



Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Ttofari Eecen, K;Eadie, P;Morgan, AT;Reilly, S

Title:

Validation of Dodd's Model for Differential Diagnosis of childhood speech sound disorders: a longitudinal community cohort study

Date:

2019-06-01

Citation:

Ttofari Eecen, K., Eadie, P., Morgan, A. T. & Reilly, S. (2019). Validation of Dodd's Model for Differential Diagnosis of childhood speech sound disorders: a longitudinal community cohort study. *Developmental Medicine and Child Neurology*, 61 (6), pp.689-696. <https://doi.org/10.1111/dmcn.13993>.

Persistent Link:

<https://hdl.handle.net/11343/284396>

DR KYRIAKI TTOFARI EECEN (Orcid ID : 0000-0002-7361-0788)

Article type : Original Article

[1 original article; 1 figure, 4 tables]

Application of Dodd's Model for Differential Diagnosis of childhood speech sound disorders: a longitudinal community cohort study

KYRIAKI TTOFARI EECEN^{1,2,3}

PATRICIA EADIE^{1,4}

ANGELA T MORGAN^{1,2}

SHEENA REILLY^{1,2,5}

1 Speech and Language, Murdoch Children's Research Institute, Parkville, VIC, Australia; **2** Department of Paediatrics, University of Melbourne, Parkville, VIC, Australia; **3** School of Allied Health, Australian Catholic University, Fitzroy, VIC, Australia; **4** Melbourne Graduate School of Education, University of Melbourne, Carlton, VIC, Australia **5** Menzies Health Institute Queensland, Griffith University, Southport, Australia.

Correspondence to Kyriaki Ttofari Eecen, Australian Catholic University, Locked Bag 4115, Fitzroy VIC 3065 Australia. E-mail: kerry.ttofariecten@acu.edu.au

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/dmcn.13993](https://doi.org/10.1111/dmcn.13993)

This article is protected by copyright. All rights reserved

PUBLICATION DATA

Accepted for publication 00th Month 2018

Published online 00th Month 2018

ABBREVIATIONS

- CAS Childhood apraxia of speech
- DEAP Diagnostic Evaluation of Articulation and Phonology
- ELVS Early Language in Victoria Study
- GFTA-2 Goldman-Fristoe Test of Articulation, Second Edition

AIM Dodd's Model for Differential Diagnosis is one of the available clinical diagnostic classification systems of childhood speech sound disorders. Yet we do not understand the validity of this system beyond clinical samples, precluding its application in epidemiological or population-based research. This study aimed to determine the prevalence of subgroups of speech sound disorders in a community sample, relative to past clinical samples, in children speaking standard Australian English.

METHOD We examined speech development in a community-ascertained sample of children at 4 years ($n=1607$). Inclusion for speech sound disorder was a score of less than or equal to 1 standard deviation on a standardized speech test, and/or research assistant concern, and/or three or more speech errors on sounds typically acquired by 4 years. Dodd's model was then applied to 126 children.

RESULTS Data revealed proportions of children across Dodd's diagnostic subgroups as follows: suspected atypical speech motor control (10%); inconsistent phonological disorder (15%); consistent atypical phonological disorder (20%); phonological delay (55%); and articulation

disorder alone (0%). The findings are in line with known prevalence of these subgroups in clinical populations.

INTERPRETATION Our findings provide additional support for speech-language pathologists to use this system in clinical practice for differential diagnosis and targeted intervention of speech sound disorders in children.

[First page footer]

© Mac Keith Press 2018

DOI: 10.1111/dmcn.xxxxx

[Left page footer]

Developmental Medicine & Child Neurology 2018; XX: 000–000

[Right page footer]

Application of Dodd's Model for Differential Diagnosis *Kyriaki Ttofari Eecen et al.*

What this paper adds:

- Dodd's Model for Differential Diagnosis is the first classification system of speech sound disorders to be applicable to both clinical and community cohorts.

