

This is the *Accepted Manuscript* of an article published by Springer Publishing in *Current Developmental Disorders Reports*, 2(3), 253-272 © 2015. The manuscript is reprinted here with permission from Springer Publishing, and the final publication is available at <https://doi.org/10.1007/s40474-015-0058-2>.

## **Outcome Measures in Developmental Speech Sound Disorders with a Motor Basis**

E. Kearney, F. Granata, Y. Yunusova, P. van Lieshout, D. Hayden, and A. Namasivayam

### **Elaine Kearney, BSc.**

Affiliation: University of Toronto, Department of Speech-Language Pathology, Speech  
Production Laboratory

Address: 160-500 University Avenue, Toronto, Ontario, M5G 1V7, Canada

Ph. Number: 1-416-801-1380

Email: [elaine.kearney@mail.utoronto.ca](mailto:elaine.kearney@mail.utoronto.ca)

### **Francesca Granata**

Affiliation: University of Toronto, Department of Speech-Language Pathology, Oral Dynamics  
Laboratory (ODL)

Address: 160-500 University Avenue, Toronto, Ontario, M5G 1V7, Canada

Ph. Number: 1-647-206-8557

Email: [francesca.granata@mail.utoronto.ca](mailto:francesca.granata@mail.utoronto.ca)

### **Yana Yunusova, Ph.D., SLP-CCC**

Affiliation: University of Toronto, Department of Speech-Language Pathology, Speech  
Production Laboratory

Address: 160-500 University Avenue, Toronto, Ontario, M5G 1V7, Canada

Ph. Number: 1-416-978-6890

Email: yana.yunusova@utoronto.ca

**Pascal van Lieshout, Ph. D.**

Affiliation: University of Toronto, Department of Speech-Language Pathology, Oral Dynamics

Laboratory (ODL)

Address: 160-500 University Avenue, Toronto, Ontario, M5G 1V7, Canada

Ph. Number: 1-416-978-8334

Email: p.vanlieshout@utoronto.ca

**Deborah Hayden, M.A., SLP-CCC, SLP (C)**

Affiliation: Research Director, The PROMPT Institute

Address: Santa Fe, NM, 1010C Marquez Place, Santa Fe, NM 87501, USA

Ph. Number: 1-505-466-7710 (Office); 1-505-310-0180 (Cell)

Email: deb@promptinstitute.com

**Aravind Namasivayam (Corresponding Author), Ph. D., SLP (C)**

Affiliation: University of Toronto, Department of Speech-Language Pathology

Address: 160-500 University Avenue, Toronto, Ontario, M5G 1V7, Canada

Ph. Number: 1-416-946-8552

Email: a.namasivayam@utoronto.ca

## **ABSTRACT**

One challenging area of Speech-Language Pathology is evaluating treatment change in children with speech sound disorder (SSD) with a motor basis. A clinician's knowledge and use of outcome measures following treatment is central to evidence-based practice. This narrative review evaluates the use of outcome measures to assess treatment change in motor-based SSDs. 7 databases were searched to identify studies reporting outcomes of treatment in SSDs between 1985 and 2014. 66 studies were identified for analysis, and reported outcome measures were categorized within the International Classification of Functioning, Disability and Health framework (ICF-CY). The majority of studies used perceptual methods (despite their limitations) to evaluate change at the impairment level of the ICF-CY and only three studies examined participation level factors. Accurate outcome measures that reflect the underlying deficit of the SSD as well as activity/participation level factors need to be implemented to document intervention success in this population.

**Keywords:** Speech sound disorder; motor speech; child; speech therapy; speech intervention; outcome measure.

## INTRODUCTION

Outcome measures in Speech-Language Pathology (SLP) are an essential component of assessing treatment efficacy, monitoring progress during intervention and planning future treatment [1]. The ASHA Scope of Practice in SLP has highlighted that a clinician's use of outcome measures is central to evidence-based practice [2]. Measurement of treatment change is of interest to both clinicians and researchers in SLP [3]. It is not always clear, however, from research literature how treatment change should be measured. Specifically, it is difficult to ascertain which behaviours should be measured and how measurement should be carried out.

The International Classification of Functioning, Disability and Health: Children and Youth Version (ICF-CY) provides a conceptual framework for measuring health and disability factors at individual and population levels [4]. The ICF-CY not only encompasses impairment level factors (body structure and function) but also considers the impact of these from a broader social perspective in terms of changes in children's activities and participation. In addition, potential environmental and personal factors that interfere with a child's ability to communicate and participate in their home and/or community are considered [4-10]. The ICF-CY has been applied broadly in many areas of SLP, including assessing performance of children with speech impairment, children who stutter and developmental language impairment [6, 11, 12].

One area of SLP that is challenging for clinicians and researchers to evaluate treatment change is children with SSD with a speech motor control component [1]. Their speech difficulties arise from an impairment of the neuromuscular and/or motor control system and lead to difficulty in planning and executing speech sounds [13]. Their speech is characterized by deletions, substitutions, and distortions, as well as inconsistent production in Childhood Apraxia of Speech (CAS) [13, 14]. Inconsistent productions and approximations of speech sounds are unreliably captured in perceptual judgement of speech due to the categorical nature of perception

[15]. For the purpose of this review, we will not include studies of SSDs arising from linguistically-based phonological issues. The primary focus, instead, is on phonetic-based articulation disorders arising from fine speech motor control issues, which include CAS, dysarthria and motor-speech disorders not otherwise specified [MSD-NOS; 13]. Children with these diagnoses are at increased risk for academic, social and emotional difficulties, and thus it is essential to monitor their speech performance during and subsequent to intervention, in order to assess intervention effectiveness [e.g. see 16].

To date there has been no comprehensive and critical examination of methodology relating to outcome measures in children with SSD and speech motor control issues. There is one review of literature published between 1990 and 2006 relating to standardized speech/non-speech motor performance tests in children [1] and a handful of individual reviews of standardized tests in this area [17, 18]. To address this lack of summary information, we carried out a narrative review of the literature (between 1985 and 2014) that examined the use of measures of treatment change beyond standardized assessments. The purpose of this review was to evaluate the use of outcome measures to assess treatment change in children with SSD with a motor basis.

## **METHOD**

### **Search Methodology**

Seven databases were searched for journal articles published between January 1, 1985 and December 31st, 2014 to identify intervention studies in children with SSD, including AMED, CINAHL, Embase, Medline (including In-Process and Other Non-Indexed Citations), PsycINFO, Scopus, and speechBITE. A preliminary search revealed that studies reporting motor speech treatment were first published in mid-1980; therefore, 1985 was selected as the start-date

for the search. Search terms relating to SSD were combined with terms relating to intervention. Specific keywords, syntax, and refinements varied depending on database search criteria and limits. The results were further narrowed using the age search limit: child (0-18 years). The search strategy used in Medline is shown in Table 1. The completed search identified a total of 4,029 articles.

#	Searches	Results
1	Articulation disorders/	1530
2	((speech or articulat\$ or phonetic\$) adj5 (disorder\$ or delay\$ or impair\$ or problem\$)).tw.	8439
3	1 or 2	9469
4	(therap* or interven*).mp.	2972678
5	Speech Therapy/	5181
6	4 or 5	2972678
7	3 and 6	2222
8	limit 7 to (yr="1985 -Current" and "all child (0 to 18 years)")	1127

**Table 1. Medline search strategy**

### Screening

Figure 1 illustrates the screening process. All references were exported to RefWorks (Version 2.0; RefWorks-Cos). Duplicate records were removed and references were screened by title and abstract. Abstracts were included if they measured treatment of developmental SSDs with a motor basis. Abstracts describing treatment in children with phonologically-based SSD were only included if the treatment studied was an articulation-based intervention. Exclusion criteria included: review articles, non-peer reviewed sources, test validity papers, assessment/

diagnostic papers, no treatment administration/ measurement studies, non-speech papers (e.g. hip dysplasia), language impairment, bilingualism, prosody/lexical deficits, phonological (linguistic-based) disorders, non-speech oro-motor exercises, alternative and augmentative communication (AAC), oral structural issues, traumatic brain injury/tumors, surgical-based intervention, and publications not in English. Articles were not rated for quality and/or levels of evidence (e.g. Oxford Centre for Evidence-Based Medicine – Levels of Evidence) [19] as the focus of the review was to examine the outcome measures used and not the efficacy of interventions reported. 250 articles were randomly selected and screened for acceptance by a second author. Krippendorff's alpha for reliability between two independent coders was 0.85. 66 articles were accepted for further analysis.

## **RESULTS**

### **Publication Year and Methodological Characteristics**

#### ***Publication Year***

The review identified 66 published studies (see Appendix A) that report outcome measures following treatment in children with SSD with a motor basis. The number of studies per year has varied over the last three decades, with a surge in publications in recent years (see Figure 2).

#### ***Participants***

Table 2 shows the number of participants by speech disorder and the number of studies evaluating treatment in these populations included in the review. With few exceptions, the majority of studies included less than 10 participants (81.8%). The age of participants ranged from 3; 0 to 16; 0 years.

<b>Disorder</b>	<b>Number of Participants</b>	<b>Number of Studies (%)</b>
Articulation Disorder:		
<i>Articulation Issues</i>	979	14 (21.2%)
<i>Residual/ Persistent</i>	77	15 (22.7%)
Phonological Disorder:		
<i>Unspecified</i>	31	3 (4.5%)
<i>Consistent</i>	13	2 (3.0%)
<i>Inconsistent</i>	18	3 (4.5%)
Mixed (Articulation & Phonological Disorder)	2	2 (3.0%)
Childhood Apraxia of Speech (CAS)	63	17 (25.8%)
Secondary to other Disorders:		
<i>Down Syndrome</i>	15	4 (6.1%)
<i>Cerebral Palsy</i>	44	9 (13.6%)
<b>Total</b>	<b>1242</b>	<b>66 (100%)</b>

**Table 2. Number of participants and number of studies by speech disorder.**

### ***Levels of Measurement***

Figure 3 shows the types of measures used according to the classification outlined in the ICF-CY [4]. The outcome measures in the review relate to two of the ICF-CY categories: impairment level (body function) and participation level. Body function measures included perceptual, physiologic and acoustic measures (e.g. rating scales, transcription measures, tongue-palate contact patterns, formant frequencies). The majority of studies (68.2%) use only



perceptual measures to document change following treatment. 25.8% of studies use instrumental (acoustic and physiological measures). Only three studies (4.5%) used participation level measures, ranging from a parent/ school questionnaire to standardized assessment, such as Focus on the Outcomes of Children Under Six FOCUS) and The Socialization Scale (from the Vineland Adaptive Behaviour Scales – Second Edition) [7, 20, 21]. See Appendix B for a detailed record of outcome measures used in the selected studies.

