Speech difficulties at school entry are a significant risk factor for later reading difficulties

Abstract

This study examined the relationship between speech difficulties at school entry and problems learning to read. We test the hypothesis that phonological skills explain the relationship between speech and reading difficulties. Speech skills were assessed in a large (*N*=569) unselected sample of 5-year old children just after school entry. Children also completed a wide range of tasks measuring oral language (expressive vocabulary, receptive grammar and listening comprehension), reading and reading-related skills (single word reading, letter-sound knowledge, phoneme awareness, rapid automatized naming) and non-verbal IQ. Assessments were repeated six months later. Speech difficulties were identified in 6.88% of children. Speech difficulties were associated with poorer non-verbal IQ, oral language and reading relative to children without speech difficulties. A mediation model demonstrated that the relationship between speech difficulties and later reading was entirely mediated by phoneme awareness. Speech difficulties at school entry are related to problems in acquiring phoneme awareness which in turn are associated with problems in learning to read. Clinically, our results imply that any child who has a speech difficulty at school entry should be assessed and monitored for broader oral language difficulties and for delays in reading development with a view to providing early intervention to ameliorate such difficulties.

Keywords: reading development, speech difficulties, oral language

Speech difficulties at school entry are a significant risk factor for later reading difficulties

Speech-sound disorder is characterised by difficulties in developing age appropriate articulation skills. Children with speech-sound disorder make speech errors (including omissions, substitutions and distortions) which result in reduced intelligibility of speech. There are few longitudinal population-based studies of speech difficulties but data suggest that speech-sound disorder occurs in 3.4% to 6.4% of 4 to 8 year old children (Beitchman et al., 1986; Eadie et al., 2015; Shriberg, Tomblin, & McSweeny, 1999; Wren, McLeod, White, Miller, & Roulstone, 2013). Speech difficulties are readily observed and a cause for parental concern and frequently result in referral to speech and language therapy services (Bishop & Hayiou-Thomas, 2008; Eadie et al., 2015; Zhang & Tomblin, 2000). There is also evidence that speech difficulties place children at risk of subsequent problems learning to read, though the mechanisms responsible for this are not clear. In this study we examine the extent to which speech difficulties predict reading ability in a large population sample. Specifically, this longitudinal study examines whether speech difficulties at school entry are related to problems in learning to decode because they compromise the development of one or more of the phonological skills that underpin learning to read (letter sound knowledge, phoneme awareness and RAN).

The association between speech-sound disorder and later literacy problems is well-documented (Anthony et al., 2011; Bird, Bishop, & Freeman, 1995; Bishop & Adams, 1990; Hayiou-Thomas, Carroll, Leavett, Hulme, & Snowling, 2017; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Nathan, Stackhouse, Goulandris, & Snowling, 2004; Peterson, Pennington, & Shriberg, 2009). The comorbidity between speech-sound disorder and reading disorder is between 25% and 30% (Peterson et al., 2009). In a recent longitudinal study (Hayiou-Thomas et al., 2017) children with speech-sound disorder at 3.5 years scored lower than their typically developing peers on measures of emergent literacy (phoneme awareness, word reading, and spelling) at 5 years, and on literacy outcomes (word reading, spelling and reading comprehension) at age 8 years. The presence of speech difficulties at 3.5 years explained a small but significant proportion of the variance (1.9%) in word reading at 8 years after controlling for language impairment status and family risk of dyslexia. The risk of literacy problems appears to be greater when speech difficulties persist to the point of school entry and the onset of formal literacy instruction (Bishop & Adams, 1990; Bird et al., 1995). Bird et al. (1995) found that children with speech-sound disorder at age 5 years had poorer phonological awareness and literacy (word and non-word reading, and spelling) skills at age 6 and 7 years than typically developing children matched for age and non-verbal IQ. Thus, speech difficulties appear to be a significant risk factor for later literacy problems, particularly when they are present at school entry.

