toddlers at-risk for these disorders. We suggest that notable gains in understanding CAS could be made by increasing investigative focus on infants and toddlers later diagnosed with CAS or who are at-risk for it (i.e., have an older sibling diagnosed with the disorder).

Conclusion: Currently, there are few studies to guide clinical decision making for infants and toddlers who may have CAS. To address this gap, we present a call to action with recommendations for researchers and clinicians. We recommend more retrospective investigative designs be conducted, inclusive of retrospective parent questionnaires and retrospective home-video analysis, as well as prospective longitudinal studies of at-risk infants. We suggest that studies not be limited to exploring an affected infant’s vocal output, but that efforts be made to acquire a broad view of an affected infant’s early developmental trajectory (e.g., social skills, eye gaze, and imitative skills). A more comprehensive understanding of CAS will guide clinicians not only in identification of the disorder, but will inform treatment decisions as well.

Key Words: apraxia, infant, research
The Need for Increased Study of Infants and Toddlers Later Diagnosed with Childhood Apraxia of Speech

Childhood apraxia of speech (CAS) is typically considered a neurobiological disorder of speech praxis motor control and/or planning (American Speech-Language-Hearing Association [ASHA], n.d.). Prevalence in the general population is estimated to be 0.1% to 0.2% (Shriberg et al., 1997). Diverse symptomatology of the disorder suggests it is not a single or unitary disorder, but possibly a ‘symptom complex’ (a diversity of deficits varying in severity but consistently present) (Nijland et al., 2015; Velleman & Strand, 1994) resulting from independent genetic and environmental factors that, in combination, determine an individual’s particular phenotypic expression (Miller et al., 2019) and accounts in part for some of the inconsistency of the presentation of the disorder as the child matures. Reported phenotypic manifestations of CAS in preschool and school-age children have included, for example, difficulty sequencing sounds and syllables (ASHA, n.d.), inconsistent speech sound production (Iuzzini-Seigel et al., 2017), timing and prosodic errors (Kopera & Grigos, 2020; Shriberg et al., 2017), and impaired literacy skills (Lewis et al., 2004; Miller et al., 2019; Gillon & Moriarty, 2007). Some children with CAS have morphological difficulties (such as errors on pronouns, auxiliary verbs, and irregular past tense verbs) which cannot be directly attributed to speech motor planning deficits or sound production errors (Ekelman & Aram, 1983; McNeill & Gillon, 2013; Murray et al., 2018). Unambiguous identification of the disorder is challenging because CAS manifests differently as a child ages and/or matures (McCabe et al., 1998; Terband et al., 2009). For example, infants and toddlers with CAS appear to have little vowel variation while older children demonstrate a high incidence of vowel errors (Davis & Velleman, 2000); although syllable segregation is one of 10 behaviors suggestive of CAS in children (Shriberg et al., 2011), it can only be present in children of
sufficient age and expressive maturity to produce multisyllabic productions. Definitive diagnosis of CAS is further complicated because speech characteristics of CAS may overlap with those of other speech sound disorders (Allison et al., 2020).

Childhood apraxia of speech (CAS) has significant negative impacts on the child, family and community. For example, in a sample of 192 parents of children with CAS, parents reported concerns about their child’s poor social communication skills and social wellbeing, as well as perceived limitations in their child’s ability to read, write, and in memory function (Teverovsky et al., 2009). Other investigators have documented impaired reading, spelling, and academic skills in individuals with persistent severe speech sound disorder (Carrigg et al., 2016) or history of suspected CAS (Lewis et al., 2004; Lewis et al., 2018), with specific deficits in phonological awareness. The functional impact of these social and academic problems is particularly distressing for affected children and their families, and the need for intensive therapy to address these issues can be associated with significant costs (financial and time) for families and governments.

Despite the significant personal and social impact of CAS, extant research guiding clinicians in the identification of CAS in the prelinguistic period is limited. Early identification of the disorder would be beneficial, possibly reducing its negative impacts through the provision of early treatment. In this article, we explain it is possible to use research to make progress in increasing the accuracy and confidence of early identification of CAS as has been done in the study of other disorders, such as autism spectrum disorder (ASD). We assert that a call to action for a similarly focused research agenda on the prelinguistic period in CAS by investigators in the profession of speech-language pathology could enable clinicians and researchers to obtain a clearer understanding of potential early markers of CAS, ultimately describing an early
developmental trajectory of the disorder, thereby improving services and outcomes for this population.