## **DISCUSSION**

This article provided a narrative review of studies reporting on outcome measures in treatment of children with motor-based SSDs. The review examined 66 treatment studies published between 1985 and 2014 (see Appendix A), and summarized publication year and methodological information from these studies. In the past 10 years, there has been a steady increase in publications under the scope of this review. 52 different outcome measures (see Appendix B) were identified, which were categorized into body function (perceptual and instrumental) and participation level measures. The range of available measures combined with limited information relating to the appropriate use of these measures makes it challenging for clinicians and researchers to accurately measure change following treatment in this population. A synthesis of the findings is discussed below in addition to recommendations for future clinical and research application.

The participants in the reviewed studies ranged in age, type and severity of speech disorder. Half of the studies included in the review evaluated treatment in children with an articulation disorder. The remaining studies included children with a phonological disorder, mixed articulation and phonological disorder, CAS, or speech disorder secondary to other disorders. The majority of studies involved a small number of participants ( $n < 10$ ), while one

large-scale study (n=730) examined outcomes of treatment of a whole speech and language therapy service cohort over a 12-year period [22]. The results highlight a need for larger-scale studies to ensure the generalizability of study findings.

### **Levels of Measurement**

All papers in the review presented outcome measures at the ICF-CY body function level (body structure issues, such as oral structural issues, were excluded from analysis) (Figure 3). The primary focus across studies was therefore impairment-based as studies aimed to increase accuracy of target sound productions, expand phonetic/phonemic inventories, decrease production variability, and increase speech intelligibility.

Since the introduction of the ICF-CY in 2007, only three studies [23-25] measured outcomes from a broader social perspective, indicating that the application of the multiple levels in the ICF-CY framework in practice has not taken flight in the area of motor-based SSDs. Although, the Mecrow et al. study [23] showed some significant and positive changes relating to how much the child's speech difficulties affected him/her at home and at school, the study was not without limitations. They had a limited study design (e.g. control group did not complete the questionnaires), lack of information regarding tool validity and reliability, as well as reduced sensitivity of the questionnaire items. Pennington et al. [25] used FOCUS, a standardized tool, to examine communicative participation in young children with CP post-intensive therapy. Even though FOCUS scores increased following therapy (mean change scores: 30.3 for parents, 28.25 for teachers), these changes did not correlate with increases in intelligibility [25]. Another standardized, norm-reference measure – The Socialization Scale (from the Vineland Adaptive Behaviour Scales – Second Edition) – was used to assess activity and participation levels following PROMPT treatment for children with CAS [24]. Increase in scores post-treatment was significant for three out of four participants based on confidence intervals provided in the test

manual. The finding of limited reporting of treatment change at the level of activity and participation are not dissimilar to those reported in the recent review by Baker and McLeod [8] for studies on phonological intervention in children. In their review, the majority of 134 studies also evaluated change in treatment only at the impairment level [8].

The lack of participation level measures is surprising, since after the late 1990's (1996-97) at least 3 outcome measures were developed that focus on measuring change from a broader social perspective, and could be used with pre-school children with speech and language disorders. These measures are: American-Speech-Language-Hearing Association National Outcome Measure System (Pre-K NOMS), Therapy Outcome Measures (TOMs) and FOCUS [7, 20, 26, 27]. Of these 3 measures, FOCUS is particularly recommended due to its sensitivity, published data on validity and reliability, and its ability to capture changes across all of the ICF-CY levels [7, 20]. In a recent study, the FOCUS measure was also shown to be sensitive to intensity of motor speech treatment in children with CAS, with larger effect sizes reported for higher (twice/week) than lower (once/week) intensity of treatment [28]. In sum, both clinicians and researchers are strongly encouraged to adopt a more comprehensive intervention measurement and reporting strategy across all ICF-CY levels. A comprehensive review of assessment and intervention procedures as they relate to ICF-CY levels can be found in McLeod and Threats [10].

### **Transcription-Based Perceptual Procedures**

Outcome measures using transcription-based approaches were very common across the reviewed articles (84.8%). These measures include standardized tests, criterion-referenced measures, and measures of intelligibility. Transcription measures were used across a range of speaking tasks from imitation to spontaneous speech at word, sentence and conversation level. In the reviewed studies, clinicians either used broad "phonemic" transcriptions (21.2%, e.g.

Goldman-Fristoe Test of Articulation-2 [GFTA-2; 29]) or narrow “phonetic” transcriptions (18.2%, e.g. Khan-Lewis Phonological Analysis-2 [KLPA-2; 30]), while the remainder of studies do not specify type of transcription employed. As a perceptual procedure, however, transcription is susceptible to bias and error. For example, listeners may ‘fill in’ information from the acoustic signal, a phenomenon known as phonemic restoration; listeners’ perception is influenced by stress and intonation patterns; and even expert judges have poor inter-rater reliability [15]. While narrow transcription provides greater level of detail, it is less reliable than broad transcription [15]. Additionally, the finer discrimination required to describe distortions in motor-based speech disorders is limited due to the categorical nature of auditory perception [15].

### ***Standardized Norm-Referenced Tests***

Standardized assessments (e.g. norm-referenced) were used in 19.7% studies. As a general rule, the use of norm-referenced standardized tests to measure change following treatment is not recommended due to serious limitations such as, regression to mean (i.e., participants with low scores at pre-test may improve more than those with high scores), and lack of sensitivity. Norm-referenced tests may sample a wide range of behaviours and those targeted in intervention may only be a subset of these behaviours; and therefore the test may not be sensitive enough to document behavioural change following treatment [31]. Thus, use of norm-referenced tests may result in under or over-estimation of change [for excellent reviews on this topic, see 1, 31, 32].

One way to remediate these problems is to utilize norm-referenced tests in a criterion referenced-mode for assessing treatment progress. For example, Namasivayam et al [33] used pre–post scores from the GFTA-2 to investigate the effect of PROMPT therapy on speech production and intelligibility in children with moderate to severe SSD. They relied on the standard error of measurement (SEM) to determine significant change following treatment that is

not a result of measurement error. The mean SEM for all pre-school age groups in the GFTA-2 is 3.7 and 3.0 for males and females, respectively [29]. Therefore, a minimum increase of 4-points was required at post-testing to indicate meaningful improvement in articulation skills.

### ***Criterion-Referenced Procedures***

Given the above difficulties using norm-referenced standardized tests, it is not surprising that researchers and clinicians most often use criterion-based scoring to assess intervention-related change in SSDs [32]. Our analysis reveal that the majority (68.2%) have utilized criterion referenced procedures (e.g. Percent Consonant Correct (PCC), Percent Vowel Correct (PVC), accuracy of target sounds) alone, or, in fewer instances, in combination with objective instrumental measures (25.8%). Although, transcription based criterion-referenced procedures like PCC [e.g., 34] are better than using norm-referenced tests, they are not without limitations. First, PCC was originally designed to assess severity (in bands, e.g. 50-65% = mod-severe) rather than measure change subsequent to intervention [35]. Second, the original calculation of PCC required measuring all consonants in all word positions - treatment of select phonemes/sounds did not significantly alter PCC scores. Several modifications to PCC have been made, such as using pre-determined subsets of sounds, or using a differential weighting approach (PCC-Revised) [36, 37]. These changes, however, still do not permit scoring of closer approximations within omitted or substituted sound categories [35].

The limitations with PCC-type measures have led to alternative procedures like the probe-word scoring system (PSS; 35] that allow monitoring of “degrees of change” or approximations towards specific therapy targets. Early PSS systems (e.g. those used by Hall et al.) [35] utilized a voice, place, and manner judgements, where a minus point is given for each feature mismatch to the target. More recent versions of PSS are more sophisticated and use a 3-point scaled perceptual scoring (0 = incorrect production, 1 = close approximation and 2 =

correct production) that includes both segmental and suprasegmental aspects of words and phrases [e.g. 24, 38-42]. These newer PSS methods are a substantial departure from earlier auditory-perceptual scoring of distinctive feature errors as they include visual observation and reporting of movement gesture approximations [e.g. 24, 42] as well as sound distortions, and temporal and prosodic aspects of speech productions [38].

Nevertheless, PSS methods do not account for changes in articulatory/sound transitions, changes in movement trajectories, subtle changes in speech motor control, vowel productions or suprasegmentals, which may affect overall speech intelligibility scores [33, 43, 44]. Further, speech intelligibility at both the word-and sentence-level was significantly correlated with speech motor control (measured using Verbal Motor Production assessment for Children (VMPAC) [45] and not articulatory proficiency (measured using GFTA-2) [29, 33].

### ***Speech Intelligibility***

Only a few studies (19.7%) reviewed in this manuscript report changes in overall speech intelligibility as a treatment outcome measure, despite this being an important goal of speech therapy in general [44, 46-48]. Intelligibility is a measure of severity of speech impairment [49] and an index of body function in the ICF-CY [10, 50]. Speech samples in the reviewed studies ranged from spontaneous speech elicited during naturalistic play to word/sentence imitation or picture naming tasks. In children with severe SSDs and unintelligible speech, eliciting sufficient spontaneous speech in a naturalistic setting may not be possible as it may be difficult to quantify listener understanding when target words are not known. Thus, elicited procedures such as imitation or picture-naming were more frequently used with these children [44, 51, 52].

The speech intelligibility assessment procedures typically involved either the listener selecting a word from multiple alternatives (closed-set; e.g. Children's Speech Intelligibility Measure (CSIM)) [53] or writing down what they hear (open-set; e.g. Beginner's Intelligibility

Test (BIT)) [54]. Impressionistic judgements and rating scales, given their reported lack of sensitivity, validity and reliability, were rarely reported in research studies reviewed here. Nevertheless, these measures are popular with clinicians, as indicated in a recent survey [52, 55]. Overall findings from the current study are not dissimilar to those reported by others for children with phonologically-based SSD, as shown in a recent review of outcome measures for children with phonologically-based SSD, where only 2 of 134 studies made reference to an intelligibility assessment [8].

Another area of speech intelligibility testing that requires further attention is the need for a behavioural standard to indicate that observed changes in speech intelligibility following treatment are not due to measurement error. Namasivayam et al. [33] indicated that ~ 8% change in CSIM word-level speech intelligibility scores following motor speech treatment was outside of 90% confidence intervals (see CSIM test manual) [50] indicating an actual change in child's performance outside of measurement error. Of course, such behavioural standards are influenced by type of elicitation procedures, type of treatment, and nature and severity of SSD; having such cut-off scores, however, will be one step closer to facilitating the integration of more robust and valid speech intelligibility testing procedures in the clinic.

### **Instrumental Procedures**

In the reviewed studies only a small percentage (30.3%) have utilized instrumental analysis to evaluate change following treatment. Instrumental procedures were most frequently used in studies providing instrumentation-based treatment including EPG, ultrasound, and motion-tracking systems such as Vicon 460 (Vicon Motion Systems, LA, USA). It is argued that in order to interact optimally with instruments and receive maximum benefits children must be at certain maturity and cognitive development; hence children under the age of 5 years are considered poor candidates. Further, due to the high cost of devices and their parts (e.g., a

custom artificial palate for EPG) the use of instruments has been restricted to children with severe articulation disorders for whom conventional treatments have failed [56].

