Burr, S., Harding, S., Wren, Y., & Deave, T. (2020). The Relationship between Feeding and Non-Nutritive Sucking Behaviours and Speech Sound Development: A Systematic Review. *Folia Phoniatica et Logopaedica*. <https://doi.org/10.1159/000505266>

Peer reviewed version

Link to published version (if available):
[10.1159/000505266](https://doi.org/10.1159/000505266)

[Link to publication record in Explore Bristol Research](#)
PDF-document

This is the author accepted manuscript (AAM). The final published version (version of record) is available online via Karger Publishers at <https://www.karger.com/Article/Abstract/505266> . Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research

General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:
<http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>

The relationship between feeding and non-nutritive sucking behaviors and speech sound development: A systematic review

Samantha Burr^{1*}, Dr. Sam Harding², Dr. Yvonne Wren², Dr Toity Deave³

¹ University of the West of England, Bristol, UK.

² Bristol Speech and Language Therapy Research Unit, North Bristol NHS Trust, UK & University of Bristol, Bristol, UK.

³ University of the West of England, Bristol, UK.

Short Title: SUCKING AND SPEECH SOUND DEVELOPMENT: SYSTEMATIC REVIEW

*Corresponding Author

Samantha Burr

Faculty of Health and Applied Sciences

University of the West of England

Glenside Campus

Blackberry Hill

BS16 1DD

Bristol

Tel: 44 (0)117 32 88534

Fax:

E-mail: sam.burr@uwe.ac.uk

Keywords: systematic review, speech sound development, speech disorder, infant feeding, non-nutritive sucking.

32 1. Abstract

33 Background

34 Children with and without Speech Sound Disorders (SSD) are exposed to different patterns of infant
35 feeding (breast/bottle feeding) and may or may not engage in non-nutritive sucking (NNS)
36 (pacifier/digit sucking). Sucking and speech use similar oral musculature and structures, therefore it is
37 possible that early sucking patterns may impact early speech sound development. The objective of this
38 review is to synthesise the current evidence on the influence of feeding and NNS on the speech sound
39 development of healthy full-term children.

40

41 Summary

42 Electronic databases (Pubmed, NHS CRD, EMBASE, MEDLINE) were searched using terms specific to
43 feeding, NNS and speech sound development. All methodologies were considered. Studies were
44 assessed for inclusion and quality by two reviewers. Of 1031 initial results, 751 records were screened
45 and five primary studies were assessed for eligibility, four of which were included in the review.
46 Evidence from the available literature on the relationship between feeding, NNS and speech sound
47 development was inconsistent and inconclusive. An association between NNS duration and SSDs was
48 the most consistent finding, reported by three of the four studies. Quality appraisal was carried out
49 using the Appraisal Tool for Cross-Sectional Studies (AXIS). The included studies were found to be of
50 moderate quality.

51

52 Key Messages

53 This review found there is currently limited evidence on the relationship between feeding, NNS and
54 speech sound development. Exploring this unclear relationship is important because of the overlapping
55 physical mechanisms for feeding, NNS and speech production, and therefore the possibility that feeding
56 and/or sucking behaviours may have the potential to impact on speech sound development. Further

57 high-quality research into specific types of SSD using coherent clinically relevant assessment measures
58 is needed to clarify the nature of the association between feeding, NNS and speech sound development,
59 in order to inform and support families and healthcare professionals.

60

61 2. Introduction

62 2.1. Background

63 There is much discussion and debate in the current literature on the advantages of breastfeeding over
64 bottle-feeding, with positive cognitive outcomes often cited for language in later childhood [1-4].

65 However, evidence on the influence of feeding type on speech sound development is less readily
66 available (e.g., Fox et al. 2002 [5]). Infant feeding (breast, bottle and mixed feeding) and non-nutritive
67 sucking (NNS) (pacifier/digit sucking) are typically concurrent practices in the early lives of infants
68 across the world [6-8]; therefore it is important to consider both of these with regard to the impact on
69 speech sound development. Evidence for an indirect detrimental impact of NNS on speech sound
70 development is indicated with regard to dentition [9-10] and hearing loss resulting from otitis media
71 [11-12]; however the question of a potential direct impact of NNS on speech sound development is of
72 interest due to the shared physical oral mechanisms of these two processes.

73 The mechanisms for successful bottle and breastfeeding have been described and compared [13], and
74 significant differences in sucking frequency, pressure and muscle activity have been identified and
75 examined [14-15]. Speech develops after these feeding mechanisms have become established and,
76 given the shared musculature between speech and sucking, it is possible that speech sound
77 development could be influenced by infants' early experiences of feeding and NNS [16-17]. If this were
78 the case, there may be observable differences in the speech sound production of children who have
79 different patterns of feeding and NNS. Furthermore, it may be that different patterns of feeding and NNS
80 are associated with Speech Sound Disorder (SSD). In taking a mechanistic view of speech sound
81 development, it is imperative to include both feeding and NNS in this review as either and both have
82 significant influence on infants' early sucking experience. While some studies have described feeding,
83 NNS and anatomical development in terms of atypical dentition and general oral development [18], the
84 evidence of the relationships between the effects of feeding, NNS and speech sound development
85 requires specific exploration to inform our understanding of these closely associated physical
86 mechanisms. Many studies report evidence against a relationship between speech and non-speech
87 mechanisms [19-23]. However, the individual work undertaken in such laboratory or clinic based

pieces of research are not compatible with understanding the complex development of that skillset in the very young child. The complexity of the development taking place during the early postnatal period means that consideration must be given to all three factors (feeding, NNS and speech sound development) as they are distinct but could also overlap and build on each other. Oral feeding from birth through infancy is a highly intensive and enduring physical behaviour. In addition, non-nutritive sucking behaviours often occur concurrently and, can be comparably intensive and enduring from birth through to early childhood. Therefore, these very early intensive sucking behaviours (nutritive and non-nutritive) may have an inevitable influence on the development of motor control and sensorimotor feedback systems for these oral mechanisms and muscle groups. As such, it may be deemed improbable that any use of the oral musculature and articulators, for the purposes of subsequent speech development, from babble through to more refined speech sound productions, could occur in an entirely sterile way. Indeed, there is recent evidence that weak sucking in infants as young as four weeks of age is a significant predictor of persistent SSD at age 8 years [17]. Bunton [21] states that speech motor control is internally driven relating vocal tract changes to acoustic targets, while non-speech motor control is driven by external visuo-spatial or proprioceptive targets. However, within the very nature of clinical therapy Speech Pathologists routinely employ visuo-spatial and proprioceptive cues to support speech production with a high frequency of success [24-26]. It can, therefore, be argued that speech and non-speech motor control cannot reasonably be considered entirely distinct. Indeed, some studies suggest a continuum for development between speech and non-speech tasks [27].