Though it is clear that speech difficulties are related to reading difficulties, the mechanism by which speech difficulties may hinder learning to read remains unclear. The relationship between speech difficulties and reading development might potentially be explained by an elevated risk of broader oral language problems in children with speech difficulties. In representative samples of 4-6 year old children, the comorbidity between speech-sound disorder and language impairment is between 1.3% and 4.6% (Beitchman et al., 1986; Eadie et al., 2015; Shriberg et al., 1999). In 3-4 year old children with speech-sound disorder, 40-50% also meet criteria for language impairment (Eadie et al., 2015; Hayiou-Thomas et al., 2017). Weak oral language skills place children at risk of problems learning to read (Hulme, Nash, Gooch, Lervag, & Snowling, 2015) and it follows that children with co-occurring speech and language difficulties will experience poorer literacy outcomes than children who have isolated speech-sound disorder (Hayiou-Thomas et al., 2017; Leitao, Hogben, & Fletcher, 1997; Nathan et al., 2004; Peterson et al., 2009; Raitano et al., 2004).

Nonetheless, speech difficulties predict reading difficulties independent of language ability (Bird et al., 1995; Hayiou-Thomas et al., 2017; Rvachew, Ohberg, Grawburg, & Heyding, 2003); language does not therefore entirely explain this relationship.

A plausible theoretical explanation is that the relationship between speech and reading difficulties is mediated by phonological skills (Anthony et al., 2011). Phonological skills are highly predictive of word reading in alphabetic languages: Measures of phoneme awareness, letter-sound knowledge and rapid automatized naming (RAN) can all be thought of as tapping into different aspects of phonological skills and performance on such measures predict a substantial proportion of the variance in word reading (Caravolas, Lervåg, Defior, Malkova, & Hulme, 2013; Furnes & Samuelsson, 2011; Hulme & Snowling, 2012). The development of these phonological skills appears compromised in children who have speech difficulties. Children with speech-sound disorder demonstrate consistently poorer performance on measures of phonological awareness and letter-sound knowledge compared to children without speech difficulties (Anthony et al., 2011; Bird et al., 1995; Eadie et al., 2004; Hayiou-Thomas et al., 2017; Raitano et al., 2004; Peterson et al., 2009; Nathan et al., 2004; DeThorne et al., 2006; Snowling et al., 2000). Children with speech difficulties also perform less well on RAN tasks (Anthony et al., 2011) although group differences are not consistent across studies (Raitano et al., 2004). Speech skills predict variations in letter-sound knowledge (Webster, Plante, & Couvillion, 1997) and phoneme awareness (Preston & Edwards, 2010). Furthermore, Nathan et al., (2004) found that speech was not a predictor of reading after controlling for phonological awareness. Thus, children with speech-sound disorder appear to experience particular problems in developing phonological skills which in turn may compromise their literacy development.

This longitudinal study examines whether speech difficulties at school entry predict problems in learning to decode in the first year of school by compromising one or more of the phonological skills that are critical for learning to read (letter-sound knowledge, phoneme awareness and RAN). We test these relationships after controlling for the effects of broader oral language skills and nonverbal IQ in a large unselected sample of children at the start of formal education. Based on previous research, our hypothesis was that speech difficulties are related to problems learning to read because they reflect underlying problems with the development of phonological skills. We therefore expected that speech difficulties would predict later reading abilities, and that this relationship would be mediated by phonological skills.

Method

Participants

This study is part of a longitudinal study conducted in 11 schools in Brisbane, Australia: 10 are fee-paying schools (eight Independent and two Catholic schools) whilst the remaining (state) school is publicly funded. The Index of Community Socio-Educational Advantage (ICSEA) provides an estimate of the socio-economic composition of the student population of each school. This variable is formed of family background information (parent occupation and education) and school characteristics (percentage of Aboriginal pupils and pupils learning English as an additional language, and geographical location; Australian Curriculum, Assessment and Reporting Authority, 2013). Based on the ICSEA scale, eight of the participating schools serve a student population with an average level of educational advantage (ICSEA values between 997 and 1090 where the average range (1SD of the mean) is 900 to 1100). The three remaining schools have higher ICSEA values (1112-1153) reflecting a student population with relatively higher levels of social advantage.