In the reviewed studies, instrumentation was used to objectively document pre-post changes [e.g. 57-59], and continuously track intervention related changes [60]. EPG measures are concerned with a proper tongue position and closure interval duration during consonant production [e.g. 57-61]. Articulatory kinematic variables reported in two studies using the Vicon motion-tracking system included displacements, peak velocities and durations of movements of the lips and jaw [62, 63]. These studies reported that changes in articulatory kinematics were associated with positive changes in PCC/PVC scores and visual improvements in speech movement accuracy and speech intelligibility following intervention. The instruments do not have to be very sophisticated or expensive. The importance of using accessible and available acoustic measures is highlighted in the study by Huer [60]. Huer tracked intervention over a 70-day period for a child with /w/ → /r/ substitution using both spectrographic analysis (e.g. second formant transition rates, standard deviation of formant values) and perceptual (percent correct) approaches. Changes in acoustic-spectrographic measures were present earlier than changes in perceptual judgement and thus offered greater precision in measuring speech production change over the course of intervention. These findings highlight the importance of using instruments to track results of response evocation strategy across time in order to modify treatment online as necessary. Considering the significant limitations of perceptual measures, we must move toward consistently using instrumentation to evaluate change during and following treatment.

### **Application to Practice**

The importance of aligning theory, disorder classification and measurement cannot be over-emphasized [64] and is key to understanding mechanism of treatment action. Treatment and measurement strategy should be aligned with underlying deficits. For example, if children with



CAS have difficulty in planning and/or programming speech movements then effective treatment and measures of treatment change should be focused on these components [65]. To illustrate, Pennington, Smallman and Farrier [66] implemented a speech breathing and speaking rate treatment to support articulatory precision with 6 children with cerebral palsy. They chose to use speech intelligibility as their only measure of treatment change. Although these strategies improve speech intelligibility as a whole, as Pennington et al., [66] pointed out without direct measures of change in speech breathing and articulation we cannot decipher factors that contributed to changes in speech intelligibility. Clinicians and researchers should routinely create a tentative hypothesis of why an intervention is expected to work i.e. a possible mechanism of therapeutic action or effect and then proceed to choose an outcome measure that best reflects this hypothesis.

Clinically, measurement of treatment change should not be restricted to post-treatment outcome measures. On-going measurement could guide decisions at every step of the clinical process [67]. The use of on-going probes that assess multi-dimensional aspects of speech (e.g. movement trajectories and prosody) can be useful to guide treatment goals [24, 42, 60, 68]. The accurate evaluation of change during treatment will help clinician's to respond efficiently to the specific needs of a child, and adjust treatment targets to optimise treatment effectiveness.

The majority of studies in the review focus on measuring specific aspects of speech, without taking into account the whole child and how they use speech to interact with their environment. As highlighted by Baker & McLeod [9], the ICF-CY framework provides a scaffold to think about the child from a broader perspective. Changes at the level of body function must also have an impact at the level of participation in order to determine that treatment is effective and functional to meet a child's needs.

## **CONCLUSION**

The narrative review identified a wide variation of measures used to document change following treatment in children with SSD with a motor basis. It is critical to first understand the nature of the underlying deficit before choosing a specific outcome measure [64]. Clinicians and researchers need to be aware of and address the limitations of perceptual measurement, for example, by using reference samples and reducing sources of variability [15]. Additionally, perceptual measures should be supplemented with instrumental measures of the same behaviours to increase reliability and precision of analysis [15]. Further studies using multiple levels of measurement (perceptual/ instrumental, body function/ participation) will strengthen our understanding of the relationship between measures and evaluate the functional, meaningful impact treatment has on children with motor-based SSD.

## **Acknowledgments**

Dr. Yunusova and Ms. Kearney report grants from Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant.

## **Compliance with Ethics Guidelines**

## **Conflict of Interest**

E. Kearney, F. Granata, Y. Yunusova, P. van Lieshout, D. Hayden, and A. Namasivayam declare that they have no conflict of interest.

## **Human and Animal Rights and Informed Consent**

This article does not contain any studies with human or animal subjects performed by any of the authors.

## References

Papers of particular interest, published recently, have been highlighted as:

- Of importance

- Of major importance

1. McCauley RJ, Strand EA. A Review of Standardized tests of Nonverbal Oral and Speech Motor Performance in Children. *Am J Speech-Lang Pat.* 2008;17: 81-91.
2. American Speech-Language Hearing Association. Scope of practice in speech-language pathology. 2007. Retrieved from <http://www.asha.org/policy/SP2007-00283/>. Accessed 1 Mar 2015.
3. Olswang LB, Bain B. Data Collection Monitoring Children's Treatment Progress. *American J Speech-Lang Pat.* 1994;3(3):55-66.
4. World Health Organization. International Classification of Functioning, Disability, and Health: Children & Youth Version: ICF-CY. Geneva: WHO Press; 2007.
5. McLeod, S. Speech pathologists' application of the ICF to children with speech impairment. *Int J Speech-Lang Pa.* 2004;6(1):75-81.
6. McLeod S, McCormack J. Application of the ICF and ICF-children and youth in children with speech impairment. *Semin Speech Lang.* 2007;28(4):254-64.
7. Thomas-Stonell N, Oddson B, Robertson B, Rosenbaum P. Predicted and observed outcomes in preschool children following speech and language treatment: Parent and clinician perspectives. *J Commun Disord.* 2009;42(1):29-42.
8. Baker E, McLeod S. Evidence-based practice for children with speech sound disorders: Part 1 narrative review. *Lang Speech Hear Ser.* 2011;42(2):102-39.

9. Baker E, McLeod S. Evidence-based practice for children with speech sound disorders: Part 2 application to clinical practice. *Lang Speech Hear Ser.* 2011;42(2):140-51.
10. McLeod S, Threats TT. The ICF-CY and children with communication disabilities. *Int J Lang Comm Dis.* 2008;10(1-2):92-109.
11. Yaruss J. Application of the ICF in fluency disorders. *Semin Speech Lang.* 2007;28:312–22.
12. Washington KN. Using the ICF within speech-language pathology: Application to developmental language impairment. *Adv Speech-Lang Pathol.* 2007;9:242-55.
13. Shriberg LD, Fourakis M, Hall SD, Karlsson HB, Lohmeier HL, McSweeny JL, et al. Extensions to the Speech Disorders Classification System (SDCS). *Clin Linguist & Phonet.* 2010;24(10):795-824.
14. Dodd B, McCormack P. A model of speech processing for differential diagnosis of phonological disorders. In: Dodd B, editor. *Differential diagnosis of children with speech disorders.* London: Whurr; 1995: p. 65-89.
15. Kent RD. Hearing and believing: Some limits to the auditory-perceptual assessment of speech and voice disorders. *Am J Speech-Lang Pat.* 1996;5(3):7-23.
16. Raitano NA, Pennington BF, Tunick RA, Boada R, Shriberg LD. Pre-literacy skills of subgroups of children with speech sound disorders. *J Child Psychol Psyc.* 2004;45:821-35.
17. Guyette TW. Review of the Apraxia Profile. In: Plake BS, Impara PC, editors. *The fourteenth mental measurements yearbook.* Lincoln: Buros Institute of Mental Measurements; 2001. p. 57–58.
18. Towne RL. Review of the Oral Speech Mechanism Screening Examination. In: Plake BS, Impara JC, editors. *The fourteenth mental measurements yearbook.* 3rd ed. Lincoln: Buros Institute of Mental Measurements; 2001. p. 868–869.

19. Howick J, Chalmers I, Glasziou P, Greenhalgh T, Heneghan C, Liberati A, et al. The 2011 Oxford CEBM Evidence Levels of Evidence (Introductory Document). Oxford Centre for Evidence-Based Medicine. Retrieved from <http://www.cebm.net/index.aspx?o=5653>. Accessed 27 Mar 2015.
20. Thomas-Stonell N, Washington K, Oddson B, Robertson B, Rosenbaum P. Measuring communicative participation using the FOCUS©: Focus on the Outcomes of Communication Under Six. *Child Care Hlth Dev.* 2013;39(4):474-80.
  - *This paper is of major importance as it validates the use of FOCUS, a participation level measure, for use with children with speech impairment, language impairment, and both speech and language impairment.*
21. Sparrow SS, Cicchetti DV, Balla DA. *Vineland Adaptive Behavior Scales*. 2nd ed. Circle Pines: AGS; 1984.
22. Broomfield J, Dodd, B. Is speech and language therapy effective for children with primary speech and language impairment? Report of a randomized control trial. *Int J Lang Comm Dis.* 2011;46(6):628-40.
23. Mecrow C, Beckwith J, Klee T. An exploratory trial of the effectiveness of an enhanced consultative approach to delivering speech and language intervention in schools. *Int J Lang Comm Dis.* 2010;45(3):354-67.
24. Dale PS, Hayden DA. Treating speech subsystems in childhood apraxia of speech with tactual input: the PROMPT approach. *Am J Speech-Lang Pat.* 2013;22(4):644-61.
25. Pennington L., Roelant E, Thompson V., Robson S, Steen, N, Miller S. Intensive dysarthria therapy for younger children with cerebral palsy. *Dev Med Child Neurol.* 2013;55:464–71

26. American Speech-Language-Hearing Association (ASHA). National Outcome Measurement System (NOMS) for Speech–Language Pathology. 1996. Retrieved from <http://www.asha.org/NOMS/>. Accessed 10 Mar 2015.
27. Enderby P, John A. Therapy Outcome Measures: Speech-Language Pathology Technical Manual. London: Singular; 1997.
28. Namasivayam AK, Pukonen M, Goshulak D, Hard J, Rudzicz F, Rietveld T, et al. Treatment intensity and childhood apraxia of speech. *Int J Lang Comm Dis.* 2015. doi: 10.1111/1460-6984.12154.
- *This paper is of importance as it is one of the first studies to include measures of articulation, speech intelligibility and functional outcomes (i.e. body function and participation level measures) in the treatment of CAS population.*
29. Goldman R, Fristoe M. Goldman Fristoe Test of Articulation. 2nd ed. San Antonio: Pearson; 2000.
30. Khan L, Lewis N. Khan-Lewis Phonological Analysis. 2nd ed. San Antonio: Pearson; 2002.
31. McCauley RJ, Swisher L. Use and Misuse of Norm-Referenced Test in Clinical Assessment: A Hypothetical Case. *J Speech Hear Disord.* 1984;49(4):338-48.
32. McCauley RJ. Familiar strangers: Criterion-referenced measures in communication disorders. *Lang Speech Hear Ser.* 1996;27:122–31.
33. Namasivayam AK, Pukonen M, Goshulak D, Yu VY, Kadis DS, Kroll R, et al. Relationship between speech motor control and speech intelligibility in children with speech sound disorders. *J Commun Disord.* 2013;46(3):264-80.
- *This paper is of major importance as it demonstrates the relationship between different levels of measurement, that is speech motor control and speech intelligibility.*