[main text]

Children with speech sound disorders differ in their presenting speech symptoms, severity, comorbidities, age of emergence, and response to intervention.^{1,2} These characteristics form speech phenotypes or systems by which children are classified into diagnostic subgroups to inform intervention selection and planning as well as prognosis. Evidence from the literature indicates that subgroups may be associated with specific comorbidities,³ various risk factors,³ and diverse deficits in underlying processing.⁴⁻⁶ Intervention approaches have been designed to target

specific aspects of the speech processing chain and there is evidence that particular subgroups of children make greater gains when undergoing distinct interventions.^{1,7}

Whilst a number of classification systems of speech sound disorders have been described in the literature, no one system is currently accepted within the field of speech-language pathology.^{2,8} The two most relied upon systems are arguably the Speech Disorders Classification System⁹ and Dodd's Model for Differential Diagnosis.² Both were derived from the study of clinical samples and designed to be dynamic and evolve in response to new research, with adjustments to the number of subgroups and terminology over time. Here we focus on the latter model, recently independently reviewed and determined to be a more clinically feasible, inclusive classification compared to other models.⁸ There is also accumulating cross-linguistic research (in Cantonese, English, German, and Putonghua) supporting the validity of Dodd's classification system and pointing towards similar deficits in underlying processing regardless of the language spoken.¹ Further, in regards to clinical practice, in 2002 Dodd et al. published a standardized assessment tool based on this classification system: the Diagnostic Evaluation of Articulation and Phonology (DEAP).¹⁰ The high uptake of this assessment tool by speech-language pathologists provides some evidence for the face validity of the classification system.⁸

The Model for Differential Diagnosis is a descriptive-linguistic classification system that originated from clinical observations⁵ and theoretical modelling. The key subgroups include: (a) inconsistent phonological disorder, (b) consistent atypical phonological disorder, (c) phonological delay, (d) articulation disorder, and (e) childhood apraxia of speech (CAS).²

Evidence to support the Model for Differential Diagnosis is mounting; however, data underpinning this model were derived from clinical samples of a wide age range, consequently influenced by recruitment bias. Research examining the relevance of this model in a population sample, more likely to present with mild cases not typically studied in clinical samples, in addition to severe cases typically obtained for clinical studies, remains elusive. Here we conducted the first study to apply Dodd's Model for Differential Diagnosis to a large community ascertained sample of children aged 4 years in Melbourne, Australia. Further, this work was conducted independently of the developers of the classification system. The study aimed to determine the prevalence of subgroups of speech sound disorders in a community sample, relative to past clinical samples, in children speaking standard Australian English.

METHOD

Data sources

This cross-sectional observational study was embedded within a prospective community ascertained cohort, the Early Language in Victoria Study (ELVS), which aims to examine speech, language, and literacy development in a longitudinal cohort. Children whose parents could speak and understand English to a sufficient level to be able to complete questionnaires were recruited into ELVS between 7.5 and 10 months of age through maternal and child health centres in the metropolitan area of Melbourne, Australia. Children were recruited from geographical areas that were broadly representative of the population of Melbourne. Children were excluded from participation in ELVS at 7.5 to 10 months of age if they had a diagnosed hearing loss or congenital disability (e.g. Down Syndrome). Parents of all participants provided written informed consent to the research and to the publication of the results. The broader ELVS recruitment, strategy, methods, and cohort profile have been documented in detail elsewhere.¹¹⁻¹³

Participants

The initial ELVS cohort consisted of 1910 infants at initial intake at 7.5 to 10 months of age. Participants consenting to the 4-year-old wave of ELVS ($n=1607$) completed a comprehensive face-to-face assessment battery which included measures of speech, language, and non-verbal intelligence. Inclusion criteria signalling eligibility to participate in the speech study were: score on the Goldman-Fristoe Test of Articulation, Second Edition (GFTA-2)¹⁴ less than or equal to 1 standard deviation, and/or clinician verified research assistant concern, and/or child errors on three or more sounds typically acquired at 4 years (see Table I for further detail). Participants meeting inclusion criteria were invited to take part in the current study ($n=270$). Ultimately just over 60 per cent of the sample consented to take part in the current study ($n=163$) and 126 participants (47% of those invited to participate and 77% of those consenting) met criteria for inclusion in the final analysis (Fig. 1). Participant characteristics are described in Table II.

Materials and procedure

All participants, with one exception, completed three standardized assessments in a single session in their home (one participant completed the assessments over two sessions), as detailed below.