Early Detection of CAS

Even though CAS is known to present differently at different ages, currently a common restriction in the study of clinical aspects of CAS has been to limit study of the disorder only to children and adults capable of producing either meaningful linguistic utterances (Shriberg et al., 2017) or to those who have a ‘moderate inventory of sounds’ (ASHA, 2007, p. 5). This approach to the study of CAS reflects difficulties associated with identifying the disorder early in the child’s life (e.g., infancy and toddlerhood) as well as the practicalities of undertaking longitudinal research with such a low-incidence disorder. Nevertheless, there have been significant research developments that have expanded our understanding of the disorder in older children and adults, including speech features such as extended pause duration (Shriberg et al., 2017) and polysyllabic production inaccuracy (Murray et al., 2015). Moreover, treatment research has highlighted the efficacy of speech motor-based treatments such as Rapid Syllable Transition Treatment (Murray et al., 2015) and Dynamic Temporal and Tactile Cueing (e.g., Strand & Debertine, 2000) for children with CAS.

However, because speech development begins long before the first word is spoken (McCune & Vihman, 2001; Newman et al., 2016; Stoel-Gammon & Cooper, 1984), one would expect to see evidence of motor programming/planning deficits in an affected infant’s earliest speech-like vocalizations (Highman et al., 2012; Maassen, 2002). Core deficits in the speech motor control system would necessarily restrict the infant’s protosyllabary, with potential impacts on the process of subsequent vocal learning (Haesler et al., 2007; Pytte & Suthers,
The continuity of prelinguistic vocal development with later speech development (Oller et al., 1999) demonstrates the potential utility of the prelinguistic period in the study of CAS.

One approach to informing the prelinguistic period of infants at-risk for CAS is to build the knowledge base of the genetic etiology of CAS and refine our understanding of which genes or chromosomal regions of interest may suggest CAS. Although recent genome research offers multiple new gene variants associated with the disorder (Hildebrand et al., 2020), few known or putative causal genes have been identified to date (Carrigg et al., 2016; Peter et al., 2016). A second approach is to examine the trajectory of speech sound development across time for infants later identified with CAS (Highman et al., 2008), an approach that is of interest to clinicians (Randazzo, 2019) and has the potential to assist in the very early detection of the disorder (Allison et al., 2020). This approach to the study of CAS could open new paths of treatment techniques, much like increased inquiry into the developmental trajectory of disorders such as ASD, Fragile X syndrome, and Rett syndrome led to suggestions for their early identification and, in the case of ASD, subsequent toddler treatment protocols. However, very few studies exploring possible early manifestations of CAS have been published.

**Early Detection of Developmental Disorders**

The early development of infants with disorders such as ASD, Fragile X syndrome, and Rett syndrome has been explored through retrospective parent reports, retrospective home-video analysis, and prospective longitudinal study of at-risk infants and toddlers (i.e., siblings of affected children). There is now compelling evidence that symptoms of these disorders are present long before many children with such a disorder are clinically referred. Behavioral signs of ASD can now be detected by 2 years of age, with notable and identifiable signs of the disorder found even as early as 1 year old (Paul et al., 2011; Roche et al., 2018; Zwaigenbaum et al., 2000).
2013). Detection has come from prelinguistic study of infants later identified with ASD across a diverse range of behaviors, such as motor development (e.g., Ozonoff, Young et al., 2008), self-regulation and temperament (e.g., De Giacomo & Fombonne, 1998), repetitive interest and behaviors (e.g., Ozonoff, Macari et al., 2008), language and cognition (e.g., Rogers & DiLalla, 1990), and social communication (e.g., Adrein et al., 1993). Developmental profiles of infants and toddlers later diagnosed with Fragile X syndrome have revealed early delays in sensory-motor features (Baranek et al., 2005; Zhang et al., 2017), socio-communicative skills (Marschik et al., 2014), and babbling (Belardi et al., 2017), suggesting pervasive delays appear earlier than previously thought (Roberts et al., 2016). For girls with Rett syndrome, early infant studies have revealed atypicalities before the age of two (Kerr & Stephenson, 1986; Bartl-Pokorny et al., 2013) and even in the first months of life (Einspieler et al., 2016), refuting a long-held belief that features of the disorder appear only after a period of typical early development. Findings such as these have decreased the mean age of diagnosis for classic Rett syndrome to around 2½ years old, although there is a need for additional study to acquire a comprehensive description of the syndrome’s early development (Marschik et al., 2018).