34. Shriberg LD, Kwiatkowski J. Phonological disorders III: A procedure for assessing severity of involvement. *J Speech Hear Disord.* 1982;47:256-70.
35. Hall R, Adams C, Hesketh A, Nightingale K. The measurement of intervention effects in developmental phonological disorders. *Int J Lang Comm Dis.* 1998;33(S1):445-50.
36. Shriberg LD, Austin D, Lewis BA, McSweeney JL, Wilson DL. The Percentage of Consonants Correct (PCC) Metric Extensions and Reliability Data. *J Speech Lang Hear Re.* 1997;40(4):708-22.
37. Lagasse B. Evaluation of Melodic Intonation Therapy for Developmental Apraxia of Speech. *Music Therapy Perspectives.* 2012;30(1):49-55.
38. Maas E, Butalla CE, Farinella KA. Feedback frequency in treatment for childhood apraxia of speech. *Am J Speech-Lang Pat.* 2012;21(3):239-57.
- *This paper is of major importance as it comprehensively covers the use of probe-word scoring system: scoring errors in both segmental and suprasegmental aspects of words and phrases.*
39. Strand EA, Debertine P. The efficacy of integral stimulation intervention with developmental apraxia of speech. *J Med Speech-Lang Pa.* 2000;8(4):295-300.
40. Strand EA, Stoeckel R, Baas B. Treatment of severe childhood apraxia of speech: A treatment efficacy study. *J Med Speech-Lang Pa.* 2006;14(4):297-307.
41. Namasivayam AK, Pukonen M, Hard J, Jahnke R, Kearney E, Kroll R, et al. Motor speech treatment protocol for developmental motor speech disorders. *Dev Neurorehabil.* 2013. doi:10.3109/17518423.2013.832431.
42. Square PA, Namasivayam AK, Bose A, Goshulak D, Hayden, D. Multi-sensory treatment for children with developmental motor speech disorders. *Int J Lang Comm Dis.* 2014;49(5):527-42.

43. Bowen C, Cupples L. PACT: Parents and children together in phonological therapy. *Adv Speech Lang Pathol.* 2006;8:282-92.
44. Lousada M, Jesus MT, Hall A, Joffe V. Intelligibility as a clinical outcome measure following intervention with children with phonologically based speech-sound disorders. *Int J Lang Comm Dis,* 2014;49(5):584-601.
45. Hayden D, Square P. *Verbal Motor Production Assessment for Children.* San Antonio: Pearson Education; 1999.
46. Flipsen P. Speaker-listener familiarity: Parents as judges of delayed speech intelligibility. *J Commun Disord.* 1995;28(1):3-19.
47. Dodd B, Bradford A. A comparison of three therapy methods for children with different types of developmental phonological disorder. *Int J Lang Comm Dis .* 2000;35(2):189-209.
48. Miller N. Measuring up to speech intelligibility. *Int J Lang Comm Dis.* 2013;48(6):601-12
49. Yorkston KM, Beukelman DR, Hakel M, Dorsey M. *Speech intelligibility test for windows.* Lincoln, Communication Disorders Software; 1996.
50. Ma EPM, Worrall L, Threats TT. Introduction: The International Classification of Functioning, Disability and Health (ICF) in clinical practice. *Semin Speech Lang.* 2007;28(4):241-3.
51. Kwiatkowski J, Shriberg LD. Intelligibility assessment in developmental phonological disorders: accuracy of caregiver gloss. *J Speech Lang Hear R.* 1992;35(5):1095-104.
52. Speake J, Stackhouse J, Pascoe M. Vowel targeted intervention for children with persisting speech difficulties: Impact on intelligibility. *Child Lang Teach The.* 2012;28(3):277-95.
53. Wilcox K, Morris S. *Children's Speech Intelligibility Measure.* San Antonio: Pearson; 1999.
54. Osberger MJ, Robbins AM, Todd SL, Riley AI. Speech intelligibility of children with cochlear implants. *Volta Rev.* 1994;96:169-80.



55. Skahen SM, Watson M, Lof GL. Speech-Language Pathologists' assessment practices for children with suspected speech sound disorders: results of a national survey. *Am J Speech-Lang Pat.* 2007;16:246-59.
56. Lundeborg I, McAllister A. Treatment with a combination of intra-oral sensory stimulation and electropalatography in a child with severe developmental dyspraxia. *Logop Phonatr Voco.* 2007;32(2):71-9.
57. Gibbon FE, Wood SE. Using electropalatography (EPG) to diagnose and treat articulation disorders associated with mild cerebral palsy: a case study. *Clin Linguist & Phonet.* 2003;17(4-5):365-74.
58. Cleland J, Timmins C, Wood SE, Hardcastle WJ, Wishart JG. Electropalatographic therapy for children and young people with Down's syndrome. *Clin Linguist & Phonet.* 2009;23(12):926-39.
59. Gibbon FE, McNeill AM, Wood SE, Watson JM. Changes in linguapalatal contact patterns during therapy for velar fronting in a 10-year-old with Down's syndrome. *Int J Lang Comm Dis.* 2003;38(1):47-64.
60. Huer MB. Acoustic Tracking of Articulation Errors [r]. *J Speech Hear Disord.* 1989;54(4):530-34.
61. Nordberg A, Carlsson G, Lohmander A. Electropalatography in the description and treatment of speech disorders in five children with cerebral palsy. *Clin Linguist & Phonet.* 2011;25(10):831-52.
62. Grigos MI, Hayden D, Eigen J. Perceptual and articulatory changes in speech production following PROMPT treatment. *J Med Speech-Lang Pa.* 2010;18(4); 46.

63. Ward R, Strauss G, Leitão S. Kinematic changes in jaw and lip control of children with cerebral palsy following participation in a motor-speech (PROMPT) intervention. *Int J Speech-Lang Pa.* 2013;15(2):136-55.
- *This paper is of importance as it shows that changes evaluated through instrumental methods (speech kinematic) are associated with positive changes in speech intelligibility.*
64. Bowen C. *Children's speech sound disorders.* Hoboken: John Wiley & Sons; 2009.
65. Martikainen AL, Korpilahti P. Intervention for childhood apraxia of speech: a single-case study. *Child Lang Teach The.* 2011;27(1):9-20.
66. Pennington L, Smallman C, Farrier F. Intensive dysarthria therapy for older children with cerebral palsy: findings from six cases. *Child Lang Teach The.* 2006;22(3): 255-73.
67. McCauley R. Measurement as a dangerous activity. *J Speech Lang Pathol Audiol.* 1989;13;29–32.
68. Tyler AA. Durational analysis of stridency errors in children with phonological impairment. *Clin Linguist & Phonet.* 1995;9(3):211-28.
69. Adler-Bock M, Bernhardt B, Gick B, Bacsfalvi P. The use of ultrasound in remediation of North American English /r/ in 2 adolescents. *Am J Speech-Lang Pat.* 2007;16(2):128-39.
70. Ballard KJ, Robin DA, McCabe P, McDonald J. A treatment for dysprosody in Childhood Apraxia of Speech. *J Speech Lang Hear R.* 2010;53:1227–45.
71. Bernhardt MB, Bacsfalvi P, Adler-Bock M, Shimizu R, Cheney A, Giesbrecht N, et al. Ultrasound as visual feedback in speech habilitation: Exploring consultative use in rural British Columbia, Canada. *Clin Linguist & Phonet.* 2008;22(2):149-62.
72. Boliek CA, Fox CM. Individual and environmental contributions to treatment outcomes following a neuro- plasticity-principled speech treatment (LSVT LOUD) in children with dysarthria secondary to Cerebral Palsy. *Int J Speech-Lang Pa.* 2014;16(4):372–85.

73. Byun TM, Hitchcock ER. Investigating the use of traditional and spectral biofeedback approaches to intervention for/r/misarticulation. *Am J Speech-Lang Pat.* 2012;21(3):207-21.
- *This paper is of major importance as it shows that changes evaluated through instrumental methods are successful in addressing persistent speech errors.*
74. Camarata SM. The application of naturalistic conversation training to speech production in children with speech disabilities. *J Appl Behav Anal.* 1993;26(2):173-82.
75. Camarata S, Yoder PP, Camarata, MM. Simultaneous treatment of grammatical and speech-comprehensibility deficits in children with Down syndrome. *Downs Syndr Res Pract,* 2006;11(1):9-17.
76. Carter P, Edwards S. EPG therapy for children with long-standing speech disorders: predictions and outcomes. *Clin Linguist & Phonet.* 2004;18(6-8):359-72.
77. Crosbie S, Holm A, Dodd B. Intervention for children with severe speech disorder: a comparison of two approaches. *Int J Lang Comm Dis.* 2005;40(4):467-91.
78. Cummings AE, Barlow JA. A comparison of word lexicality in the treatment of speech sound disorders. *Clin Linguist & Phonet.* 2011;25(4):265-86.
79. Edeal DM, Gildersleeve-Neumann CE. The importance of production frequency in therapy for childhood apraxia of speech. *Am J Speech-Lang Pat.* 2011;20(2):95-110.
80. Forrest K, Elbert M, Dinnsen DA. The effect of substitution patterns on phonological treatment outcomes. *Clin Linguist & Phonet.* 2000;14(7):519-31.
81. Gibbon F, Stewart F, Hardcastle WJ, Crampin L. Widening access to electropalatography for children with persistent sound system disorders. *Am J Speech-Lang Pat.* 1999;8:319-34.
82. Gierut JA, Champion AH. Interacting error patterns and their resistance to treatment. *ClinLinguist & Phonet.* 1999;13(6):421-31.

83. Günther T, Hautvast S. Addition of contingency management to increase home practice in young children with a speech sound disorder. *Int J Lang Comm Dis.* 2010;45(3):345-53.
84. Holm A, Ozanne A, Dodd B. Efficacy of intervention for a bilingual child making articulation and phonological errors. *Int J Biling,* 1997;1(1):55–69.
85. Iuzzini J, Forrest K. Evaluation of a combined treatment approach for childhood apraxia of speech. *Clin Linguist & Phonet.* 2010;24(4-5):335-45.
86. Kadis DS, Goshulak D, Namasivayam AK, Pukonen M, Kroll R, Luc F, et al. Cortical thickness in children receiving intensive therapy for idiopathic apraxia of speech. *Brain Topogr.* 2014;27(2):240-7.
- *This paper is of importance as it is the first article that shows cortical changes in children with CAS following speech therapy.*
87. Klein, E. S. Phonological/traditional approaches to articulation therapy: a retrospective group comparison. *Lang Speech Hear Ser.* 1996;27(4):314–23.
88. Koegel RL, Koegel LK, Ingham JC, Van Voy K. Within-clinic versus outside-of-clinic self-monitoring of articulation to promote generalization. *J Speech Hear Disord.* 1988;53(4):392-9.
89. Lousada M, Jesus LM, Capelas S, Margaça C, Simões D, Valent, A, et al. Phonological and articulation treatment approaches in Portuguese children with speech and language impairments: a randomized controlled intervention study. *Int J Lang Comm Dis.* 2013;48(2):172-87.
90. Maas E, Farinella KA. Random versus blocked practice in treatment for childhood apraxia of speech. *J Speech Lang Hear R.* 2012;55(2):561-78.
91. Marchant J, McAuliffe MJ, Huckabee ML. Treatment of articulatory impairment in a child with spastic dysarthria associated with cerebral palsy. *Dev Neurorehabil.* 2008;11(1):81-90.