Assessments were video-recorded and transcription occurred online and then checked with reference to the video recordings

GFTA-2

The GFTA-2 Sounds-in-Words section is a single word task that elicits consonants in word initial, medial, and final position in most cases.¹⁴ Standard scores and centile ranks are provided for the standardization sample. The GFTA-2 Sounds-in-Words section was used to (1) identify the children eligible to participate in this study and (2) analyse the speech sound errors made by the children to classify them according to subgroups.

The GFTA-2 Stimulability section examines the production of sounds misarticulated in the Sounds-in-Words section. A modified version of this task was administered where only sounds expected to be produced correctly at this age and were produced in error in the GFTA-2 Sounds-in-Words section were stimulated in isolation, in syllable initial position, and syllable final position. The children were asked to watch, listen, and produce the speech sounds three times in each context. The GFTA-2 Stimulability section was used to classify children into the articulation disorder subgroup.

DEAP

The DEAP¹⁰ Inconsistency Assessment was used in this study. This assessment yields an inconsistency score, that is, number of words produced differently across three trials of the same word. Participants' responses were recorded using broad transcription, with the addition of common diacritics.

The DEAP Inconsistency Assessment was used to identify the speech errors made by the participants and to differentiate between consistent atypical phonological disorder and inconsistent phonological disorder.

Verbal Motor Production Assessment for Children

The Verbal Motor Production Assessment for Children¹⁵ is a standardized tool that assesses speech motor function in children aged 3 to 12 years of age. Two Verbal Motor Production Assessment for Children subtests (Focal Oromotor Control and Sequencing) were used in this

study. The Focal Oromotor Control section assessed both non-speech and speech oromotor movements in four areas: jaw, lips, face, and tongue. The preciseness of motor control movements was scored. The Sequencing section assessed the sequence of movements, whether all movements were completed, and whether the movements were in the correct order. A percentage was provided for each subscale and the percentage was interpreted according to a severity rating scale. The Verbal Motor Production Assessment for Children was used in this study to identify any motor control issues in relation to the child's speech sound production difficulty.

Analysis of error patterns

In this study, speech sound error patterns were identified when they occurred three or more times in either of the single word naming tests, namely, the GFTA-2 Sounds-in-Words subtest or the DEAP Inconsistency Assessment. In the DEAP Inconsistency Assessment each word was produced three times. If the error was the same in each trial of the word, the error was counted once. If there were different errors over repeated attempts of the same word, they were recorded as different errors. If there were multiple errors in the one sound, syllable, or word, these were counted as separate errors (e.g. /k/→[d]=fronting and voicing).

Classification of children into subgroups

The criteria for classification into the Model for Differential Diagnosis was based on a hierarchy (highest to lowest) whereby children with oromotor problems combined with inconsistency (suspected atypical speech motor control) were ranked highest in the hierarchy, followed by children with inconsistent errors but no oromotor problems, children with consistent atypical phonological errors, children with consistent typical delayed phonological errors, and lastly children with consistent articulation errors only. This hierarchy is based on most disordered and atypical to least disordered. The hierarchical classification worked as follows. If a child was classified into one of the higher subgroups in the hierarchy (i.e. atypical speech motor control was listed as highest in the hierarchy of disorder), they were precluded from receiving a second classification in another subgroup lower down the rank (refer to the hierarchy discussed above), for example a child with inconsistent speech errors who also made non-age appropriate articulation errors received a single classification of inconsistent phonological disorder rather than a dual classification of inconsistent phonological disorder and articulation disorder. Children

with inconsistent speech errors without oromotor difficulties, regardless of the types of errors (atypical phonological, delayed typical phonological, or articulation errors) were classified into the inconsistent disorder group, because the inconsistency itself is a sign of disorder. Proportions of children with suspected atypical speech motor control or a phonological disorder or delay who made articulation errors concurrently were also reported.

Comparison to cross-linguistic research

A literature search identified cross-linguistic studies that applied Dodd's Model for Differential Diagnosis. The proportion of children from each study who were classified into each of Dodd's subgroups were tabulated to enable cross-linguistic study comparisons.

Ethical approval

Ethical approval to enable the collection of data for this study was obtained from the Royal Children's Hospital Human Research Ethics Committee (#27078/33195) and La Trobe University Ethics Committee (#03-32).

RESULTS

Data were analysed using descriptive statistics.