107

The aim of this systematic review is to synthesise the available evidence about the relationships between feeding (breastfeeding, bottle feeding, mixed feeding methods), NNS behaviours and speech sound development and the incidence of SSD in children from birth to early childhood. This review addresses the following key questions:

- Is there evidence that infant feeding methods and NNS impact the way young children develop speech sounds?

- Is there evidence that children who experience different patterns of NNS as babies have different outcomes in their speech sound development, such as SSD?

This systematic review investigates the literature on feeding and NNS in the development of speech sounds in healthy, full-term, preschool children. For the avoidance of confusion, the term “speech sound development” is consistently written in full, whereas the term “Speech Sound Disorder” is consistently abbreviated to SSD.

2.2. Methods

The review strategy was adapted from the Cochrane Collaboration systematic review methodology and uses a narrative synthesis [28] and guidance from Petticrew & Roberts [29]. A narrative synthesis approach was deemed most appropriate due to the mixed nature (qualitative and quantitative) of the data likely to be retrieved from the included papers. The review was registered on the PROSPERO database (CRD42018106268).

2.3. Identification of Selection Criteria

The Booth & Fry-Smith [30] PICO model (population, intervention, comparison, outcome) guided the development of the search strategy. The population of interest was children from birth into early childhood, with or without identified SSD. Table 1 below lists the inclusion and exclusion criteria. Papers that reported samples including children born prematurely (more than 15% of the total sample), or those with diagnosed congenital disorders, identified learning difficulties, sensorineural hearing loss, or populations that had received speech therapy intervention as part of the reported study were excluded from the review as these factors could also impact on speech sound development. This follows principles set out in similar systematic reviews in comparable cohorts (e.g., Roulstone et al. 2015 [31]). The intervention (behaviour) of interest was infant feeding, comparing outcomes in speech sounds across three comparator interventions – breast-feeding, bottle-feeding and mixed feeding. A second analysis considered presence or absence of NNS and its associations with speech sound outcomes. Only papers reporting both feeding and NNS with regard to speech sound development were included in this review. This systematic review of the current evidence base of journals and

140 abstracts in this topic area considered all methodologies and settings. Globally accessible articles were
141 examined, providing that they had been published, or were available, in the English language.

142 **2.3.1. Outcomes of Interest**

143 All included studies were required to include an outcome for speech sound development, whether
144 qualitative (e.g., descriptive responses to parent questionnaires) or quantitative (e.g., statistical results
145 obtained from objective clinical speech sound assessments).

146

147 [Table 1 about here]

148 **2.4. Search Strategy**

149 The search strategy was designed in consultation with all authors and the search terms following a
150 review of the Cochrane database, PROSPERO and database of abstracts of reviews of effectiveness.
151 Discussions with a specialist speech and language pathologist working with children with SSD
152 facilitated the identification of specific search terms relevant to all possible and appropriate
153 terminology for speech sound development and SSD. A combination of 'free text' terms with Boolean
154 operators and truncations were used as follows:

155 **2.4.1 Feeding Search Term**

156 *(((((((bottlefe*) OR (bottle-fe*) OR (bottle fe*)))) AND (((breastfe*) OR (breast-fe*) OR (breast fe*))))))*

157 **2.4.2 Non-Nutritive Sucking Search Term**

158 *(((dumm*) OR (pacifier*) OR (non-nutritive sucking)))*

159 **2.4.3 Speech Search Term**

160 *(((phon*) OR (speech) OR (speech disorder*) OR (speech impairment*) OR (speech sound disorder*) OR
161 (speech sound difficult*) OR (speech retard*) OR (speech delay*) OR (speech disabilit*) OR (speech
162 handicap*) OR (speech problem*))))))*

163 **2.5. Findings of the Search Process**

164 **2.5.1. Traditional Search Strategy**

165 The process and screening results for the database searches are described in Figure 1. Six separate
166 searches were conducted in electronic databases: Pubmed, (inc. PubMed Health, PubMed Central and
167 NCBI Bookshelf Database), NHS CRD <https://www.crd.york.ac.uk/CRDWeb/>, OVID full text Journals,
168 Embase 1974 to 2018 week 31, Ovid MEDLINE(R) and Epub Ahead of print, In-Process & Other Non-
169 Indexed Citations, and Daily 1946 to July 27, 2018, CINAHL (inc. MEDLINE, Chicano Database, Child
170 Development and Adolescent Studies and AMED (Allied and Complementary Medicine) 1985 to July
171 2018. The PRISMA checklist [32] was followed and a flow chart (Figure 1) details the process of article
172 selection from the formal database searches. Of 981 results, 702 papers were screened (following
173 duplicate removal) and 698 were excluded in accordance with the validity criteria (Table 1). Four full-
174 text articles were assessed for eligibility, two of which were excluded as they did not meet the inclusion
175 criteria. All references from the four full-text papers were reviewed to check for additional articles. No
176 appropriate papers were identified for inclusion in the full paper review stage. Only two papers were
177 retained for inclusion in the narrative synthesis.

178

179 [Figure 1 about here]

180 **Figure 1. PRISMA Flow Chart for Traditional Database Searches**

181

182 2.5.2. Novel 'Google' Search Strategy

183 An additional search of Google, a major search engine [33], was conducted using the simplified search
184 term [infant feeding, speech development and sucking]. Figure 2 shows the PRIMSA flow chart
185 detailing the process of article screening and selection based on the Google search. The first five pages
186 of the Google search, which represented 50 results, were screened for title relevance. Of these results,
187 one article/post was a duplicate from the original formal database search and 48 were rejected; one
188 paper was identified for inclusion in the full article review (see Figure 2). The Google search results
189 also included a website with a bibliography, which was scrutinised. All of the papers had been
190 previously identified in other searches.

191 In addition to the above searches, one unpublished paper [34], identified through discussions with
192 review colleagues, was included in the screening process and subsequently retained. A total of four
193 papers were included in the full review: two identified from traditional database searches, one from
194 Google and one unpublished paper.

195

196 [Figure 2 about here]

197 **Figure 2. PRISMA Flow Chart for Google Search Engine**

198

199 **2.6. Search Validation**

200 The first author (SB) excluded irrelevant articles by screening titles and abstracts (see Figure 1). The
201 remaining abstracts were fully reviewed by the first author and SH independently. Any disagreements
202 were resolved through discussion and when consensus was not met the article was included in the next
203 stage. Four full text articles were then retrieved and further considered against inclusion criteria by the
204 SB and SH.

205 **2.7. Data Extraction**

206 The data extraction was undertaken by the first two reviewers using an adapted version of the
207 published data extraction template for Randomised Control Trials (RCT) and non-RCTs [35]. The
208 results from the data extraction stage were discussed and agreed between the first and second
209 reviewers.