Schools provided informed consent for all children enrolled in the first year of school to participate unless parents opted to withdraw their child. A total of 569 children were assessed (time 1; t1) soon after school entry (274 boys; $M = 63.86$ months, range 54 – 82 months, $SD = 4.36$). This sample represented 86.2% of the total number of children (n=660) enrolled in Prep Year across the 11 participating schools. The proportion of children in the Year group taking part in the study within each school ranged from 49% to 98%.

Assessments were repeated six months later (time 2; t2; $n = 552$; $M = 69.66$ months, $SD = 4.19$). This period of development captures the first 6 months of formal literacy instruction making this an ideal period in which to examine predictors of reading development. A small number of children were unavailable at t2; there were no differences on any of the t1 measures between these children and those who completed the study (ts = .10 – 1.07, ps > .05, Cohen's d = .02 - .20).

According to teacher reports at t1, 13.2% of the sample ($N = 75$) were growing up with more than one language in the home. A small number of children (7.7%; $N = 44$) had a diagnosed or suspected learning difficulty (Autism Spectrum Disorder = 15; Speech and Language difficulties = 9; Hearing/Auditory processing problems = 8; Physical development difficulties = 3; Vision problems = 2; No further information = 2; Other = 5). Ethical approval for the study was provided by the Australian Catholic University Human Research Ethics Committee (2015-269H).

Assessments and procedure

Children were assessed at t1 and t2 on measures of speech articulation, word-level reading, phonological awareness, letter-sound knowledge, Rapid Automatized Naming (RAN) and language skills (listening comprehension, vocabulary and grammar). Nonverbal IQ was assessed at t1 only. All assessments were individually administered with the exception of nonverbal IQ which was administered as a group test (see below). Individual assessments were conducted in a quiet room in school to avoid any distractions. Testing was conducted by a team of research staff and undergraduate and postgraduate research assistants studying Psychology. All testers were fully trained (by authors KB and SM) prior to school visits. Training included modelling, practice and observations of test administration. Reliability estimates and maximum scores for all tests are reported in Table 1.

Speech articulation. Speech articulation was measured using the articulation subtest from the Diagnostic Evaluation of Articulation and Phonology (DEAP; Dodd, Hua, Crosbie, Holm, & Ozanne, 2002). Children were asked to name 30 pictures (e.g., pig, moon, television) including all the consonants in British English. Responses were audio-recorded and scored for percentage of consonants (43 consonants in total) correctly produced. Percentage consonants correct (PCC) is a widely used measure for assessing severity of a speech-sound disorder (see e.g., Hayiou-Thomas et al., 2017). This score is based on the total number of speech sound errors a child makes, and weights all types of errors (including distortions, substitutions and omissions) equally. Concurrent validity for the DEAP is high (r = .95; Dodd et al., 2002).

Word-level reading. At t1, children completed the Early Word Reading (EWR) subtest from the York Assessment of Reading for Comprehension (YARC; Hulme et al., 2012). This test requires children to read a list of 30 single words of increasing difficulty. Following 5 consecutive errors the child was asked if they could read any more words on the list. If the child correctly identified a word later in the list, testing was continued from this point until a further 5 consecutive errors were made. Testing was then discontinued. A score of 1 was given for each word read correctly.

At t2, children completed measures of single word reading and non-word reading. *Single word reading* was assessed using the EWR (as described above) and the Single Word Reading test (SWR; Foster, 2007). The SWR test presents a list of 60 single words increasing in difficulty. Following 5 consecutive incorrect responses, children were asked if they could read any more words listed. As with the EWR, if the child could read any of the later words, testing continued from this point until 5 consecutive errors were made. *Non-word reading*: Children were asked to read 14 decodable non-words of 2-3 phonemes from the phonemic decoding subtest of the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 2012). Practice items were administered before the test items; test items were not administered if a child scored zero on the practice items. Testing was discontinued after 4 consecutive errors on test items. For all reading measures, a score of one was given for each correct response. These measures of word-level reading have strong validity. The SWR and EWR tests correlate well with each other (r = .93) and with measures of phoneme awareness (rs = .68 - .77; Hulme et al., 2012). The TOWRE test of non-word reading (phonemic decoding efficiency) correlates well with sight word reading (r = .75; Torgesen et al., 2012).