Subgroup proportions

Of the 163 children who completed assessments in this study, 13 (7.98%) were excluded from classification because they had missing oromotor scores, leaving 150 participants. Of these 150 participants, 24 (16.0%) did not meet the criteria for classification into any of the four subgroups in Dodd's Model for Differential Diagnosis or the suspected atypical speech motor control subgroup, leaving 126 children eligible for this study (Fig. 1). Although 16 of these 24 children had errors of articulation, they were not eligible for the articulation disorder subgroup because the errors were age appropriate according to the normative data used in this study,¹⁴ and/or the errors were variable, and/or the sounds in error could be stimulated. For example, six of these children produced /l/ interdental, and three children produced lateral /ʃ/, /tʃ/, and/or /dʒ/, however, these sounds were not expected to be produced correctly at 4 years of age according to the normative data used in this study. In addition, four children produced interdental /t/, /d/, and/or /n/, however, these were variable errors, that is, they were produced in some contexts but no in others. In order to be classified in the category of articulation disorder, age appropriate speech sounds needed to

be produced incorrectly, and the sounds needed to be non-stimulable. Of the 126 children examined here, 10 per cent of children ($n=13$) presented with atypical speech motor control, 15 per cent ($n=19$) presented with inconsistent phonological disorder, 20 per cent ($n=25$) had consistent atypical phonological disorder, and 55 per cent ($n=69$) had phonological delay. No children presented with an isolated articulation disorder. Of the children in the inconsistent phonological disorder subgroup, 42 per cent ($n=8$) had atypical speech errors and 58 per cent ($n=11$) had delayed but typical speech errors.

Table III reports the proportion of children classified into each of the subgroups. Although no children presented with articulation disorder alone, the proportion of children presenting with articulation errors in each of the other subgroups is listed. The proportion of children with articulation errors in each of the subgroups varied, with the more atypical subgroups having a larger proportion of children with articulation errors (e.g. suspected atypical speech motor control: 77 per cent of children had articulation errors; inconsistent phonological disorder: 58 per cent of children had articulation errors; consistent atypical phonological disorder: 29 per cent of children had articulation errors; and phonological delay: 35 per cent of children presented with articulation errors).

Comparison to cross-linguistic research

Table IV compares cross-linguistic research using Dodd's model with the current study. Taking the most atypical or disordered speech diagnostic subtype first, suspected atypical speech motor control, thirteen children (10%) were classified into this subgroup, that is, made inconsistent errors in the presence of oromotor impairment. Other cross-linguistic studies in the literature did not examine this subgroup.

For the next most atypical subtype, inconsistent phonological disorder, our occurrence rate of 15 per cent in the present study was similar to studies of English at 10 per cent³ and 18 per cent,¹⁶ Cantonese (12%),¹⁷ German (14%),¹⁸ and Putonghua (18%).¹⁹

The next group considered, those with atypical phonological disorder, presented at a rate of 20 per cent across the population; paralleling Broomfield and Dodd's finding of 21 per cent³ in an English speaking clinical sample and Bradford and Dodd's finding of 29 per cent in an Australian English sample¹⁶ and research in other languages: 29 per cent (Cantonese),¹⁷ 20 per cent (German),¹⁸ and 24 per cent (Putonghua).¹⁹

The third and largest subgroup reported here is the phonological delay subgroup (55%), again in line with previous research in both English (58%)³ and cross-linguistic research (47% of Cantonese speakers,¹⁷ 61 per cent of German speakers,¹⁸ and 55 per cent of Putonghua speakers).¹⁹ Bradford and Dodd's 'speech delay' group included children with delayed phonology and/or delayed articulation, and they reported a subgroup prevalence of 43 per cent in their Australian English speaking sample.¹⁶

The final subgroup, articulation disorder, did not align with previous research. In our study there were no participants classified with an articulation disorder, as opposed to 12.5 per cent in a British English sample,³ 20 per cent in a German speaking sample,¹⁸ 3 per cent in Putonghua speakers,¹⁹ and 11.8 per cent in Cantonese speakers.¹⁷

DISCUSSION

A number of classification systems of speech sound disorders have been described in the literature, yet none are universally accepted by speech pathologists or other health professionals. Classification systems are important for differential diagnosis, planning of intervention,¹ identification of phenotypes for epidemiological and generic research,²⁰ and for the collection of statistics.²¹ Evidence to endorse the Model of Differential Diagnosis has been accumulating over the past two decades since the model was proposed,²² yet data are based on clinical samples, which suffer from recruitment bias. To reduce the chance of bias, community samples are recommended.²³ This is the first research to apply any classification system of speech sound disorders to a community sample of children.