210 **2.8. Quality Appraisal**

211 Selection of the quality appraisal tool was undertaken once the final list of included papers had been
212 obtained and reviewed for their methodology. All four papers used a cross-sectional study design and
213 subsequently the Appraisal Tool for Cross-Sectional Studies (AXIS) was used by SB and SH [36]. This
214 tool was selected as the most appropriate for assessing the quality of the included papers because it has
215 been specifically designed for the critical and quality appraisal of cross-sectional studies. The AXIS

comprises 20 questions to appraise each paper's introduction, methods, results, discussion and other issues related to bias and ethical conduct. The authors assigned a score to each of the categories. 2 for papers that clearly provide the information required by the AXIS tool, 1 if this information is partially present, but not clearly stated, and 0 if it is not present at all. This led to a maximum possible score of 40 on the AXIS. The quality appraisal of the included papers was completed separately by SH and SB and scoring consensus was reached following discussion.

Table 2 below summarises the total quality scores awarded to each paper. Baker *et al* [34] scored highest in the quality appraisal with almost 75% of the maximum score, while Pereira *et al* [37] and Vieira *et al* [38] obtained the lowest scores with just over 50% of the maximum.

[Table 2 about here]

2.8. Data Synthesis

Heterogeneity precluded meta-analysis; therefore, a narrative synthesis was used which summarised the findings descriptively and guided the synthesis.

3. Results

3.1. Review of the Data

The following section describes the presentation of the data in each of the four included papers.

3.1.1. Statistical Techniques

Variation was found in the statistical approaches employed across the four papers (Table 3). In their data tables^{[39](p.5-6)} Barbosa *et al* [39] provided overall calculated probability, or p values, relating to each variable when compared with age or speech sound assessment classification. Specific p values corresponding to the reported odds ratios and confidence intervals for more specific associations presented in the results are not provided. In contrast, Vieira *et al* [38] consistently reported associated odds ratios (ORs) with 95% confidence intervals (CIs) alongside their p values. Baker *et al* [34] and Pereira *et al* [37] only reported p values.

241 3.1.2. Methodological Approaches

242 All four included papers used parent/carer questionnaires to collect data on participant feeding and
243 sucking histories. Both Vieira *et al* [38] and Pereira *et al* [37] reported the use of a ‘structured
244 interview’ approach. Information is not provided on the interviewer or recording of these data.
245 Barbosa *et al* [39] and Baker *et al* [34] distributed self-administered parent questionnaires. While all
246 studies collected data on presence and duration of feeding and NNS behaviours, only Barbosa *et al* [39]
247 collected data on the frequency of bottle-feeding and pacifier use.

248 All except one of the papers attempted objective assessment of the participants’ speech sound
249 development. Pereira *et al* [37] based their findings solely on parent report and provided no objective
250 measure for the speech sound development of the children in their study. Although Pereira *et al* [37]
251 referenced specific phonemes in their definition of ‘speech disorder’ or ‘speech changes’, the single item
252 on their parent questionnaire relating to this measure required only a binary yes/no response and
253 asked simply “difficulties / changes in speech?” without reference to specific sounds or clarification on
254 the authors’ intended meaning of ‘speech’. As such it is difficult to draw firm conclusions on the basis of
255 this paper due to the potential for variation in respondents’ concept of ‘speech’, and therefore
256 inconsistency in their responses.

257 3.1.3. Sample Populations

258 Details of the population samples for each study are provided in Table 3. Only two of the four papers
259 [34, 38] reported any use of exclusion criteria in their sample definitions, and only one of these, hearing
260 loss, was common to both studies (see Table 4). Baker *et al* [34] reported the most comprehensive
261 exclusion criteria, including genetic, medical and developmental factors known to have some
262 association with SSD.

263 Table 3. Summary Table of Included Studies.

264 [Table 3 about here]

[Table 4 about here]

3.1.4. Definition of SSD

A key challenge for this review was the disparity in what is meant by the term ‘Speech Sound Disorder’ between papers. Barbosa *et al* [39] used the terms ‘speech disorder(s)’ and ‘speech processing’, the former of which they broadly describe as having the potential to “*impair communication and literacy*”^{[39](p2)}. Specific reference to distinct types of SSD was not made; however through their use of the Brazilian speech sound assessment TEPROSIF [40] to “*determine the type and number of errors in the child-age related phonological processes*”^{[39](p3)}, the implication was to focus on phonological impairment (PI). Baker *et al* [34] were more explicit in stating their specific focus on children with diagnosed PI, and defined the group as presenting with “*one or more age-inappropriate common phonological error patterns [...] with no evidence of motor speech involvement*”^{[34](p7)}. As Baker *et al* [34] themselves acknowledged, “*PI is presumed to be a cognitive-linguistic difficulty involving a difficulty abstracting rules about the phonological system, and the abstract phonological representation of speech rather than an articulation difficulty. As such, it is reasonable to suggest that non-nutritive sucking habits would be unrelated*”^{[34](p11)}. Pereira *et al* [37] made reference to both ‘speech disorder(s)’ and ‘speech changes’ and acknowledged that they did not distinguish between types of SSD. They provided some definition of their application of the term ‘speech disorders’ as “*those reported by the parents and/or guardians with respect to the production of the phonemes /t/, /d/, /n/, /l/, /r/, /s/, and /z/, considered comprehensively as they are associated with alterations in the SS [stomatognathic system]*”^{[37](p2)}. The repeated emphasis within this paper on the structures and functions of the stomatognathic system, defined by the authors as comprising the functions of suction, swallowing, mastication, respiration and speech^{[37](p.2)}, indicated the author’s intention to explore ‘speech disorders’ relating to articulation, rather than those that are cognitive-linguistic in nature. Vieira *et al* [38] also referred to ‘speech disorders’, ‘speech changes’ and the SS, as well as ‘speech impairment’. They defined their case group as children with “*omissions, substitutions, additions or distortions of phonemes related to functionality*

292 *and associated with the motor aspect of speech production*"^{[38](p1361)}. Vieira *et al* [38] specifically stated
293 that "*phonemic productions associated with [...] chronology of acquisition of children's phonemes*"^{[38](p1361)}
294 (i.e., age-appropriate developmental phonological processes) were not considered pathological. It may
295 be argued that, as with Pereira *et al* [37], this paper focused on articulatory SSD.

296 **3.2.5. Definition of Population**

297 Exclusion criteria for defining the study samples were not included in either Barbosa *et al* [39] or
298 Pereira *et al* [37] (Table 3). This may mean that their samples included children who had additional
299 difficulties, which, in turn, could have impacted on, or been the underlying cause of, their SSD. Of the
300 four included studies, Baker *et al* [34] presented the most comprehensive exclusion criteria.