Prelinguistic investigation of some developmental disorders has led to standardized measures of a disorder’s early development or general trajectories of its likely emergence (Zwaigenbaum et al., 2013) and in some cases have led to clear changes to policy. The American Academy of Pediatrics (AAP), for example, has updated practice guidelines to screen 18- and 24-month old toddlers for ASDs (Zwaigenbaum et al., 2015). Recent Australian national autism guidelines also support early developmental screening and surveillance (Whitehouse et al., 2018). No such AAP recommendations currently exist for Fragile X or Rett syndromes because standardized trajectories of a disorder’s early development requires extensive testing.
across hundreds of affected and/or at-risk infants within a diverse body of researchers, a standard not yet met for these syndromes.

Research on the Prelinguistic Period in CAS

There is comparatively little contemporaneous research on the prelinguistic behaviors of infants and toddlers later identified with CAS (Table 1). Fewer than 40 infants later diagnosed with CAS or at-risk for the disorder have been studied and only 30 infants have been studied indirectly through parent questionnaire. Despite this small body of literature, results have been generally consistent in finding that the prelinguistic development of children who later are identified with CAS or are at-risk for CAS is notably different from that of typically developing children.

Many (41%-42%) parents of children later diagnosed with CAS recall that their child struggled to speak or had minimal speech (Teverovsky et al., 2009) and that babbling was reduced (Aziz et al., 2010; Highman et al., 2008), containing no apparent variegated syllable sequences (Highman et al., 2008). In one study, only 1 of 10 infants later diagnosed with CAS achieved a canonical babbling ratio ≥.15 between 7-12 months old (Overby et al., 2020). A limited phonetic inventory may be a possible red flag for CAS, specifically the acquisition of three or fewer consonants between 8-16 months, five or fewer consonants between 17-24 months of age, or acquiring the first consonant after age 1 year old (Overby & Caspari, 2015; Overby et al., 2019).

Results from a longitudinal investigation of infant siblings of children with CAS (Highman et al., 2013) confirm the possibility that a significantly restricted phonetic inventory and lack of consonant-vowel babble may indicate pre-linguistic CAS. One infant sibling later
diagnosed with CAS produced no consonants at 9 months of age, only three consonants at 12 months of age (/d/, /b/, and /m/), and limited vowels, in the context of strong communicative intent and use of gestures.

**Why Early Identification?**

Early diagnosis of a communication disorder takes advantage of brain neuroplasticity, thereby creating opportunities for children to benefit more fully from intervention (Bruder, 2010; Zwaigenbaum et al., 2013). Early intervention can empower families and impact parent self-efficacy, which has a significant impact on a child’s early learning and development (Bruder, 2010). Early intervention programs such as the Early Start Denver Model have demonstrated 18-30 month old toddlers with an early diagnosis of ASD experience more growth in IQ and adaptive behavior than when receiving community intervention (Dawson et al., 2010), even showing evidence of EEG normalization of cortical activation (Dawson et al., 2012). Furthermore, recent clinical trials of interventions commenced during infancy for children showing early signs of autism have reported preliminary efficacy on parent-reported communication skills (Whitehouse et al., 2019). Based on a review of 700 references on ASD early intervention, a working group for the AAP concluded that early intervention for ASD should begin as early as possible (i.e., before age 3; Zwaigenbaum et al., 2015), but clearly implementation of any such recommendation requires early diagnosis or identification of early risk features.