Phoneme Awareness. The sound deletion subtest from the YARC was used to assess phoneme awareness. Children were asked to delete sounds (in initial, final and middle positions) in spoken words. The test included 7 demonstration items and 12 test items. Full feedback was given on demonstration items. For each trial, children were asked to repeat the item (e.g., “Say sheep”), before being asked to delete one of the speech sounds (e.g., “now say it with the /p/”). This task was discontinued after 4 consecutive errors. Each correct answer was scored 1.

Letter-sound knowledge. The letter-sound knowledge subtest from the YARC assessed children’s ability to provide the sound for 17 (core test; t1) or 32 (full test; t2) printed letters and digraphs. Children were asked to produce the sound associated with each letter or digraph. A score of 1 was given for each correct sound produced. These measures of phoneme awareness and letter sound knowledge have good validity as evidenced by strong correlations with each other (*r* = .69) and with early word reading (*r*s = .72 - .77; Hulme et al., 2012).

Rapid automatized naming (RAN). Children completed two versions of the RAN task: colour and object naming. Each task contained 5 stimuli (objects: dog, eye, key, lion and table; colours: brown, blue, black, red and green). Children were first asked to name each of the stimuli, with any naming errors corrected. They were then shown an array in which the items were presented 8 times each in a random order and were asked to name them as quickly as possible. Children completed 2 trials of each task at t1, and a single trial of each task at t2. A trial was discontinued if a child made three consecutive naming errors. The total time taken (in seconds) to name all the items and the number of errors was recorded for each trial. A rate score was calculated for each by dividing the number of items named correctly (max. 40) by the time taken to complete the trial. These tasks have been used in previous studies (e.g., Hulme et al., 2015) and are correlated with single word reading (*r* .26-.36).

Oral Language. Language skills were assessed using two subtests (Expressive Vocabulary and Sentence Structure) from the CELF 4^{AU} (Semel, Wiig, & Secord, 2006) and a measure of listening comprehension. For *Expressive Vocabulary*, children were asked to name a series of pictures depicting objects (e.g., skeleton, saxophone) or actions (e.g., drawing). Testing was discontinued after 7 consecutive errors. Following test guidelines, each response was scored as 0 (incorrect), 1 (partial response) or 2 (correct response). In the *Sentence Structure* test, children heard a spoken sentence (e.g., “The boy is being followed by the dog”) and selected one of four pictures which matched the meaning of the sentence. Sentences were formed using a range of syntactic structures. Testing was discontinued following 7 consecutive incorrect responses. Each correct answer was scored 1. The CELF subtests are well standardized measures of language ability and correlate moderately together (*r* = .46) and with general language indices (*r*s = .60 - .85; Semel et al., 2006).

Listening Comprehension. Children listened to a short 6-sentence story adapted from the YARC (Hulme et al., 2012) and answered questions about it. The story was played on a digital recorder via headphones. Immediately after the story, children answered 8 open-ended comprehension questions that tapped literal and inferential information from the story. A score of 1 was provided for each correct response. Incorrect or partial answers were scored 0.

Nonverbal IQ (t1 only). The Ravens Coloured Progressive Matrices was adapted to assess nonverbal IQ as a group-administered task (whole classes). Children were shown a series of puzzles with a piece missing and were asked to choose one of 6 pieces to complete the puzzle. There were 3 practice trials and 12 test trials. Each correct response was awarded 1 point. The Ravens Coloured Progressive Matrices is a well-used assessment of cognitive ability with strong construct validity as evidenced by its high correlation with the Wechsler Intelligence Scale for Children ($r = .91$; Martin & Wiechers, 1954).