301 **3.2.6. Confounding Factors**

302 Barbosa *et al* [39] acknowledged the likely influence of confounding factors in their study; however
303 they adjust only for gender and age (Table 4). Pereira *et al* [37] considered only gender, age and
304 number of children per household. No information is provided as to whether their statistical analysis
305 accounted for these factors. Baker *et al* [34] collected information for age, gender, hearing,
306 oromuscular structure and function. They also did not state whether these were included in their
307 statistical analysis. Of the four included studies, Vieira *et al* [38] collected information on age, gender,
308 'shift in educational unit', family income, maternal age, maternal schooling and family history of speech
309 impairments. They did not state whether these were included in their statistical analysis.

310 **3.2.7. Missing Data**

311 Unreported missing data presents a challenge in the interpretation of the data tables in Vieira *et al* [38].
312 When case and control group sample size totals for the different variables are manually calculated the
313 extent of missing data becomes clear. Moreover, when the overall group total (i.e., case and control
314 combined) is calculated for bottle use the number of cases exceeds the reported sample total, indicating
315 some measurement error [38]. This leads to concern about the validity of the analysis and
316 interpretation of the data in this paper. Manual calculations of group totals in Table 2 of Barbosa *et al*
317 [39] indicate missing data across the variables, but this was not acknowledged by the authors. Pereira

318 *et al* [37] also failed to acknowledge the extent of missing data within their report. Their paper
319 presents data on the correlation between NNS and SSD (Table 4). 127 children were reported as having
320 used a pacifier, but only 119 were included in the analysis. Baker *et al* [34] reported the extent of
321 missing data in their analysis.

322 3.2.8. Exposure Measures – Nutritive and Non-nutritive Sucking

323 All four of the included papers reported data on infant feeding type and duration. Three of the four
324 included papers [34, 37, 39] collected data on NNS duration. However, only one [39] collected data on
325 NNS frequency.

326 3.2.9. Outcome Measures – Speech Sound Disorder (SSD)

327 The SSD outcome measurement approach varied across the four papers in this review and although
328 formal assessment was attempted by three studies, the administration quality of the measures was
329 inconsistent. Unusually the questionnaire implemented within Pereira *et al* [37] specifically asked for
330 perceived speech sound changes, but they explicitly chose not to collect this information from the
331 parents of children aged 1-3 years. The modification of the questionnaire for this age group was not
332 defended by Pereira *et al* [37] and does not find a basis among the current literature, which suggests
333 the potential for identification of SSD within this age bracket [41-43].

334 Barbosa *et al* [39] used the TEPROSIF assessment, which requires the child to imitate a word, either
335 from a spoken phrase or in isolation [40]. Their criteria of “Below Normal” speech sound performance
336 as at least -1 standard deviation represents a liberal cut-off as many other studies have used more
337 stringent criteria [44-46]. It must be assumed that the “Below Normal” group includes a proportion of
338 children who could be considered typically developing in some other studies. As the authors did not
339 provide specific scoring information, further exploration of this issue is not possible. Vieira *et al* [38]
340 also used a published validated assessment, the Children’s Language Test [47], to assess speech sound
341 production on both naming and imitation tasks. Only those children who presented with a sound error
342 occurring in both tests were assigned to the ‘case’ group. The authors implied that children presenting
343 with errors pertaining to age-appropriate phonological processes were not included in the case group

[38]. As scoring information was not presented for the case or control groups, it is not possible to determine or assess the severity of children's speech sound errors within the case group. Baker *et al* [34] provided a clear description and explanation of their selected published assessment tool, the Diagnostic Evaluation of Articulation and Phonology (DEAP) [48]. Following administration of the Phonology Assessment single word naming test, children were assigned to one of four groups based on their obtained DEAP standard score, percentage of consonants correct (PCC) score and error patterns. Only data from the PI group were included in the study. Children assigned to the PI group obtained a DEAP standard score of 6 or less based on their PCC score. A score of 7-13 is understood to fall within the normal range [48].

3.3. Managing Bias

The following section considers risk and evidence of bias across the four included papers.

3.3.1. Sample Baseline Imbalances

Imbalances between groups of baseline variables, such as age and gender, can influence or bias the outcome, and so it is important to consider these when interpreting the reported findings.

Pereira *et al* [37] reported a sample population containing essentially equal genders, although no information was provided on sample selection.

In Vieira *et al* [38] there is a reporting error in the paper. They reported equal overall sample sizes for the case and control groups; however, manual calculations of the group totals from the data presented in their analysis^{[38](p.1362)} indicate a marked group imbalance (see Table 1). There is also a significant gender imbalance within the total sample, which contains 73% more males than females. Vieira *et al* [38] briefly acknowledged this imbalance in their discussion. Baker *et al* [34] also reported a sample gender imbalance, with 55% more males than females in their PI group. The SSD prevalence figures in the wider literature also show a tendency for more boys than girls [17, 49-52].

Barbosa *et al* [39] included in their sample children born prematurely (n=19) and, as acknowledged by the authors, this population are significantly more likely to present with "increased risk of

developmental problems with speech”^{[39](p4)}. The inclusion of this population, which constitutes 15% of the total study sample, may have some impact on the results as they potentially comprise almost 1/3 of the reported ‘below normal’ group. Prematurity is often cited in the wider literature as being associated with speech sound difficulties in later development [53-55].

3.3.2. Recall Bias

Inherent in the methodological use of participant questionnaires is the risk of recall bias [56]. While all four studies in this review employ this data collection approach, only Baker *et al* [34] did not acknowledge the potential limitation. Recall bias is perhaps most problematic with regard to the Pereira *et al* [37] study, which relied solely upon parent report for information on early feeding, sucking and speech sound development and included children up to age 12 years. The remaining studies focussed on the age range 3-5 years; therefore perhaps the influence of recall bias in each case may be considered to be broadly equal.

3.4. Summary of Findings from Included Papers

Although numerical data from the papers was insufficient to undertake meta-analysis, statistical information such as odds ratios and confidence intervals are included in each of the four papers. As previously stated, provision of this information by the authors is inconsistent across the papers.

3.4.1. Feeding Type and Speech Sound Development

Barbosa *et al* [39] suggested an association between bottle feeding and SSD in preschool children, such that delaying bottle use until after age nine months appeared to show some small protective effect (OR: 0.32, 95% CI: 0.10-0.98). Pereira *et al* [37] also reported a significant correlation between speech sound difficulties and bottle feeding ($p=0.056$). This may indicate a liberal application of their reported adopted 5% significance level^{[37](p.2)}. Vieira *et al* [38] found no significant association between feeding type and SSD. Baker *et al* [34] similarly found no association between feeding type and the presence or absence of SSD (specifically PI).