There are no early intervention studies in CAS, although a one-group quasi-experimental 10-week investigation of 32 children with possible CAS (Mean age = 29.7; SD = 3.44) reported post-test gains in children’s sound repertoires and imitative skills (Kiesewalter et al., 2017). A notable component of the therapy approach was parent education and parent-child activities.
focused on imitation of word shapes and sounds, suggesting that this therapeutic strategy is an area worthy of further investigation. Other researchers propose therapy techniques for infants and young toddlers to include encouraging vocalizations and communication more broadly, expanding phonetic inventory, and the use of various syllable shapes (Davis & Velleman, 2000; Fish, 2016). A Babble Boot Camp conducted between 2-24 months for infants with classic glactosemia revealed an increase in the infants’ babbling and meaningful speech when parents engaged in daily reinforcement of their infant’s babbling, expanding utterances, and shared with their infant in joint book reading (Peter et al., 2020). Shriberg and colleagues (2011) reported that children with glactosemia have higher prevalence rates of CAS (24%) compared to the general population (0.1-0.2%). Despite these promising reports, the general paucity of experimental intervention studies with infants and toddlers with suspected CAS is likely due to the lack of any valid developmental profiles or consensus regarding the early behavioral presentation of the disorder.

A Call to Action

We propose the following actions could provide a more comprehensive perspective of CAS and potentially lead to its earlier diagnosis and treatment in affected individuals. First, we believe there needs to be an increase in the publication of retrospective investigative designs, including retrospective parent questionnaires and retrospective study of infant behavior via home-videos. Moreover, prospective longitudinal studies of at-risk infants (i.e., those infants with an older affected sibling) are crucial and will assist in the development of longitudinal maps showing trajectories of symptom emergence. Second, quantitative and qualitative studies are needed to address not only an infant’s vocal output, but multiple aspects of an affected infant’s early development, such as, for example, parents’ recall of details about their child’s early
feeding, sensory and motor development, social skills and self-regulation, and first sounds/words. Other areas of need include early vowel development, vocal and non-vocal imitative skills, eye gaze, and social interaction/engagement. Exploring all aspects of early communication, social skills, gross motor, and fine motor development will help provide a comprehensive picture of the trajectory of the disorder. Third, once a critical mass of data have been collected, screening criteria with high levels of sensitivity and specificity should emerge suitable for use by physicians and other health professionals, similar to what has occurred for ASD. Early referrals by physicians and other health professionals to speech-language pathologists skilled in their understanding of CAS will aid in early identification and early treatment for infants and toddlers. Fourth, ultimately there will need to be treatment studies focused on the infant and toddler population. Compared to preschool and school-aged children, these very young children have quite different needs and skills in attention, memory, and learning style that will impact the effectiveness of the treatment they receive.

**Recommendations for Clinicians**

Clinicians and researchers can work together in these endeavours. Until more is known about the genetic influences of CAS, clinicians are advised to actively monitor younger siblings of children with CAS, as well as take note of infants and toddlers displaying any ‘red flags’ (e.g., lack of canonical babbling by 10 months, absence of any consonants by 12 months, less than five consonants by 2 years of age) (Overby & Caspari, 2015; Overby et al., 2019). Getting the balance ‘right’ for younger siblings, in particular, can be difficult – clinicians do not want to cause undue worry for families, given that many siblings may go on to have no issues with speech and language development. However, parents may want to be proactive in identifying any potential speech and/or language disorder expressed by these younger siblings. Questionnaires
focusing on early communication development, in particular those that ask about the emergence
of canonical syllables and the types of consonants used by the infant or toddler, should be
considered [e.g. Communication and Symbolic Behavior Scales, (Wetherby & Prizant, 2002);
Infant Monitor of vocal Production, (Moore & Colyvas, 2008)].

Conclusion

In this article, we discuss how an energized research and clinical focus by the profession
of speech-language pathology on infant and toddler early vocalizations can lead to progress in
understanding and treating CAS. Due to the limited literature on pre-linguistic CAS, there is little
evidence to guide diagnosis of CAS in infants and toddlers until the child has sufficient speech
(or moderate inventory of sounds) to allow an examination for features of the disorder. Until
such time as a reliable predictor/s is/are identified, clinicians should use their theoretical and
clinical knowledge to carefully observe/monitor children displaying those differences in early
vocalizations reported in the literature.