Results

The means (standard deviations), maximum scores and reliabilities for all measures are shown in Table 1. Scores were higher on all measures at t2 showing clear developmental progression across the first 6 months of school. Correlations between the measures are shown in Table 2 (simple correlations below the diagonal; partial correlations controlling for age above the diagonal); as expected, there were significant associations between many of the study measures.

The speech articulation data were highly skewed with only a minority of children having an appreciable number of articulation errors (see Figure 1). We therefore created a speech difficulties dummy variable where children were classified as having speech difficulties if they scored 1.5 standard deviations below the sample mean (PCC score <= 85%; Hayiou-Thomas et al., 2017). Thirty-eight children (6.88% of the sample) fulfilled this criterion (24 boys); PCC scores for this group of children ranged from 53.49% to 83.72% (mean=78.27%).

There were no significant differences between children with and without speech difficulties in chronological age (t (550) = 1.12, p =.26) but those with speech difficulties had lower nonverbal IQ (t (521) = 2.71, p = .007, d = .43). There were more boys (63.2%) in the group with speech difficulties than in the comparison group (47.5%) but this difference was not significant (χ (1) = 3.49, p = .06). We used a cut-off score of a scaled score below 7 on both CELF subtests (*Expressive Vocabulary* and *Sentence Structure*) to identify children with language impairment. Six children with speech difficulties (15.8%) met this criteria compared to 32 children without speech difficulties (6.5%; a significant difference, χ (1) = 5.28, p = .02). The teacher reports collected at t1 noted isolated speech or speech and language difficulties for 5 children categorized here as having speech-sound disorder. Three additional children in the group with speech difficulties were identified by teachers as having known or suspected learning difficulties (1 child was recorded as having ADHD, and 2 children were noted to have hearing impairment).

Next we assessed whether speech difficulties were associated with poorer scores relative to the comparison group on measures of language and literacy (Table 3). The group with speech difficulties achieved lower language and literacy scores than the group without speech difficulties on all measures at t1 and t2. On the language measures, group differences at t1 were significant only for expressive vocabulary; at t2 differences were also significant for receptive grammar (sentence structure). On measures of letter-sound knowledge, phoneme awareness and word reading, the group with speech difficulties were performing around 0.5 standard deviations below the sample mean, a significant difference (see Table 3 for test statistics).

We next assessed the longitudinal relationships between reading at t2 and key predictors at t1. Critically, we explored whether speech difficulties predict variations in the phonological skills that directly predict later word-level reading skills. To do this the latent variable path model shown in Figure 2 was estimated using Mplus 8.0 (Muthén & Muthén, 1998-2017) with the small number of missing values being handled with Full Information Maximum Likelihood estimation. In this model the critical cognitive foundations of early word reading ability (Hulme & Snowling, 2013) are represented by 3 latent variables assessed at school entry (phoneme awareness, letter-sound knowledge, RAN). These foundational skills are in turn predicted by two theoretically plausible determinants of these skills (oral language skills and speech articulation) as well as nonverbal IQ which we treat as a control variable. Reading ability is represented by a latent variable at school entry (t1) and some six months later (t2). The correlations between all the latent variables in this model are shown in Table 4.

In this model, t1 language is a powerful concurrent predictor of reading, letter-sound knowledge, phoneme awareness, and RAN. Nonverbal IQ is also a weak concurrent predictor of reading, letter-sound knowledge and RAN. Most critically, however, speech difficulties predict variations in t1 phoneme awareness after controlling for the effects of language and nonverbal IQ. Finally, t2 reading is predicted by t1 reading, letter-sound knowledge, phoneme awareness and RAN. In this model although speech (t1) has no direct effect on reading (t2) there is a significant indirect effect (t1 speech → t1 phoneme awareness → t2 reading; standardized indirect effect = -.037 [95% CI -.87, -.002]). This effect is negative since speech difficulties are coded 1= difficulties, 0 = no difficulties.