92. McAuliffe MJ, Cornwell PL. Intervention for lateral /s/ using electropalatography (EPG) biofeedback and an intensive motor learning approach: a case report. *Int J Lang Comm Dis.* 2008;43(2):219–29.
93. McCabe P, Macdonald-D’Silva AG, van Rees LJ, Ballard KJ, Arciuli J. Orthographically sensitive treatment for dysprosody in children with Childhood Apraxia of Speech using ReST intervention. *Dev Neurorehabil.* 2014;7(2):137-46.
94. McIntosh B, Dodd B. Evaluation of Core Vocabulary intervention for treatment of inconsistent phonological disorder: Three treatment case studies. *Child Lang Teach The.* 2009;25(1):09-29.
95. Modha G, Bernhardt B, Church R, Bacsfalvi, P. Case study using ultrasound to treat. *Int J Lang Comm Dis.* 2008;43(3):323-9.
96. Mowrer DE, Conley D. Effect of peer administered consequences upon articulatory responses of speech-defective children. *J Commun Disord.* 1987;20(4):319-25.
97. Preston JL, Brick N, Landi N. Ultrasound biofeedback treatment for persisting childhood apraxia of speech. *Am J Speech-Lang Pat.* 2013;22(4):627-43.
98. Flipsen P Jr, Sacks S, Neils-Strunjas J. Effectiveness of systematic articulation training program accessing computers (SATPAC) approach to remediate dentalized and interdental /s, z/: a preliminary study. *Percept Mot Skills.* 2013;117(2):559-77.
99. Shawker TH, Sonies BC. Ultrasound biofeedback for speech training. Instrumentation and preliminary results. *Invest Radiol.* 1985 Jan-Feb;20(1):90-3.
100. Shriberg LD, Kwiatkowski J, Snyder T. Tabletop Versus Microcomputer-Assisted Speech Management Response Evocation Phase. *J Speech Hear Disord.* 1990;55(4):635-55.
101. Skelton SL, Hagopian AL. Using Randomized Variable Practice in the Treatment of Childhood Apraxia of Speech. *Am J Speech-Lang Pat.* 2014;23(4):599-611.

102. Stokes SF, Ciocca V. The substitution of [s] for aspirated targets: perceptual and acoustic evidence from Cantonese. *Clin Linguist & Phonet.* 1999;13(3):183-197.
103. Stokes SF, Griffiths R. The use of facilitative vowel contexts in the treatment of post-alveolar fronting: a case study. *Int J Lang Comm Dis.* 2010;45(3):368-80.
104. Thomas DC, McCabe P, Ballard K. Rapid Syllable Transitions (ReST) treatment for Childhood Apraxia of Speech: The effect of lower dose-frequency. *J Commun Disord.* 2014;51:29-42. doi: 10.1016/j.jcomdis.2014.06.004.
105. Tung LC, Lin CK, Hsieh CL, Chen CC, Huang CT, Wang CH. Sensory integration dysfunction affects efficacy of speech therapy on children with functional articulation disorders. *Neuropsychiatr Dis Treat.* 2013;9:87.
106. Weaver-Spurlock S, Brasseur J. The effects of simultaneous sound-position training on the generalization of [s]. *Lang Speech Hear Ser.* 1988;19(3):259-71.
107. Ward R, Leitão S, Strauss G. An evaluation of the effectiveness of PROMPT therapy in improving speech production accuracy in six children with cerebral palsy. *Int J Speech Lang Pathol.* 2014;16(4):355-71.
108. Dodd B. Children with speech disorder: Defining the problem. In: Dodd B, editor. *Differential diagnosis and treatment of children with speech disorder.* London: Whurr; 2005: p. 3-23.

## APPENDIX A: Anthology of 66 Reviewed Studies

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Adler-Bock, Bernhardt, Gick & Bacsfalvi (2007)	Residual articulation problem /r/	2	12;0, 14;0	Case study: pre-post treatment design	Biofeedback	<ul style="list-style-type: none"> <li>• Acoustics (formant frequencies)</li> <li>• Probe words</li> <li>• Ultrasound tongue shape</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> <li>• Reading target word in carrier phrase</li> </ul>	Response: No Stimulus: No	No
Ballard, Robin, McCabe & McDonald (2010)	CAS	3	7;0-10;0	Multiple baseline across behaviours	Prosody	<ul style="list-style-type: none"> <li>• Probe words</li> <li>• Percentage accuracy of target treatment sounds (target=stress patterns)</li> <li>• Acoustics (formant frequencies, syllable/ vowel duration, dB SPL, pairwise variability indices of lexical stress)</li> <li>• Perceptual rating scale</li> </ul>	<ul style="list-style-type: none"> <li>• Orthographicall -y presented</li> </ul>	Response: Yes Stimulus: No	Yes
Bernhardt et al. (2008)	Residual articulation problems	13	7;0-15;0	ABA design	Biofeedback	<ul style="list-style-type: none"> <li>• Informal report of consistency in production</li> <li>• Percentage accuracy of target treatment sounds</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> <li>• Imitation (if necessary)</li> </ul>	Response: No Stimulus: No	No
Boliek & Fox (2014)	Articulation issues secondary to CP	2	10;09	Case study: pre-post design	LSVT Loud	<ul style="list-style-type: none"> <li>• Overall intelligibility</li> <li>• Acoustics: formant frequencies</li> <li>• Acoustics: dB SPL</li> <li>• Duration for sustained 'ahs'</li> <li>• Perceptual rating scale</li> </ul>	<ul style="list-style-type: none"> <li>• Not specified</li> </ul>	Response: Yes Stimulus: No	Yes

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Broomfield & Dodd (2011)	Primary speech and/or language impairment	730	Aged up to 16;0	RCT	Phonological contrast therapy; Core vocabulary approach; Derbyshire language scheme	<ul style="list-style-type: none"> <li>• DEAP (Inconsistency word score)</li> </ul>	<ul style="list-style-type: none"> <li>• Not specified</li> </ul>	Response: No Stimulus: No	No
Byun & Hitchcock (2012)	Articulation error /r/	11	6;0-11;9	Pre-test post-test single group	Biofeedback	<ul style="list-style-type: none"> <li>• Acoustics (formant frequency)</li> <li>• Perceptual rating scale</li> </ul> Probe words	<ul style="list-style-type: none"> <li>• Not specified</li> </ul>	Response: Yes Stimulus: No	No
Camarata (1993)	Mixed (articulation + phonology)	2	3;10-4;3	Multiple baseline across behaviours and across subjects	Naturalistic conversation training	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>	<ul style="list-style-type: none"> <li>• Play-based spontaneous speech sample</li> </ul>	Response: No Stimulus: Yes	Yes
Camarata, Yoder & Camarata (2006)	Articulation issues secondary to Down syndrome	6	4;4-7;4	Multiple baseline multiple probe design	Recast	<ul style="list-style-type: none"> <li>• Connected speech intelligibility</li> </ul>	<ul style="list-style-type: none"> <li>• Spontaneous</li> </ul>	Response: No Stimulus: Unclear	No
Carter & Edwards (2004)	Residual articulation problems	10	7;04-14;01	Single-subject pre-post design	Biofeedback	<ul style="list-style-type: none"> <li>• PCC</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Reading</li> </ul>	Response: No Stimulus: No	No
Cleland, Timmins, Wood, Hardcastle & Wishart (2009)	Articulation issues secondary to Down syndrome	6	10;01 - 18;09	Pre-post design	Biofeedback	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• EPG (patterns, COG, variability index)</li> <li>• PCC</li> <li>• Probe words</li> <li>• Single word/connected speech phoneme agreement (DEAP)</li> </ul>	<ul style="list-style-type: none"> <li>• Reading</li> </ul>	Response: No Stimulus: No	No



Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Crosbie, Holm & Dodd (2005)	Phonological impairment	18	4;08-6;05	Multiple baseline alternating treatments design	Core vocabulary approach; Phonological contrast therapy	<ul style="list-style-type: none"> <li>• DEAP (Inconsistency word score)</li> <li>• PCC</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming (if failed, imitation)</li> </ul>	Response: Yes Stimulus: No	Yes
Cummings & Barlow (2011)	Mixed (articulation + phonological)	4	3;0-6;9	Single-subject multiple-baseline design	Phonological contrast therapy	<ul style="list-style-type: none"> <li>• Error Consistency Index</li> <li>• Percentage accuracy of target treatment sound</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> </ul>	Response: Yes Stimulus: No	No
Dale & Hayden (2013)	CAS	4	3;6-4;8	2 groups: 1) ABB, 2) ACB	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• Average percent correct</li> <li>• Probe words</li> <li>• DEAP (standard score)</li> <li>• Perceptual rating scale</li> <li>• Visual analysis of articulatory movement</li> <li>• The Socialization Scale</li> <li>• VMPAC</li> </ul>	<ul style="list-style-type: none"> <li>• Imitation</li> </ul>	Response: Yes Stimulus: No	Yes
Dodd & Bradford (2000)	SSD with phonological basis	3	3;5-4;8	Multiple baseline with alternating treatments	Core vocabulary approach; Phonological contrast therapy; Moto-kinesthetic	<ul style="list-style-type: none"> <li>• Probe words</li> <li>• DEAP (Inconsistency word score)</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> </ul>	Response: Yes Stimulus: No	Yes
Edeal & Gildersleeve-Neumann (2011)	CAS	2	3;4, 6;2	Alternating treatment AB design	Integral stimulation	<ul style="list-style-type: none"> <li>• PCC</li> <li>• Percentage accuracy of target treatment sound</li> <li>• Percentage occurrence of phonological processes</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Not specified</li> </ul>	Response: Yes Stimulus: No	Yes