Similar prevalence rates of diagnostic subgroups were found here in alignment with other international clinical research. A point of distinction from our data set compared with previous clinical studies of Dodd's model is that no participant received a classification of isolated articulation disorder. This is in contrast to other cross-linguistic research that reported prevalence rates ranging from 3 per cent (Putonghua)¹⁹ to 14 per cent (English).⁵ It is known that the prevalence of subgroups of speech sound disorders can vary with age, for example, children with phonological disorder tend to be referred earlier, between 3 and 4 years, whereas children with articulation disorder are likely to be referred between 7 and 11 years.³ Children in this research were all 4 years old. As a point of contrast, the participants in the other studies supporting Dodd's model comprised a wide age range, specifically, 0 to 11 years or above,³ 2 years 7 months to 7

years 7 months,¹⁸ 2 years 8 months to 7 years 6 months,¹⁹ and 3 years 6 months to 5 years 4 months.¹⁷ If the children in our study were older, perhaps a proportion would have been categorized with articulation disorder, as their articulation errors would not be considered age appropriate. Some children in the current study made errors of articulation; however, as age appropriateness is considered when diagnosing articulation disorder, they were not classified as having an articulation disorder at 4 years of age. In clinical practice, it is important to consider speech acquisition norms when diagnosing speech sound disorders, whether the suspected speech sound disorder is phonological or articulatory in nature. More longitudinal research to investigate the trajectories of subgroups of speech sound disorders over time would contribute to our knowledge of whether children switch between subgroups as they age.

The most disordered subgroup, suspected atypical speech motor control, consisted of 13 children (10%) who made inconsistent errors in the presence of oromotor impairment. This finding aligns with a US-based study that found 10.3 per cent of 97 cases had ‘motor speech disorder – not otherwise specified’,²⁴ a group differentiated from CAS and dysarthria. Whilst the presence of CAS has been estimated to occur as infrequently as one to two children per 1000,²⁵ there has been no epidemiological population-based study of this condition, making reliable comparison impossible. Oral motor impairment and inconsistent speech errors, as assessed here, are only two possible features of speech motor dysfunction. Children in our study were not examined for the presence of prosodic errors or coarticulation errors, two core consensus-based diagnostic features of CAS²⁶ and we would not suggest they have CAS based on the features identified here. Yet our data have provided a valuable starting point for noting the proportion of the general population of children to present with some features of speech motor dysfunction at an earlier age; although whether these cases would go on to present with chronic speech motor dysfunction remains unknown.

Dodd’s model is inclusive of delay or disorders of articulation and phonology. The model was not designed for use with children with motor speech disorder. Hence there are limitations of applying this model to broader populations who may also present with rarely occurring motor speech disorders of CAS and dysarthria. Whilst CAS has been mentioned at times in the Dodd model, dysarthria has not been included in any iteration and is a consideration for future expansions of the model.

Two of the three standardized measures, the GFTA-2 and the Verbal Motor Production Assessment for Children, did not have Australian normative data and this is acknowledged as a limitation to the research. A second limitation is that inter- and intrarater reliability of the transcription was not conducted. Finally, sampling context can impact on speech errors, and this study examined speech in single word contexts. Future research could investigate the classification of speech sound disorders using connected speech samples.

The congruence between our study and other studies on the prevalence of Dodd's subgroups provides support for speech-language pathologists to use Dodd's system in clinical practice for differential diagnosis of children with suspected speech sound disorders. As research accumulates that the unique subgroups have unique underlying cognitive profiles⁴ and benefit from different intervention approaches,^{1,7} this provides additional rationale for using this system in clinical practice for targeted intervention that will result in more efficient outcomes for individuals.

Future research could replicate and compare different classification systems of speech sound disorders, for example, Dodd's model and Shriberg's Speech Disorders Classification System.⁹ Here we demonstrated that a classification system of speech sound disorders appears highly applicable to the community, as well as clinical cohorts, suggesting the potential use of Dodd's model in future epidemiological or population-based studies of child speech sound disorders.