3.4.2. Duration of Feeding Type and Speech Sound Development

Pereira *et al* [37] and Vieira *et al* [38] both collected data on duration of feeding method and speech sound development but did not report on these data within their papers. Baker *et al* [34] suggested a trend whereby longer breastfeeding duration is associated with higher percentage consonants correct (PCC) scores, resulting in more accurate speech sound production for spoken words. Barbosa *et al* [39] reported that children scoring as normal or 1 standard deviation above normal on the “Test para evaluar los procesos fonológicos de simplificación” (TEPROSIF) speech sound assessment tended to have been breastfed for longer than those scoring below expectation for their age [40]. They asserted that delaying bottle feeding until after age 9 months may be to some extent a protective factor against subsequent SSD (OR: 0.32, 95% CI: 0.10-0.98).

3.4.3. Non-nutritive Sucking and Speech Sound Development

Barbosa *et al* [39] suggested an association between NNS and SSD in preschool children. They found that children who sucked their fingers were three times more likely to have speech sound difficulties than children who did not present with this behaviour (OR: 2.99, 95% CI: 1.10-8.00). It is important here to note the wide confidence interval reported for this finding. Pereira *et al* [37] found a correlation between pacifier use and speech sound difficulties ($p=0.046$). Neither Vieira *et al* [38] nor Baker *et al* [34] found a significant association between NNS and SSD.

3.4.4. Duration of Non-nutritive Sucking and Speech Sound Development

Baker *et al* [34] reported that, while the relationship between NNS and presence of SSD was non-significant, they did identify a trend between longer pacifier use and lower PCC scores. Barbosa *et al* [39] reported that children who used a pacifier for more than three years were much more likely to present with below normal speech sound development (OR: 3.4, 95% CI: 1.08-10.81). Pereira *et al* [37] suggested that using a pacifier for less than one year was not associated with speech sound difficulties, whereas digit sucking persisting for up to four years was positively correlated with the presence of SSD ($p=0.012$). Vieira *et al* [38] found no association between NNS and SSD.

4. Discussion

419 This review aimed to examine the evidence of the relationship between infant feeding methods, NNS
420 behaviours and speech sound development in early childhood. The deliberate inclusion of only those
421 papers that address all three aspects of this relationship is due to the high prevalence of concurrent
422 feeding and NNS behaviours in infancy and early childhood [5-7]. To exclude one or other elements
423 would be to disregard significant relevant factors in this association, and risk drawing false conclusions
424 from incomplete information.

425 **4.1. Methodological Limitations of this Paper**

426 Although clear systematic criteria were used for search and inclusion strategies, it is possible that a
427 number of biases may enter into the process by way of variations in definitions (e.g., SSD) and in
428 general by the specific inclusion criteria. For example, by including only studies that contain both
429 feeding and NNS, the possibility of deriving a fuller understanding of the impact of a single type of
430 sucking behaviour on the development of speech sounds is not possible. For the purposes of this
431 review, we purposely searched for evidence that allowed for the comparison of feeding and NNS. The
432 aim was to develop a picture of the current status of comparative findings.

433 The limited number of studies available for review makes it difficult to draw firm conclusions and
434 develop hypotheses about how differing characteristics and conditions may lead to SSD. It is worth
435 noting that two of the included papers, Vieira *et al* [38] and Pereira *et al* [37], have been translated from
436 the original language. This may have had some impact on the clarity of some of the language and
437 explanations within the papers.

438 **4.2. Limitations of Reviewed Studies**

439 The following section discusses the limitations of the four studies included in this review.

440 **4.2.1. Definition of SSD**

441 It is evident that, in terms of the defined outcome of SSD, there is an equal division between the four
442 included papers. Barbosa *et al* [39] and Baker *et al* [34] explored a link between physical oral sucking
443 behaviours (nutritive and non-nutritive) and the cognitive-linguistic aspect of speech sound

development, which, as Baker *et al* [34] acknowledged, is perhaps an unlikely association. Vieira *et al* [38] and Pereira *et al* [37] attempted to explore a possible relationship between physical sucking and the physical act of speech articulation, which may perhaps present a more probable association, and therefore should be the focus of further research in this area. However, it is important to consider that the nature of the chosen speech sound assessment method does not determine the type of SSD a child may have [57]. For example, children with phonological impairments, which may be identified using the phonology subtest of the DEAP [48] can also present with speech motor difficulties and vice versa. Therefore, while the four included studies report findings of atypical speech sound development, these cannot reliably be interpreted as identifying specific types of SSD.

4.2.2 Definition of Population

The lack of exclusion criteria in Barbosa *et al* [39] and Pereira *et al* [37] significantly weakens, in each case, the reliability of their findings and emphasises the importance of clearly defined sample populations for future research in this area. The decision by Baker *et al* [34] to exclude children whose parents were not concerned about their speech may be argued to risk the exclusion of otherwise potentially eligible children from the study on the basis of assumed parent awareness, knowledge or understanding [58].

4.2.3 Confounding Factors

The inclusion of comprehensive confounding factors identified from the literature is crucial in order to isolate the relationship between feeding, NNS and speech sound development as far as possible from these additional factors. Only by including and adjusting for these confounding factors in the statistical analysis can the relationship between NNS and speech sound development be described more accurately.

4.2.4. Missing Data

Unreported missing data was apparent in all but one [34] of the studies included in this review. This presents significant challenges for data interpretation and for the conclusions we are able to draw from the findings.

4.2.5. Exposure Measures – Nutritive and Non-nutritive Sucking

The nature of NNS behaviours vary significantly within and across cultures, with some children engaging only in these behaviours before sleep, while others show persistent behaviours throughout the day [59]. It is surprising that NNS sucking frequency was not reported in more of the papers. The authors of the current review would suggest that future research in this area include information on behaviour frequency as well as duration and causation (e.g., self-soothing behaviour at certain times of the day) in order to provide a comprehensive account of sucking behaviours, with which to then explore speech sound development outcomes in relation to early feeding methods.

4.2.6. Outcome Measures – Speech Sound Disorder (SSD)

While the need for inclusion of objective, formalised outcome measures for SSD in the examination of the relationship between feeding, sucking and speech sound development is evident, the nature of these assessments is also vital in establishing a clear speech sound profile for each child. Of the three studies in this review that completed objective speech sound assessments, all of them focussed on speech sounds at the single word level. There is a substantial and growing body of evidence that advocates the need for broader speech sound assessments to obtain a complete profile of a child's speech sound development; this includes collecting single sound, word, phrase level and connected speech [60]. In considering studies from a broader range of literature, such as those considering either, rather than both, feeding or NNS and speech sound development, no formal speech sound assessment approaches were identified [5, 61-63] and only one study, Baker *et al* [34], used the PCC measure. However, it is important to note the inherent weakness in using PCC as a measure to determine SSD type (e.g., participant assignment to PI group), as PCC scores would be lower among children with any type of SSD. The findings of these studies represent an incomplete picture with regard to patterns of feeding and NNS and any observable impact on speech sound development.