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Forrest, Elbert & Dinnsen (2000)	Consistent and inconsistent speech disorders	10	3;04-4;06	Single subject design with staggered baseline	Phonological contrast therapy	<ul style="list-style-type: none"> <li>Percentage accuracy of target treatment sounds</li> <li>Probe words</li> </ul>	<ul style="list-style-type: none"> <li>Not specified</li> </ul>	Response: Yes Stimulus: No	No
Gibbon, McNeill, Wood & Watson (2003)	Articulation issues secondary to Down syndrome	1	10;11	Case study; time-series	Biofeedback	<ul style="list-style-type: none"> <li>EPG (patterns, COG, centre of gravity, variability index)</li> </ul>	<ul style="list-style-type: none"> <li>Picture-naming</li> </ul>	Response: No Stimulus: No	No
Gibbon, Stewart, Hardcastle & Crampin (1999)	Residual articulation problem /t, d, n/	1	8;2	Single-subject pre-post design	Biofeedback	<ul style="list-style-type: none"> <li>EPG (patterns, COG)</li> </ul>	<ul style="list-style-type: none"> <li>Not specified</li> </ul>	Response: No Stimulus: No	No
Gibbon & Wood (2003)	Articulation issues secondary to CP	1	8;08	Single case study	Biofeedback	<ul style="list-style-type: none"> <li>EPG (COG, duration of contact)</li> </ul>	<ul style="list-style-type: none"> <li>Picture-naming</li> </ul>	Response: No Stimulus: No	No
Gierut & Champion (1999)	/s/ speech error	2	4;0, 4;8	Single-subject staggered multiple baseline design	Phonological contrast therapy	<ul style="list-style-type: none"> <li>Percentage accuracy of target treatment sound</li> <li>Probe words</li> </ul>	<ul style="list-style-type: none"> <li>Picture-naming</li> </ul>	Response: Yes Stimulus: No	Yes
Grigos, Hayden & Eigen (2010)	Articulation disorder	2	3;7 (mean)	Pre-post treatment design	Moto-kinesthetic	<ul style="list-style-type: none"> <li>PCC, PVC</li> <li>Probe words</li> <li>Speech kinematics (jaw duration, displacement, velocity)</li> </ul>	<ul style="list-style-type: none"> <li>Not specified</li> </ul>	Response: Yes Stimulus: No	Yes
Günther & Hautvast (2010)	Articulation disorder	91	4;0-6;0	Pre-post experimental design	Traditional Articulation	<ul style="list-style-type: none"> <li>Number of speech errors</li> </ul>	<ul style="list-style-type: none"> <li>Picture-naming</li> </ul>	Response: No Stimulus: Yes	No

Reference	Population	n	Age	Design	Intervention	• Outcome Measures	• Elicitation	Generalization	Maintenance
Holm, Ozanne & (1997)	Mixed (articulation + phonological)	1	5;0	Case study	Traditional Articulation Phonological contrast therapy	• Percentage accuracy of target treatment sounds	• Picture-naming • Picture description	Response: Yes Stimulus: No	Yes
Huer (1989)	Articulation errors	1	10;0	Single-subject pre-post design	Traditional Articulation	• Acoustics: F2 transition rate • Percentage accuracy of target treatment sounds	• Imitation	Response: No Stimulus: Yes (conducted not measured)	Yes
Iuzzini & Forrest (2010)	CAS	4	3;7-6;10	Single subject multiple baseline across subjects	Core vocabulary approach; Stimulability Training	• CSIP (Consonant Substitute Inconsistency Percentage) • ISP (Inconsistency Severity Percentage) • PCC • Probe words	• Not specified	Response: Yes Stimulus: No	No
Kadis et al. (2014)	Idiopathic AOS	14; 14	3;9-6;6 4;1-6;3	Experimental group design	Moto-kinesthetic	• HCAPP Phon Analysis • GFTA Phonetic Inventory • VMPAC	• Picture-naming	Response: No Stimulus: No	No
Klein (1996)	Articulation disorder	36	4;04 (mean)	Retrospective design	Traditional Articulation; Phonological contrast therapy	• Speech Severity Score (AAPS) • Treatment duration/discharge rate	• Picture-naming	Response: No Stimulus: No	No
Koegel, Koegel, Van Voy & Ingham (1988)	Residual articulation problems (interdentals)	7	Grades 2, 3, 4	Multiple baseline	Traditional Articulation	• Percentage accuracy of target treatment sounds	• Spontaneous/naturalistic	Response: No Stimulus: Yes	Yes
Lagasse (2012)	CAS	2	5;0, 6;0	Single-case experiment alternating treatments ABABABA BA	Melodic Intonation Therapy	• Probe words • Standardized articulation test • Standardized phonological test	• Picture-naming (GFTA) • Imitation (SPT) test	Response: No Stimulus: No	No

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Lousada et al., (2013)	SSD with phonological basis	14	4;0-6;7	RCT	Traditional Articulation; Phonological contrast therapy	<ul style="list-style-type: none"> <li>• PCC</li> <li>• Percentage occurrence of phonological processes</li> <li>• Probe words</li> <li>• Single-word phonetic-phonological test (Mendes et al., 2009)</li> </ul>	• Picture-naming	Response: Yes Stimulus: No	No
Lousada, Luis, Hall & Joffe (2014)	SSD with phonological basis	14	4;0-6;7	RCT	Traditional Articulation; Phonological contrast therapy	<ul style="list-style-type: none"> <li>• PCC</li> <li>• Word list intelligibility</li> <li>• Connected speech intelligibility</li> </ul>	• Picture-naming; picture description	Response: Yes Stimulus: No	No
Lundeborg, McAllister (2007)	Severe developmental verbal dyspraxia	1	5;01	Pre-post treatment design	Biofeedback Integral Stimulation	<ul style="list-style-type: none"> <li>• PCC , PPC, PWC</li> <li>• Probe words</li> <li>• Word list intelligibility</li> <li>• Visual analysis of articulatory movement</li> </ul>	• Picture-naming	Response: No Stimulus: No	No
Maas, Butalla & Farinella (2012)	CAS	4	5;4-8;4	Alternating treatments design with multiple baselines across behaviours over 2 phases	Integral stimulation	• Probe words	• Imitation	Response: Yes Stimulus: No	Yes
Maas & Farinella (2012)	CAS	4	5;0-7;9	Alternating treatment design with multiple baselines across behaviours	Integral stimulation	• Probe words	• Imitation	Response: Yes Stimulus: No	Yes

Reference	Population	n	Age	Design	Intervention	• Outcome Measures	• Elicitation	Generalization	Maintenance
Marchant, McAuliffe & Huckabee (2008)	Articulation issues secondary to CP	1	13;0	Case study ABACA design	Traditional Articulation Phonetic placement therapy	<ul style="list-style-type: none"> <li>• Acoustics (formant frequency)</li> <li>• Assids for single word intelligibility</li> <li>• DDK (AMR, syllable duration, inter-syllable-gap duration)</li> <li>• Intelligibility of connected speech (Duffy Scale/Grandfather passage)</li> <li>• Perceptual rating scale</li> <li>• Surface EMG</li> </ul>	• Not specified	Response: No Stimulus: No	No
Martikainen & Korpilahti (2011)	CAS	1	4;07	Case study	Melodic Intonation Therapy Moto-kinesthetic	<ul style="list-style-type: none"> <li>• Length of utterance</li> <li>• PCC, PVC, PWC, PWP</li> <li>• Probe words</li> </ul>	• Spontaneous	Response: Yes Stimulus: No	Yes
McAuliffe & Cornwell (2008)	Residual articulation problems /s/	1	11;0	Single-subject case-study, pre- pose design	Biofeedback	<ul style="list-style-type: none"> <li>• Acoustics (spectral distribution - centroid frequency and skewness)</li> <li>• EPG patterns</li> <li>• Perceptual rating scale</li> </ul>	• Not specified	Response: No Stimulus: No	No
McCabe et al. (2014)	CAS	4	5;5-8;6	Single case AB design	Rapid syllable transition treatment	<ul style="list-style-type: none"> <li>• PCC</li> <li>• PVC</li> <li>• Probe words</li> </ul>	• Orthographicall -y presented pseudo-words (not specified if also verbally presented)	Response: No Stimulus: No	Yes
McIntosh & Dodd (2008)	Inconsistent speech disorder	3	3;08-4;02	Pre-post treatment design	Core vocabulary approach	<ul style="list-style-type: none"> <li>• DEAP: single words/connected speech phoneme agreement; inconsistency word score</li> <li>• PPC, PVC, PWC</li> </ul>	• Picture-naming	Response: Yes Stimulus: No	Yes

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Mecrow, Beckwith & Klee (2010)	Phonological impairment	35	4;2-6;10	Pre-post treatment design	Phonological awareness	<ul style="list-style-type: none"> <li>• Parent/school questionnaire</li> <li>• PPC</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Not specified</li> </ul>	Response: No Stimulus: No	Yes
Modha, Bernhardt, Church & Bacsfalvi (2008)	/r/ misarticulation	1	13;0	ABCBCA alternating treatments	Biofeedback	<ul style="list-style-type: none"> <li>• Acoustics (formant frequency)</li> <li>• Perceptual rating scale</li> </ul>	<ul style="list-style-type: none"> <li>• Reading</li> </ul>	Response: No Stimulus: No	Yes
Mowrer & Conley (1987)	Articulation disorder	20	Grade 2	Pre-post treatment design	Traditional Articulation	<ul style="list-style-type: none"> <li>• Probe words</li> <li>• Percentage accuracy of target treatment sounds</li> </ul>	<ul style="list-style-type: none"> <li>• Spontaneous</li> </ul>	Response: No Stimulus: No	No
Namasivayam et al. (2013)	Moderate-severe mixed + motor control issues	12	3;11-6;07	Prospective single group pre-post test design	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• Standardized articulation test</li> <li>• Connected speech intelligibility</li> <li>• VMPAC</li> </ul>	<ul style="list-style-type: none"> <li>• Imitation</li> <li>• Picture-naming</li> </ul>	Response: No Stimulus: No	No
Namasivayam et al. (2013)	Severe-profound mixed + Motor speech difficulties	5	3;03 (mean)	Multiple baseline across subjects	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• Connected speech intelligibility</li> <li>• Visual analysis of articulatory movement</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Not specified</li> </ul>	Response: Yes Stimulus: No	Yes
Nordberg, Carlsson & Lohmander (2011)	Articulation issues secondary to CP	5	7;07-13;09	Pre-post design	Biofeedback	<ul style="list-style-type: none"> <li>• EPG (patterns, COG, duration of contact, timing (approach, closure, release phase), alveolar total contact)</li> <li>• Perceptual rating scale</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> </ul>	Response: No Stimulus: No	No
Pennington et al. (2013)	Articulation issues secondary to CP	15	5;0-11;0	Pre-post treatment design	Systems approach	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• Connected speech intelligibility</li> <li>• Parent questionnaire (rating of treatment effectiveness)</li> <li>• FOCUS</li> </ul>	<ul style="list-style-type: none"> <li>• Word-imitation</li> <li>• Connected speech</li> </ul>	Response: No Stimulus: No	Yes

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Pennington, Smallman & Farrier (2006)	Articulation issues secondary to CP	6	10;0-18;0	Pre-post treatment design	Systems approach	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• Connected speech intelligibility</li> </ul>	<ul style="list-style-type: none"> <li>• Word-imitation</li> <li>• Connected speech</li> </ul>	Response: No Stimulus: No	Yes
Preston, Brick & Landi (2013)	CAS	6	9;10-15;10	Multiple baseline across behaviour design	Biofeedback	<ul style="list-style-type: none"> <li>• PCC</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Imitation</li> </ul>	Response: Yes Stimulus: No	Yes
Preston et al. (2014)	Residual articulation disorder	7	10;0-13;0	Multiple baseline single-subject design	Mixed articulation biofeedback + prosody	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> <li>• Probe words</li> </ul>	<ul style="list-style-type: none"> <li>• Word reading</li> <li>• Sentence imitation</li> </ul>	Response: Yes Stimulus: No	Yes
Sacks, Flipsen & Neils-Strunjas (2013)	Residual articulation problems (interdentals)	18	6;9-11;10	Cross-over design	Systematic Articulation Training Program Accessing Computers	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>	<ul style="list-style-type: none"> <li>• Phrase repetition</li> <li>• Spontaneous speech</li> </ul>	Response: Yes Stimulus: No	Yes
Shawker & Sonies (1985)	Residual articulation problems /r/	1	9;0	Single case study	Biofeedback	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>	<ul style="list-style-type: none"> <li>• Reading</li> </ul>	Response: No Stimulus: No	Yes
Skelton & Hagopian (2014)	CAS	3	4;0-6;1	Multiple baseline across participants	Traditional Articulation	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> <li>• Verbal stimulus</li> </ul>	Response: Yes Stimulus: No	No
Speake, Stackhouse & Pascoe (2012)	Articulation disorder	2	10;0	Pre-post treatment design	Traditional Articulation; Phonological contrast therapy; Phonological awareness	<ul style="list-style-type: none"> <li>• Connected speech intelligibility</li> <li>• Word list intelligibility</li> <li>• PCC, PVC</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> </ul>	Response: Yes Stimulus: No	No

Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Square et al. (2014)	Moderate-profound SSD	5	4;0-4;9	Multiple baseline across behaviours and subjects	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• Probe words</li> <li>• Perceptual rating scale</li> <li>• Visual analysis of articulatory movement</li> </ul>	• Imitation	Response: Yes Stimulus:	Yes
Stokes & Ciocca (1999)	Mixed (articulation + phonological)	1	5;0	Case study	Phonological contrast therapy	<ul style="list-style-type: none"> <li>• Acoustics (spectrographic analysis)</li> <li>• Percentage accuracy of target treatment sounds</li> <li>• Non-sense words</li> </ul>	• Imitation	Response: No Stimulus: No	No
Stokes & Griffiths (2010)	Residual articulation problems	1	7;0	Single-subject pre-post design	Traditional Articulation (Facilitative vowel contexts)	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> <li>• Probe words</li> </ul>	• Picture-naming	Response: Yes Stimulus: No	Yes
Strand & Debertine (2000)	CAS	1	5;0	Multiple-baseline across behaviours	Integral stimulation	<ul style="list-style-type: none"> <li>• Perceptual rating scale</li> <li>• Probe words</li> </ul>	• Imitation	Response: Yes Stimulus: No	No
Strand, Stoeckel & Baas (2006)	CAS	4	5;5-6;1	SCED	Integral stimulation	<ul style="list-style-type: none"> <li>• Perceptual rating scale</li> <li>• Probe words</li> </ul>	• Imitation	Response: Yes Stimulus: Yes	No
Thomas, McCabe & Ballard (2014)	CAS	4	4;8-8;0	Multiple baseline across participants	Rapid syllable transition treatment	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> <li>• Standardized Articulation Test</li> </ul>	• Imitation	Response: Yes Stimulus: No	Yes
Tung et al. (2013)	Articulation disorder	30	3;6-6;0	Pre-post treatment design	Traditional Articulation	<ul style="list-style-type: none"> <li>• Number of speech errors</li> </ul>	• Not specified	Response: No Stimulus: No	No



Reference	Population	n	Age	Design	Intervention	Outcome Measures	Elicitation	Generalization	Maintenance
Ward, Strauss & Leitao (2013)	Articulation issues secondary to CP	6	3;0-11;0	ABCA single-subject - multiple baseline design	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• Probe words</li> <li>• Speech kinematics (jaw: distance travelled, open distance, midline control, lip: rounding/ retraction, inter-lip distance during bilabial contact, velocity, movement duration)</li> </ul>	• Imitation	Response: Yes Stimulus: No	Yes
Ward, Leitao & Strauss (2014)	Moderate-severe speech impairment	6	3;0-11;0	Single subject design (A1BCA2)	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• Perceptual rating scale</li> <li>• Probe words</li> <li>• Visual analysis of articulatory movement</li> </ul>	• Not specified	Response: Yes Stimulus: No	Yes
Weaver-Spurlock & Brasseur (1988)	Residual articulation problems /s/	3	5;0-5;7	Single-subject multiple baseline across subjects	Traditional Articulation	<ul style="list-style-type: none"> <li>• Perceptual rating scale</li> <li>• Probe words</li> <li>• Visual analysis of articulatory movement</li> </ul>	<ul style="list-style-type: none"> <li>• Picture-naming</li> <li>• Conversational speech</li> </ul>	Response: Yes Stimulus: No	No
Wood et al. (2009)	Articulation issues secondary to Down syndrome	2	11;0-14;0	Case study	Biofeedback	<ul style="list-style-type: none"> <li>• CSIM</li> <li>• EPG patterns</li> <li>• EPG variability index</li> <li>• PCC</li> </ul>	• Picture-naming	Response: Yes Stimulus: No	Yes
Wu & Jeng (2004)	Articulation issues secondary to CP	2	11;09, 12;05	Single-subject pre-post design	Traditional Articulation; Phonological awareness; Phonological contrast	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>	• Not specified	Response: No Stimulus: No	Yes
Yu et al. (2014)	Motor-based SSD	6;6	4;0-6;5, 4;2-5;5	Experimental group design	Moto-kinesthetic	<ul style="list-style-type: none"> <li>• Acoustics: VOT</li> <li>• GFTA phonetic inventory</li> <li>• VMPAC</li> </ul>	• /pa/ spontaneous	Response: No Stimulus: No	No

## APPENDIX B: Outcome Measures

SPC* Level Targeted	Technique	Population	Article Numbers (n)	Outcome Measures
Perception	Integral Stimulation (DTTC)	CAS	6	<ul style="list-style-type: none"> <li>• PCC, PPC, PWC</li> <li>• Probe words</li> <li>• Perceptual rating scale (auditory)</li> <li>• Percentage accuracy of target treatment sounds</li> <li>• Percentage occurrence of phonological processes</li> <li>• Visual analysis of articulatory movement</li> <li>• Intelligibility (word)</li> </ul>
Phonological system	Phonological awareness	Articulation issues Articulation issues secondary to CP Phonological disorder	1 1 1	<ul style="list-style-type: none"> <li>• PCC, PPC, PVC</li> <li>• Percentage accuracy of target treatment sounds</li> <li>• Intelligibility (word, connected-speech)</li> <li>• Parent/child questionnaire</li> </ul>
	Contrast therapy	Articulation issues Articulation issues secondary to CP Phonological disorder Mixed (articulation + phonology) Phonologically-based SSD	5 1 2 3 2	<ul style="list-style-type: none"> <li>• PCC, PVC</li> <li>• Probe words</li> <li>• Percentage accuracy of target treatment sounds</li> <li>• Percentage occurrence of phonological processes</li> <li>• Inconsistency (word score, error consistency index)</li> <li>• Speech-severity score (AAPS)</li> <li>• Single-Word Phonetic-Phonological Test (Mendes et al., 2009)</li> <li>• Acoustics (spectrographic analysis)</li> <li>• Intelligibility (word, connected speech)</li> <li>• Treatment duration/discharge rate</li> <li>• DEAP (inconsistency word score)</li> </ul>

SPC Level Targeted	Technique	Population	Article Numbers (n)	Outcome Measures
Motor	Articulation therapy	Articulation issues	4	<ul style="list-style-type: none"> <li>• PCC, PVC</li> <li>• Probe words</li> <li>• DDK (AMR, syllable duration, inter-syllable-gap duration)</li> <li>• Percentage accuracy of target treatment sounds</li> <li>• Percentage occurrence of phonological processes</li> <li>• Perceptual rating scale (auditory, visual)</li> <li>• Number of speech errors</li> <li>• Speech-severity score (AAPS)</li> <li>• Single-Word Phonetic-Phonological Test (Mendes et al., 2009)</li> <li>• Surface EMG</li> <li>• Acoustics (F2 transition rate, formant frequencies)</li> <li>• Intelligibility (word, connected speech)</li> <li>• Treatment duration/discharge rate</li> </ul>
		Residual/persistent articulation issues	3	
		Articulation issues secondary to CP	2	
		Phonologically-based SSD	1	
		CAS	1	
	Biofeedback (EPG, Ultrasound)*	Articulation issues	2	<ul style="list-style-type: none"> <li>• PCC, PPC, PWC, SvC</li> <li>• Probe words</li> <li>• Percentage accuracy target treatment sounds</li> <li>• Inconsistency (informal report)</li> <li>• Perceptual rating scale (auditory, visual)</li> <li>• Acoustics (formant frequencies, spectral distribution, central frequency, skewness)</li> <li>• EPG (alveolar total contact, centre of gravity, duration of contact, contact patterns, timing, variability index)</li> <li>• Intelligibility (word, connected speech)</li> <li>• Ultrasound (tongue shape)</li> </ul>
		Residual/persistent articulation issues	6	
		Articulation issues secondary to DS	3	
		Articulation issues secondary to CP	2	
		CAS	2	
	Moto-kinaesthetic	Articulation issues	3	<ul style="list-style-type: none"> <li>• Average percentage correct</li> <li>• PCC, PVC, PWC, PWP</li> <li>• Probe words</li> <li>• DEAP (standard score, inconsistency word score)</li> <li>• GFTA Phonetic Inventory</li> <li>• HCAPP Phon analysis</li> <li>• VMPAC</li> <li>• Length of utterance</li> <li>• Standardized articulation test</li> </ul>
		Articulation issues secondary to CP	1	
		CAS	2	
		Idiopathic AOS	1	
		Moderate-severe speech impairment	1	
		Motor-based SSD	1	
		Moderate-profound SSD	1	
		Phonologically-based SSD	1	

- Speech kinematics
- Perceptual rating scale (visual)
- Acoustics (VOT)
- Intelligibility (connected speech)

SPC Level Targeted	Technique	Population	Article Numbers (n)	Outcome Measures	
Functional units	Phonetic placement	Articulation issues secondary to CP	1	<ul style="list-style-type: none"> <li>• PCC</li> <li>• DDK (AMR, syllable duration, inter-syllable-gap duration)</li> <li>• Perceptual rating scale (auditory)</li> <li>• Surface EMG</li> <li>• Acoustics (formant frequencies)</li> <li>• Intelligibility (word, connected speech)</li> </ul>	
	Stimulability training	CAS	1	<ul style="list-style-type: none"> <li>• PCC</li> <li>• Inconsistency (severity percentage, consonant substitute inconsistency percentage)</li> <li>• Probe words</li> </ul>	
	Computer-based	Residual/persistent articulation issues	1	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>	
	Core vocabulary	Articulation issues	1	<ul style="list-style-type: none"> <li>• PCC, PPC, PVC, SvC</li> <li>• Inconsistency (word score, percentage, consonant substitute inconsistency percentage, severity percentage)</li> <li>• Probe words</li> <li>• DEAP (inconsistency word score)</li> </ul>	
		Phonological disorder	1		
		Inconsistent phonological disorder (unspecified)	1		
		CAS	1		
		Phonologically-based SSD	1		
		Whole language			
		Recast	Articulation issues secondary to DS	1	<ul style="list-style-type: none"> <li>• Percentage accuracy of target treatment sounds</li> </ul>
	Naturalistic conversation training	Mixed (articulation + phonology)	1	<ul style="list-style-type: none"> <li>• Intelligibility (connected speech)</li> </ul>	
	Melodic Intonation Therapy	CAS	2	<ul style="list-style-type: none"> <li>• PCC, PVC, PWC, PWP</li> <li>• Probe words</li> <li>• Length of utterance</li> <li>• Standardized articulation test</li> <li>• Standardized phonological test</li> </ul>	
	Systems approach	Articulation issues secondary to CP	1	<ul style="list-style-type: none"> <li>• Intelligibility (word, connected speech)</li> </ul>	
		Dysarthria secondary to CP	1	<ul style="list-style-type: none"> <li>• CSIM</li> </ul>	