Acknowledgements

We would like to thank all the children and parents who took part in ELVS. This study was a component of the first author's PhD research and has been funded by the Murdoch Children's Research Institute and the Australian National Health and Medical Research Council (NHMRC project grants 237106, 436958, 1041947). The authors have stated that they had no interests that might be perceived as posing a conflict or bias.

REFERENCES

1. Crosbie S, Holm A, Dodd B. Intervention for children with severe speech disorder: a comparison of two approaches. *Int J Lang Commun Disord* 2005; **40**: 467–91.

2. Dodd B. Differential diagnosis of pediatric speech sound disorder. *Curr Dev Disord Rep* 2014; **1**: 189–96.
3. Broomfield J, Dodd B. The nature of referred subtypes of primary speech disability. *Child Lang Teach Ther* 2004; **20**: 135–51.
4. Waring R, Eadie P, Rickard Liow S, Dodd B. The phonological memory profile of preschool children who make atypical speech sound errors. *Clin Linguist Phon* 2018; **32**: 28–45.
5. Dodd B, Leahy J, Hambly G. Phonological disorders in children: underlying cognitive deficits. *Br J Dev Psychol* 1989; **7**: 55–71.
6. Bradford A, Dodd B. The motor planning abilities of phonologically disordered children. *Int J Lang Commun Disord* 1994; **29**: 349–69.
7. Dodd B, Bradford A. A comparison of three therapy methods for children with different types of developmental phonological disorder. *Int J Lang Commun Disord* 2000; **35**: 189–209.
8. Waring R, Knight R. How should children with speech disorders be classified? A review and critical evaluation of current classification systems. *Int J Lang Commun Disord* 2013; **48**: 25–40.
9. Shriberg LD, Fourakis M, Hall SD, et al. Extensions to the Speech Disorders Classification System (SDCS). *Clin Linguist Phon* 2010; **24**: 795–824.
10. Dodd B, Hua Z, Crosbie S, Holm A, Ozanne A. Diagnostic evaluation of articulation and phonology. London UK: The Psychological Corporation, 2002.
11. Reilly S, Eadie P, Bavin EL et al. Growth of infant communication between 8 and 12 months: a population study. *J Paediatr Child Health* 2006; **42**: 764–70.
12. Reilly S, Wake M, Ukoumunne OC, et al. Predicting language outcomes at 4 years of age: findings from Early Language in Victoria Study. *Pediatrics* 2010; **126**: e1530–7.
13. Reilly S, Cook F, Bavin EL, et al. Cohort profile: the Early Language in Victoria Study (ELVS). *Int J Epidemiol* 2018; **47**: 11–20.

14. Goldman R, Fristoe M. Goldman-Fristoe Test of Articulation, Second Edition. Circle Pines, MN: American Guidance Service, 2000.
15. Hayden D, Square P. Verbal motor production assessment for children. San Antonio, TX: The Psychological Corporation, 1999.
16. Bradford A, Dodd B. Do all speech disordered children have motor deficits? *Clin Linguist Phon* 1996; **10**: 77–101.
17. So LKH, Dodd B. Phonological disordered Cantonese-speaking children. *Clin Linguist Phon* 1994; **8**: 235–55.
18. Fox AV, Dodd B. Phonologically disordered German-speaking children. *Am J Speech Lang Pathol* 2001; **10**: 291–307.
19. Hua Z, Dodd B. Putonghua (modern standard Chinese)-speaking children with speech disorder. *Clin Linguist Phon* 2000; **14**: 165–91.
20. Shriberg LD, Lewis BA, Tomblin JB, McSweeney JL, Karlsson HB, Scheer AR. Toward diagnostic and phenotype markers for genetically transmitted speech delay. *J Speech Lang Hear Res* 2005; **48**: 834–52.
21. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. Washington, DC: American Psychiatric Association, 2000.
22. Dodd B. Procedures for classification of subgroups of speech disorder. In Dodd B, editor. *Differential diagnosis and treatment of children with speech disorder*. London: Whurr, 1995: 49–64.
23. Goodyer, IM. Language difficulties and psychopathology. In Bishop DV, Leonard LB, editors. *Speech and language impairments in children: causes, characteristics, intervention and outcome*. East Sussex: Psychology Press, 2000: 226–43.