493 4.2.7. Managing Bias

494 There is significant inconsistency in the statistical reporting of results across the four included studies
495 in this review. Indeed, the chosen statistical presentation of some of the results may be considered to
496 risk reporting bias. As illustrated in section 3.2.1 above, ORs are reported by only two of the four
497 studies [38-39], and only one of these consistently reported confidence intervals [38]. This paucity of
498 accurate, consistent statistical reporting can lead to misrepresentation of the results, complicates the
499 interpretation of the findings and can be misleading [64].

500 Recall bias is inherent in studies reliant on participant questionnaires for data collection, and applies to
501 each of the four studies included in this review. A way to address this would be to carry out a
502 prospective study, such as the Avon Longitudinal Study of Parents and Children [65].

503 4.3. Conclusions

504 This review has established that the current evidence around the relationship between infant feeding,
505 NNS and speech sound development is very limited, of questionable quality and provides inconsistent
506 findings. Greater clarity is required with regard to the nature of SSD being explored and coherence of
507 approaches to outcome measurement. While the limited evidence examined within this review
508 suggests some association between persistent NNS behaviors and the presence of SSD, the strength of
509 this association is not clear. The question of a relationship between feeding type and SSD per se
510 remains unanswered; however when duration is considered, there is some limited evidence for a
511 protective effect of longer breastfeeding duration.

512 4.4. Potential Impact of Review Findings

513 The studies included in this review explore two distinct types of SSD: PI and articulation disorder.
514 Several different classifications of SSD are presented in the literature [52, 66-67]. It has been suggested
515 that an association between physical sucking and physical speech articulation may present a more
516 logical relationship than that between physical sucking and cognitive speech sound processing [34].
517 The potential impact of the findings of this review is that further research is required to explore the

relationship between the physical aspects of sucking and speech sound development. This work should use more precise and detailed measures for sucking behaviours and speech sound development with explicit consideration of the different classifications of SSD. Fundamental to this is the careful consideration of the many documented confounding variables involved in this proposed association [17]. Future research should aim to provide clinically relevant findings that might be easily and usefully applied to the clinical settings where these populations receive support. An optimal outcome measurement approach would include detailed speech sound assessment from single sound imitation through to connected speech samples [60]. Ideally, these data would be captured through video recording in order to facilitate precise and accurate transcription by a qualified Speech and Language Pathologist (SLP). Audio recording of the data with the assessment administration and transcription completed by a qualified SLP is recommended as a minimum requirement for future research in this area.

5. Appendix

Appendix 1. PRISMA Flow Chart – Search Engine Searches

6. Supplementary Material

535 **7. Statements**

536 **7.1 Acknowledgments**

537 Not applicable.

538 **7.2. Statement of Ethics**

539 The authors have no ethical conflicts to enclose.

540 **7.3. Disclosure Statement**

541 The authors have no conflicts of interest to declare.

542 **7.4. Funding Sources**

543 The systematic review has been completed as part of a larger PhD study funded by the National
544 Institute for Health Research (NIHR) (award reference: ICA-CDRF-2016-02-053).

545 **7.5. Author Contributions**

546 SB, TD and YW discussed the aim and objectives of this review. SB completed the initial searches and
547 shortlisted at the abstract stage. SB and SH reviewed the included papers and completed the Quality
548 Appraisal separately for subsequent discussion. SH was a major contributor in writing the final
549 manuscript. All authors read, edited and approved the final manuscript.

8. References

- [1] Jedrychowski W, Perera F, Jankowski J, Butscher M, Mroz E, Flak E, Kaim I, Lisowska-Miszczuk I, Skarupa A, Sowa A. Effect of exclusive breastfeeding on the development of children's cognitive function in the Krakow prospective birth cohort study. *Eur J Pediatr*. 2012;171(1):151-8. doi:10.1007/s00431-011-1507-5.
- [2] Belfort MB, Rifas-Shiman SL, Kleinman KP, Guthrie LB, Bellinger DC, Taveras EM, Gillman MW, & Oken E. Infant feeding and childhood cognition at ages 3 and 7 years: Effects of breastfeeding duration and exclusivity. *JAMA Pediatr*. 2013;167(9):836-44.
- [3] Lee H, Park H, Ha E, Hong Y-C, Ha M, Park H, Kim B, Lee S, Lee K, Kim J, Jeong K, Kim Y. Effect of Breastfeeding Duration on Cognitive Development in Infants: 3-Year Follow-up Study. *J Korean Med Sci*. 2016;31(4):579-584. doi:10.3346/jkms.2016.31.4.579.
- [4] Huang J, Vaughn MG, Kremer KP. Breastfeeding and child development outcomes: an investigation of the nurturing hypothesis. *Matern Child Nutr*. 2016;12(4):757-767. doi:10.1111/mcn.12200
- [5] Fox AV, Dodd B, Howard D. Risk factors for speech disorders in children. *Int J Lang Commun Disord*. 2002;37(2):117-31. doi:10.1080/13682820110116776
- [6] Bishara SE, Warren JJ, Broffitt B. & Levy SM. Changes in the prevalence of nonnutritive sucking patterns in the first 8 years of life. *Am J Orthod Dentofacial Orthop*. 2006;130(1):31-6. doi:10.1016/j.ajodo.2004.11.033.
- [7] dos Santos SA, de Holanda ALF, de Sena MF, Gondim LAM, Ferreira MAF. Nonnutritive sucking habits among preschool-aged children. *J Pediatr (Rio J)*. 2009;85(5):408-414. doi:10.1590/S0021-75572009000500007.

577

578 [8] Chitra P, Vishnupriya P. Estimate the Prevalence of Non-Nutritive Sucking among the Pre-School
579 Children in Selected Schools at Ernakulam. *Int J Nurs Educ*. 2015;7:197. doi:10.5958/0974-
580 9357.2015.00164.6.

581

582 [9] Duncan K, McNamara C, Ireland AJ, Sandy JR. Sucking habits in childhood and the effects on the
583 primary dentition: findings of the Avon Longitudinal Study of Pregnancy and Childhood. *Int J Paediatr*
584 *Dent*. 2008;18(3):178-188.

585

586 [10] Warren JJ, Bishara SE, Steinbock KL, Yonezu T, Nowak AJ. Effects of oral habits' duration on dental
587 characteristics in the primary dentition. *J Am Dent Assoc*. 2001;132(12):1685-1693.

588

589 [11] Niemelä M, Uhari M, Möttönen M. A pacifier increases the risk of recurrent acute otitis media in
590 children in day care centers. *Pediatr*. 1995;96:884-8.

591

592 [12] Warren JJ, Levy SM, Kirchner HL, Nowak AJ, Bergus GR. Pacifier use and the occurrence of otitis
593 media in the first year of life. *Pediatr Dent*. 2001;23(2):103-7.