			<ul style="list-style-type: none"> <li>• Parent questionnaire (rating of treatment effectiveness)</li> <li>• FOCUS</li> </ul>
LSVT Loud	Dysarthria secondary to CP	1	<ul style="list-style-type: none"> <li>• Acoustics: dB SPL</li> <li>• Acoustics: formant frequencies</li> <li>• Duration for sustained 'ahs'</li> <li>• Overall intelligibility</li> <li>• Perceptual rating scale</li> </ul>
Prosody	CAS	1	<ul style="list-style-type: none"> <li>• Probe words</li> <li>• Percentage accuracy of target treatment sounds (target=stress)</li> <li>• Acoustics: formant frequencies</li> <li>• Acoustics: syllable vowel duration</li> <li>• Acoustics: dB SPL</li> <li>• Acoustics: pairwise variability indices of lexical stress</li> <li>• Perceptual rating scale</li> </ul>
Rapid Syllable Transition Treatment	CAS	2	<ul style="list-style-type: none"> <li>• PCC, PVC</li> <li>• Probe words</li> <li>• Percentage accuracy of target treatment sounds</li> <li>• Standardized articulation test</li> <li>•</li> </ul>

---

\* SPC: Speech-processing chain, based on model provided by Dodd [108]

---

## FIGURES AND CAPTIONS

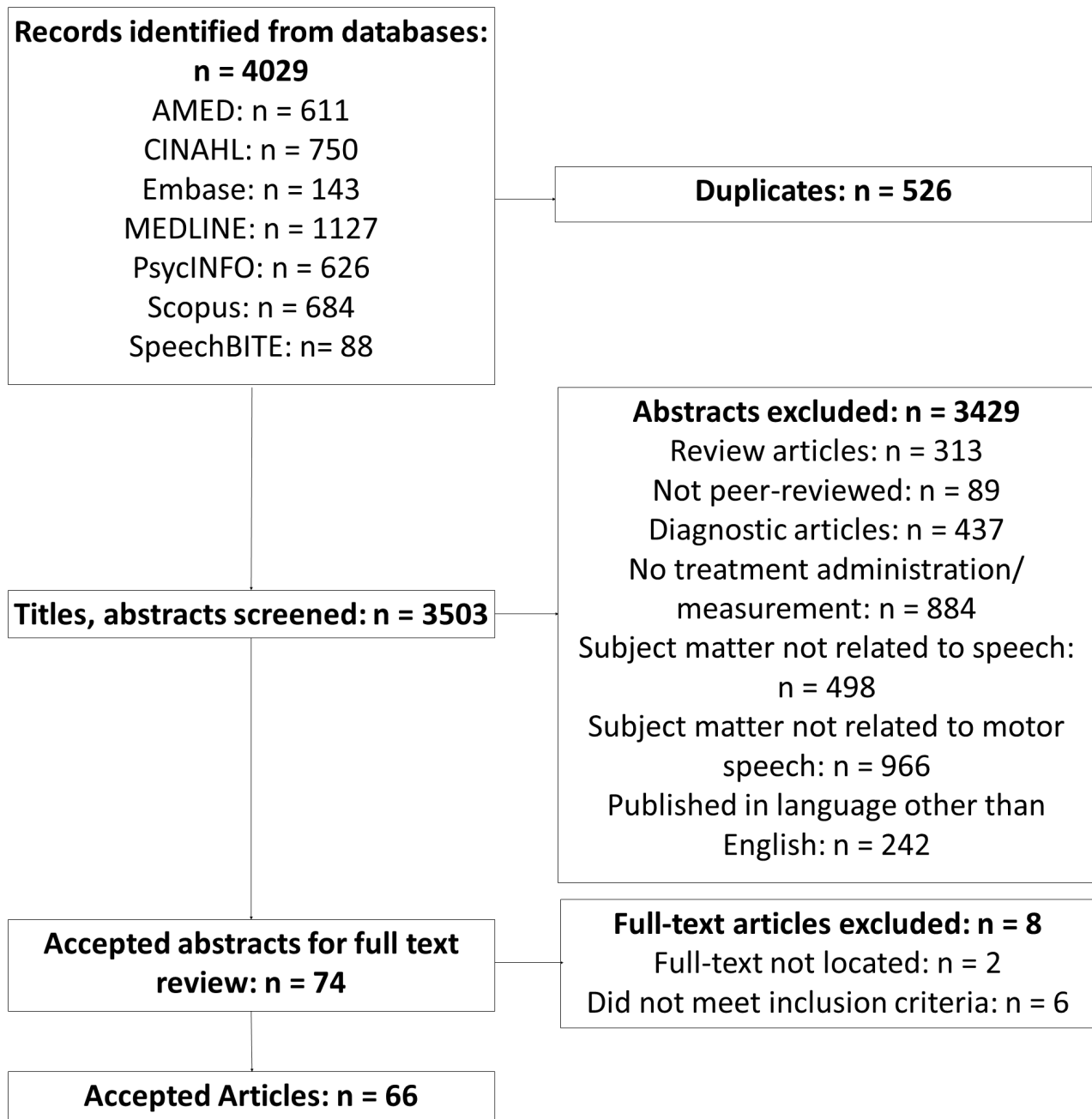
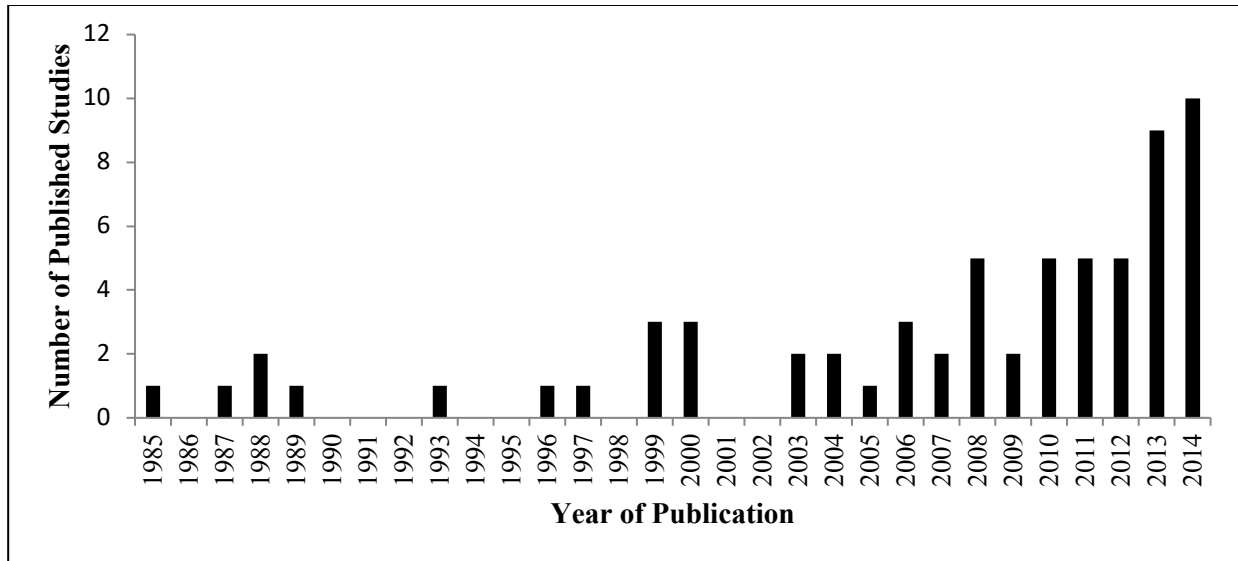
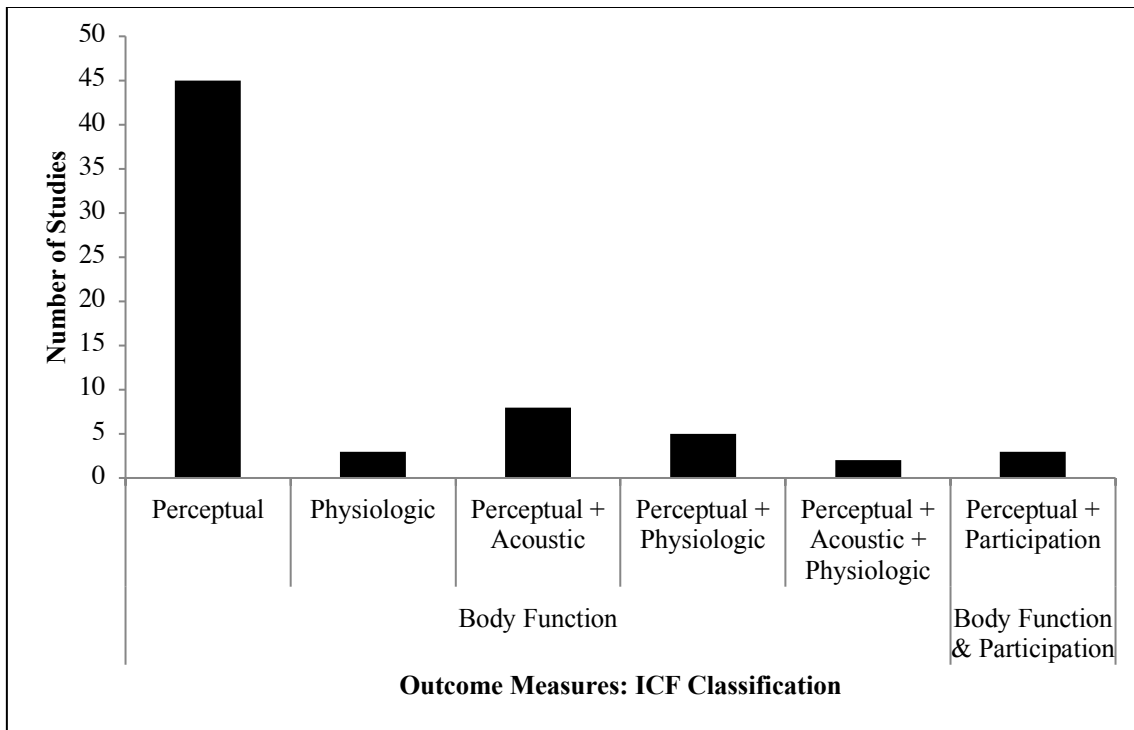


Figure 1. Screening and Review Process.



**Figure 2. Number of published studies from 1985-2014.**



**Figure 3. Number of studies reporting outcome measures used according to ICF-CY classification.**