24. Vick JC, Campbell TF, Shriberg LD, et al. Data-driver subclassification of speech sound disorders in preschool children. *J Speech Lang Hear Res* 2014; **57**: 2033–50.
25. Shriberg L, Aram DM, Kwiatkowski J. Developmental apraxia of speech I: descriptive and theoretical perspectives. *J Speech Lang Hear Res* 1997; **40**: 273–85.
26. American Speech-Language-Hearing Association Ad-Hoc Committee on Apraxia of Speech in Children. Childhood apraxia of speech: Technical Report [Internet]. 2007 Available at: <http://www.asha.org/policy/tr2007-00278.htm> (accessed 21 April 2017).

[figure legend]

Figure 1: Flowchart of participants from baseline (8 months) to 4 years (denominator for percentages is number participating at baseline [$n=1910$]). Figure modified from Reilly et al.¹³

Table I: Eligibility criteria for invitation to participate in the study

| Assessment | Criteria |
|---|--|
| GFTA-2 Sounds in Words subtest AND/OR | Standard score ≤ 1 SD below the mean. |
| GFTA-2 Sounds in Words subtest AND/OR | Incorrect production of three or more of the following consonants and/or consonant clusters expected at 4 years at word initial position: p, m, n, w, h, b, g, k, f, d, t, kw ('expected sounds'). These consonants and consonant clusters were produced at word initial position by 85% of the GFTA-2 standardization sample at 4 years of age. ¹⁴ |
| GFTA-2 Sounds in Words subtest and/or conversational speech | Researcher concern, for example, reduced intelligibility in conversation, vowel errors, or atypical errors. |

GFTA-2, Goldman-Fristoe Test of Articulation, Second Edition; SD, standard deviation.

Table II: Participant characteristics

| Characteristic | Completed speech assessments ($n=163$) | Participated in final analysis ($n=126$) |
|----------------|--|--|
| | n (%) | |
| Male | 90 (55.2) | 71 (56.3) |
| Twin birth | 5 (3.1) | 3 (2.4) |

| | | |
|--------------------------------------|---------------|---------------|
| Preterm birth ^a | 12 (7.4) | 7 (5.6) |
| Positive family history ^b | 58 (35.6) | 43 (34.1) |
| NESB | 0 (0) | 0 (0) |
| Maternal education | | |
| 11 years of school | 13 (8.0) | 9 (7.1) |
| 12 years of school | 28 (17.2) | 25 (19.8) |
| 13 years of school | 78 (47.9) | 60 (47.6) |
| University/postgraduate | 44 (27.0) | 32 (25.4) |
| Mean (SD) | | |
| SEIFA ^c | 1040.2 (56.2) | 1037.3 (56.0) |

^aPreterm birth \leq 36 weeks gestation; ^bfamily history of communication problems; ^cSocio-Economic Indexes for Areas (SEIFA) Index of Disadvantage. NESB, non-English speaking background; SD, standard deviation.

Table III: Subgroup proportions using Dodd's Model for Differential Diagnosis

| Subgroup | Description | <i>n</i> (%) | <i>n</i> (%) with |
|----------|-------------|--------------|-------------------|
|----------|-------------|--------------|-------------------|

| | | belonging to this subgroup, Total <i>n</i> =126 | articulation errors ^a |
|--|---|---|-------------------------------------|
| Suspected atypical speech motor control ^b | Errors were inconsistent (words produced differently $\geq 40\%$ of the time based on 25 words generated three times on the DEAP Inconsistency Assessment; variations between a correct production and a developmentally age appropriate error were not counted as inconsistent when calculating the inconsistency score), and oromotor problems on the VMPAC. | 13 (10%) | 10 (77%) |
| Inconsistent phonological disorder | Errors were inconsistent (words produced differently $\geq 40\%$ of the time based on 25 words generated three times on the DEAP Inconsistency Assessment; variations between a correct production and a developmentally age appropriate error were not counted as inconsistent when calculating the inconsistency score) and no oromotor problems on the VMPAC. | 19 (15%) | 11 (58%) |
| Consistent atypical phonological disorder | The presence of at least one atypical (non-developmental) ^c phonological error pattern (e.g. backing) and errors were consistent (produced differently $< 40\%$ of the time based on 25 words generated three times on the DEAP Inconsistency Assessment). The child may have also had typical delayed ^d or typical age appropriate phonological error patterns or articulation errors. | 25 (20%) | 11 (44%) |
| Phonological delay | The presence of at least one typical phonological error pattern that was not age appropriate (delayed). ^d Errors were consistent (produced differently $< 40\%$ of the time based on 25 words generated three times on the DEAP Inconsistency | 69 (55%) | 24 (35%) |