594

595 [13] Moral A, Bolibar I, Seguranyes G, Ustrell JM, Sebastiá G, Martínez-Barba C, Ríos J. Mechanics of
596 sucking: comparison between bottle feeding and breastfeeding. *BMC Pediatr*. 2010;10:6.
597 doi:10.1186/1471-2431-10-6.

598

599 [14] Mizuno K, Ueda A. Changes in sucking performance from nonnutritive sucking to nutritive sucking
600 during breast- and bottle-feeding. *Pediatr Res*. 2006;59(5):728-31.
601 doi:10.1203/01.pdr.0000214993.82214.1c.

602

603 [15] Taki M, Mizuno K, Murase M, Nishida Y, Itabashi K, Mukai Y. Maturational changes in the feeding
604 behaviour of infants - a comparison between breast-feeding and bottle-feeding. *Acta Paediatr.*
605 2010;99(1):61-67. doi:10.1111/j.1651-2227.2009.01498.x.
606

607 [16] MacNeilage PF. The frame/content theory of evolution of speech production. *Behavioural and*
608 *Brain Sciences.* 1998;21(4):499-511.
609

610 [17] Wren Y, Miller LL, Peters TJ, Emond A, Roulstone S. Prevalence and Predictors of Persistent Speech
611 Sound Disorder at Eight Years Old: Findings From a Population Cohort Study. *J Speech Lang Hear*
612 *Res.* 2016;59(4):647-673. doi:10.1044/2015_JSLHR-S-14-0282.
613

614 [18] Palmer B. The Influence of Breastfeeding on the Development of the Oral Cavity: A Commentary. *J*
615 *Hum Lact.* 1998;14(2):93-98. doi:10.1177/089033449801400203.
616

617 [19] Wilson EM, Nip ISB. Physiologic studies provide new perspectives on early speech development.
618 *Perspect Speech Sci Orofac Disord.* 2010;20:29-36.
619

620 [20] Watson MM, Lof GL. Epilogue: What we know about nonspeech oral motor exercises. *Semin Speech*
621 *Lang.* 2008;29(4):339-344.
622

623 [21] Bunton K. Speech versus nonspeech: different tasks, different neural organization. *Semin Speech*
624 *Lang.* 2008;29:267-275.
625

626 [22] Clark K. (2008). The role of strength training in speech sound disorders. *Semin Speech Lang.*
627 2008;29: 276-283.
628

629 [23] Wilson EM, Green JR, Yunusova Y, Moore CA. Task specificity in early oral motor development.

630 Semin Speech Lang. 2008;29(4): 257-266.

631

632 [24] Hayden D, Eigen J, Walker A, Olsen L. PROMPT: A tactually grounded model for the treatment of

633 childhood speech production disorders. In: Williams L, McLeod S, McCauley R, editors. Treatment for

634 speech sound disorders in children. Baltimore, MD: Brookes Publishing; 2010

635

636 [25] Harding A, Bryan A. The use of multisensory input-modelling to stimulate speech output

637 processing. A therapy demonstration video for speech and language therapists for the treatment of

638 speech disorders. [DVD] Cleft Lip and Palate Network, Cambridge, UK. 2002.

639

640 [26] Passy J. Cued Articulation: Consonants and Vowels. Revised ed. Australia: ACER Press 2010.

641

642 [27] Ruark JL, Moore CA. Coordination of lip muscle activity by 2-year-old children during speech and

643 nonspeech tasks. J Speech Lang Hear Res. 1997;40(6):1373-85. doi:10.1044/jslhr.4006.1373.

644

645 [28] Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions (Version 5.1.0).

646 The Cochrane Collaboration; 2011. <http://www.cochrane.org/training/cochrane-handbook>. Accessed

647 14 Oct 2018.

648

649 [29] Petticrew M, Roberts H. Systematic reviews in the social sciences. Malden, MA: Blackwell

650 Publishing, 2006.

651

652 [30] Booth A, Fry-Smith A. Developing a research question. In: Petticrew M, Roberts H,

653 editors. Systematic reviews in the social sciences. Oxford: Blackwell; 2004.

654

655 [31] Roulstone S, Marshall JE, Powell G, Goldbart J, [Wren Y](#), Coad J, Daykin N, Powell JE, Lascelles L,

656 Hollingworth W, Emond A, Peters TJ, Pollock JI, Fernandes C, Moultrie J, Harding SA, Morgan L, Hambly

657 HF, Parker NK, Coad RA. [Evidence-based intervention for preschool children with primary speech and](#)
 658 [language impairments: Child Talk - an exploratory mixed-methods study](#). Programme Grants for
 659 Applied Research. 2015 Aug 1;3(5). [doi:10.3310/pgfar03050](#)
 660
 661 [32] Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for
 662 Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 2009;6(7):e1000097.
 663 doi:10.1371/journal.pmed1000097.
 664
 665 [33] Google [www.google.com](#)
 666
 667 [34] Baker E, Masso S, McLeod S, and Wren Y. Pacifiers, thumb sucking, breastfeeding, and bottle use:
 668 Oral sucking habits of children with and without phonological impairment.
 669 Folia Phoniatr Logop. 2018;70:165-173. doi:10.1159/000492469.
 670
 671 [35] Effective Practice and Organisation of Care (EPOC). Data collection form. EPOC Resources for
 672 review authors. Oslo: Norwegian Knowledge Centre for the Health Services; 2013.
 673 [http://epoc.cochrane.org/epoc-specific-resources-review-authors](#). Accessed 14 Aug 2018.
 674
 675 [36] Downes MJ, Brennan ML, Williams HC, Deane RS. Development of a critical appraisal tool to assess
 676 the quality of cross-sectional studies (AXIS). BMJ Open. 2016;6(12):e011458. doi:10.1136/bmjopen-
 677 2016-011458.
 678
 679 [37] Pereira TS, Oliveira F de, Cardoso MC. Association between harmful oral habits and the structures
 680 and functions of the stomatognathic system: perception of parents/guardians. Cotas.
 681 2017;29(3):e20150301. doi:10.1590/2317-1782/20172015301.
 682

683 [38] Vieira VCAM, Araújo CMT de, Jamelli SR. Speech development and infant feeding: possible
684 implications. *Revista CEFAC*. 2016;18(6):1359-1369. doi:10.1590/1982-0216201618611516.
685

686 [39] Barbosa C, Vasquez S, Parada MA, Gonzalez JCV, Jackson C, Yanez ND, Gelaye B. & Fitzpatrick AL.
687 The relationship of bottle feeding and other sucking behaviors with speech disorder in Patagonian
688 preschoolers. *BMC Pediatr*. 2009;9:66. doi:10.1186/1471-2431-9-66.
689

690 [40] Maggiolo M, Pavez MM. Test para evaluar los procesos fonológicos de simplificación (TEPROSIF).
691 Escuela de Fonoaudiología, Facultad de Medicina, Universidad de Chile, Santiago, Chile; 2000.
692