STUDY OF INFANTS AND TODDLERS WITH CAS


Table 1
Published Research on Pre-linguistic Behaviours of Infants At-Risk or Later Identified With Childhood Apraxia of Speech

<table>
<thead>
<tr>
<th>First author and year of publication</th>
<th>Participants</th>
<th>Method</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highman et al. (2008)</td>
<td>60 parents of preschoolers</td>
<td>Questionnaire about infant development</td>
<td>Compared to TD, sCAS less vocal, less likely to babble; later emergence of first words</td>
</tr>
<tr>
<td></td>
<td>20 with children with suspected CAS (sCAS); mean age = 48 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 with children with Specific Language Impairment (SLI); mean age = 60 months</td>
<td></td>
<td>Compared to SLI, sCAS babbled less; later emergence of two-word combinations</td>
</tr>
<tr>
<td></td>
<td>20 TD; mean age = 61 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aziz et al. (2010)</td>
<td>30 Cairo-Egyptian Arabic-speaking preschoolers aged 4-6</td>
<td>Parent interviews about volubility of infants and toddlers</td>
<td>50% of parents of MPD children reported their child babbled little and with little phonetic diversity; only 30% of parents of TD infants did</td>
</tr>
<tr>
<td></td>
<td>10 with multiple phonological disorders (MPD)</td>
<td></td>
<td>First word emergence delayed in MPD and CAS groups</td>
</tr>
<tr>
<td></td>
<td>10 with CAS</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>10 typically developing (TD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highman et al. (2012)</td>
<td>9 children (3-4 years old) who had failed a screening at 9 months</td>
<td>Retrospective analysis of screening performance</td>
<td>Two participants with features consistent with CAS showed lower expressive language and infrequent babbling</td>
</tr>
<tr>
<td></td>
<td>21 TD children (3-4 years old)</td>
<td></td>
<td>One participant with features consistent with severe CAS showed frequent babbling</td>
</tr>
<tr>
<td>First author and year of publication</td>
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<td>Method</td>
<td>Main Findings</td>
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<tr>
<td>Highman et al. (2013)</td>
<td>8 infants (9-months old) with family history of CAS (at-risk group)</td>
<td>Evaluation of early speech and language via standardized questionnaires, inventories, and scales</td>
<td>At-risk siblings scored lower on expressive language, speech development, and fine motor skills</td>
</tr>
<tr>
<td></td>
<td>8 TD infants (9-months old)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overby and Caspari (2015)</td>
<td>4 preschoolers (36-54 months) later diagnosed with CAS (LCAS)</td>
<td>Retrospective home-video analysis</td>
<td>Significant differences in volubility of resonant productions</td>
</tr>
<tr>
<td></td>
<td>2 TD preschoolers (52-76 months)</td>
<td></td>
<td>Early sound productions restricted to Early Eight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LCAS preferred vowel and vowel-consonant syllable shapes</td>
</tr>
<tr>
<td>Overby et al. (2019)</td>
<td>10 infants LCAS</td>
<td>Retrospective home video analysis</td>
<td>LCAS had fewer canonical babbles, later canonical babbling onset, and less volubility than TD</td>
</tr>
<tr>
<td></td>
<td>4 infants later identified with a speech sound disorder (LSSD) other than CAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 TD infants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overby et al. (2019)</td>
<td>7 LCAS, 5 LSSD, 5 TD infants</td>
<td>Retrospective home video analysis</td>
<td>LCAS infants had less volubility, used fewer consonants, had less diverse consonant repertoire, and acquired consonants later than TD or LSSD</td>
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Learner Outcomes to “The Need for Increased Study of Infants and Toddlers Later Diagnosed with Childhood Apraxia of Speech”

As a result of this activity, the learner will be able to:
1. identify emerging ‘red flags’ associated with the prelinguistic development of children later diagnosed with childhood apraxia of speech, and
2. summarise key issues pertaining to the importance of research into the early developmental trajectory of children with childhood apraxia of speech