| | | | |
|-----------------------|--|--------|----------------|
| | Assessment). May have also presented with articulation errors. | | |
| Articulation disorder | The presence of only articulation error/s that were not age appropriate ^e and the sounds in error were not stimulable. Errors were consistent (produced differently <40% of the time based on 25 words generated three times on the DEAP Inconsistency Assessment). | 0 (0%) | Not applicable |

^aArticulation errors included errors on consonants expected at 4 years of age (consonants produced by 85% of the Goldman-Fristoe Test of Articulation, Second Edition [GFTA-2] standardization sample at word initial position at 4 years of age in a ‘perceptually acceptable’ manner)¹⁴ or distortions regardless of the child’s age (e.g. lateral /s/, however, correct production of /s/ was not in the list of GFTA-2 expected consonants at 4 years of age). ^bThe definition of suspected atypical motor control in this study is different to Dodd’s criteria.² Dodd’s fifth subgroup is Childhood Apraxia of Speech, described as ‘inconsistency, oromotor signs (e.g. groping, difficulty sequencing articulatory movements), slow speech rate, disturbed prosody, short utterance length, poorer performance in imitation than spontaneous production’.² ^cThe atypical patterns were the ones listed in the Diagnostic Evaluation of Articulation and Phonology (DEAP);¹⁰ the criteria to determine whether a process was atypical was based on occurrence in <10% of the normative sample; when a child had typical (age appropriate or delayed) and atypical phonological errors, this child received a classification of consistent atypical phonological disorder. ^dThe age appropriateness of phonological error patterns was determined using the normative data of the DEAP.¹⁰ ^eThe determination of whether articulation errors were age appropriate was based on the GFTA-2 norms (consonants produced by 85% of the GFTA-2 standardization sample at word initial position at 4 years of age in a ‘perceptually acceptable’ manner).¹⁴ VMPAC, Verbal Motor Production Assessment for Children.

Table IV: Cross-linguistic research comparison. Applying Dodd’s Model for Differential Diagnosis

| Study, language | Age range (y:mo) | <i>n</i> | Recruitment | Subgroup prevalence (%) | | | | |
|--|------------------|----------|--|-------------------------|------|------|-----------------|------|
| | | | | Other | IPD | CAPD | PD | AD |
| Bradford and Dodd, ¹⁶ Australian English | 3:2–6:7 | 51 | Referred by speech-language pathologists, most children were on waiting lists for assessment and therapy | 10 ^c | 18 | 29 | 43 ^d | |
| Broomfield and Dodd, ³ British English | 0–11+ | 320 | Referred to a therapy service | Not reported | 9.4 | 20.6 | 57.5 | 12.5 |
| Fox and Dodd, ¹⁸ German, | 2:7–7:7 | 100 | Referred with a suspected SSD | Not reported | 12 | 17 | 51 | 20 |
| Hua and Dodd, ¹⁹ Putonghua ^a | 2:8–7:6 | 33 | Identified by teachers with atypical speech | Not reported | 18.2 | 24.2 | 54.5 | 3 |
| So and Dodd, ¹⁷ Cantonese | 3:6–5:4 | 17 | Referred to a university phonology clinic | Not reported | 11.8 | 29.4 | 47.1 | 11.8 |
| Ttofari Eecen et al. (current study), Australian English | 4:0–4:7 | 126 | Community ascertained sample | 10 ^b | 15 | 20 | 55 | 0 |

^aPutonghua is modern standard Chinese; ^bsuspected atypical speech motor control; ^cDevelopmental Verbal Dyspraxia; ^din the Bradford and Dodd¹⁶ study, ‘speech delay’ consisted of delayed phonology and/or delayed articulation. IPD, inconsistent phonological disorder; CAPD, consistent atypical phonological disorder; PD, phonological delay; AD, articulation disorder; SSD, speech sound disorder.