693 [41] Lewis BA, Freebairn LA, Hansen AJ, Stein CM, Shriberg LD, Iyengar SK, Gerry Taylor H. Dimensions
694 of early speech sound disorders: A factor analytic study. *J Commun Disord*. 2006;39(2):139-57.
695 doi:10.1016/j.jcomdis.2005.11.003.
696

697 [42] Paul D, Roth FP. Guiding Principles and Clinical Applications for Speech-Language Pathology
698 Practice in Early Intervention. *Lang Speech Hear Serv Sch*. 2011;42:320-330. doi:10.1044/0161-
699 1461(2010/09-0079).
700

701 [43] Claessen M, Beatie T, Roberts, Leitao S, Whitworth A, Dodd B. Is two too early? Assessing toddlers'
702 phonology. *Speech Lang Hear*. 2016;20(2):91-101. doi:10.1080/2050571X.2016.1222723.
703

704 [44] Fey M. Language intervention with young children. 1986. San Diego: College-Hill Press: 1986.
705

706 [45] Paul R. Language disorders from infancy through adolescence: Assessment and intervention. St
707 Louis, MO: Mosby: 1995.
708

709 [46] Tomblin JB, Records NL, Zhang X. A system for the diagnosis of specific language impairment in
710 kindergarten children. *J Speech Lang Hear Res.* 1996;39:1284-1294. doi:10.1044/jshr.3906.1284.
711

712 [47] Wertzner HF. ABFW: teste de linguagem infantil nas áreas de fonologia, vocabulário, fluência e
713 pragmatic. Barueri (SP): Pró-Fono;2004.
714

715 [48] Dodd B, Zhu, Hua , Crosbie S, Holm A, Ozanne A. Diagnostic evaluation of articulation and
716 phonology (DEAP). London: Psychology Corporation; 2002.
717

718 [49] Shriberg LD, Tomblin JB, McSweeny JL. Prevalence of speech delay in 6-year-old children and
719 comorbidity with language impairment. *J Speech Lang Hear Res.* 1999;42(6):1461-81.
720

721 [50] Silva GMD, Couto MIV, Molini-Avejonas DR. Risk factors identification in children with speech
722 disorders: pilot study. *Codas.* 2013;25(5):456-62. doi:10.1590/S2317-17822013000500010.
723

724 [51] Longo IA, Tupinelli GG, Hermógenes C, Ferreira LV, Molini-Avejonas DR. Prevalence of speech and
725 language disorders in children in the western region of São Paulo. *Codas.* 2017;29(6):e20160036.
726 doi:10.1590/2317-1782/20172016036.
727

728 [52] Shriberg LD, Fourakis M, Hall SD, Karlsson HB, Lohmeier HL, McSweeny JL, Potter NL, Scheer-
729 Cohen AR, Strand EA, Tilkens CM, Wilson DL. Extensions to the Speech Disorders Classification System
730 (SDCS). *Clin Linguist Phon.* 2010;24(10):795-824. doi:10.3109/02699206.2010.503006.
731

732 [53] Smith VL, Gerber SE. Infant feeding and phonologic development. *Int J Pediatr Otorhinolaryngol.*
733 1993;28(1):41-9.
734

735 [54] Jansson-Verkasalo E, Ruusuvirta T, Huotilainen M, Paavo A, Kushnerenko E, Suominen K, Rytty S,
 736 Luotonen M, Kaukola T, Tolonen U, Hallman, M. Atypical perceptual narrowing in prematurely born
 737 infants is associated with compromised language acquisition at 2 years of age. BMC Neurosci.
 738 2010;11(88). doi:10.1186/1471-2202-11-88.
 739
 740 [55] Wocadlo C, Rieger I. Phonology, rapid naming and academic achievement in very preterm children
 741 at eight years of age. Early Hum Dev. 2007;83:367–377. doi:10.1016/j.earlhumdev.2006.08.001.
 742
 743 [56] Althubaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. J
 744 Multidiscip Healthc. 2016;9:211–217. doi:10.2147/JMDH.S104807.
 745
 746 [57] Stackhouse J, Wells B. Children’s Speech and Literacy Difficulties I: A psycholinguistic framework.
 747 London: Whurr Publishers; 1997.
 748
 749 [58] Wilson P, McQuaige F, Thompson L, McConnachie A. Language Delay Is Not Predictable from
 750 Available Risk Factors. The Scientific World Journal. 2013;947018. doi:10.1155/2013/947018.
 751
 752 [59] Castilho SD, Rocha MAM. Pacifier habit: history and multidisciplinary view. J Pediatr (Rio
 753 J). 2009;85(6):480-489. doi:10.1590/S0021-75572009000600003.
 754
 755 [60] Mcleod S, Baker E. Speech-language pathologists' practices regarding assessment, analysis, target
 756 selection, intervention, and service delivery for children with speech sound disorders. Clin Linguist
 757 Phon. 2014;28(7-8):508-31. doi:10.3109/02699206.2014.926994.
 758
 759 [61] Broad FE. The effects of infant feeding on speech quality. N Z Med J. 1972;76(482):28-31.
 760

761 [62] Broad FE. Further studies on the effects of infant feeding on speech quality. N Z Med
762 J. 1975;82(553):373-6.
763

764 [63] Broad E, Duganzich DM. The effects of infant feeding, birth order, occupation and socio-economic
765 status on speech in six-year-old children. N Z Med J. 1983;96(734):483-6.
766

767 [64] Vittinghoff E, Glidden DV, Shiboski SC, McCulloch CE. Regression Methods in
768 Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models. Dordrecht: Springer; 2012
769

770 [65] Avon Longitudinal Study of Parents and Children (ALSPAC). Bristol University.
771 <http://www.bristol.ac.uk/alspac/about/>. Accessed 08 Oct 2018.
772

773 [66] Lewis BA, Shriberg LD, Freebairn LA, Hansen AJ, Stein CM, Taylor HG, Iyengar SK. The genetic bases
774 of speech sound disorders: evidence from spoken and written language. J Speech Lang Hear
775 Res. 2006;49(6):1294-1312. doi:10.1044/1092-4388(2006/093).
776

777 [67] Dodd B. Differential Diagnosis of Pediatric Speech Sound Disorder. Curr Dev Disord Rep.
778 2014;1(3):189-196. doi:10.1007/s40474-014-0017-3.

779 **9. Figure Legends**

780	Fig. 1.	PRISMA Flow Chart for Traditional Database Searches.
781	Fig 2.	PRISMA Flow Chart for Google Search
782	Table 1.	Table 1. Inclusion and Exclusion Criteria
783	Table 2.	Table 2. Quality Assessment Criteria and Scoring
784	Table 3.	Table 3. Summary Table of Included Studies.
785	Table 4.	Table 4. Summary Table of Exclusion Criteria Reported by Included Papers