Overall, the model accounts for 70% of the variance in t2 reading and provides a good fit to the data (χ^2 (68) = 135.92, $p < .001$; Root Mean Square Error of Approximation (RMSEA) = .042 (90% CI = .031, .052), Comparative Fit Index (CFI) = 0.98, Tucker-Lewis Index (TLI) = .98).

In summary, these findings show that speech difficulties at school entry are associated with poorer language skills and lower nonverbal IQ. Speech difficulties also show a unique relationship with later reading ability which is mediated by phoneme awareness. This relationship is independent of both oral language skills and nonverbal IQ. It is worth noting that in this model the paths from t1 speech, language and nonverbal IQ on t2 reading are all fully mediated (dropping direct paths from t1 speech, language and nonverbal IQ to t2 reading resulted in no change in model fit (χ^2 difference (3) = 4.31, $p < .231$)).

To estimate the effect size of t1 speech difficulties on t2 reading, we ran a simplified model in which we regressed t2 reading on t1 speech alone. The y-standardized regression coefficient of t1 speech on t2 reading in this model was -0.7. This figure is equivalent to Cohen's *d* since it expresses the size of the difference in t2 reading scores in *z*-score units between children with and without speech difficulties: having a speech articulation difficulty at school entry is therefore a powerful predictor of differences in reading skills measured 6 months later.

Discussion

We examined the extent to which speech difficulties assessed just after school entry are longitudinal predictors of variations in reading development in a large population sample of children. Speech difficulties were associated with poorer language and reading skills. Importantly, we found evidence of a mediated relationship between speech and reading: speech difficulties are related to problems developing phoneme awareness skills which, in turn, predicts word-level reading measured six months later. Critically, the indirect relationship between speech and reading holds after controlling for language and nonverbal IQ. In contrast to the association between speech difficulties and phoneme awareness, we found no evidence that the relationship between speech difficulties and reading was mediated by letter-sound knowledge or RAN. Clinically, our findings confirm that speech difficulties at school entry are a substantial risk factor for problems learning to read, though part of this risk is shared with measures of oral language skills and nonverbal IQ.

Prevalence of speech sound difficulties

In the current study a speech difficulty was defined by a cut-off score of below 85% consonants correct on the DEAP (Hayiou-Thomas et al., 2017). Using this criterion, 6.88% of 5 year old children have speech difficulties. Prevalence estimates are affected by differences between studies, including the way in which speech sound difficulties are defined, the measures of speech used, and sample characteristics including age. The prevalence of speech difficulties here is in line with, albeit at the higher end, of previous estimates from population-based studies of 4- to 8-year-old children (3.4% to 6.4%; Eadie et al., 2015; Shriberg et al., 1999; Wren et al., 2013; Beitchman et al., 1986). An earlier community cohort study of Australian 4-year-old children reported a prevalence of speech sound difficulties of 3.4% (Eadie et al., 2015). That study, however, utilised a more conservative cut-off (standardized scores $\leq$ 79 on a speech assessment) to identify speech sound difficulties. Our study is also consistent with previous work showing that speech difficulties are more common in boys, and are associated with poorer nonverbal IQ, and an increased likelihood of co-occurring language difficulties (Eadie et al., 2015; Hayiou-Thomas et al., 2017).

Relationships with language and reading skills

Children with speech difficulties had significantly poorer expressive vocabulary scores than children without speech difficulties at t1; these differences remained six months later, and at that point children with speech difficulties also had poorer receptive grammar scores. Potentially, early vocabulary difficulties may give rise to delays in grammatical development. Such a finding would be consistent with the view that lexical development provides one of the foundations for grammatical development, though recent evidence disputes this idea (Hoff, Quinn, & Giguere, 2018). Further studies, with longer term follow up, are needed to examine the development of broader oral language skills in children with speech difficulties over time.

We found clear evidence that speech difficulties are associated with poorer phonological and early reading skills. Children with speech difficulties scored significantly poorer than the comparison group on measures of letter-sound knowledge, phoneme awareness and word reading at the outset of school. These differences remained significant after approximately 6 months in school which indicates that typical classroom reading instruction was not sufficient (at least in that time) to enable these children to catch up with their peers.

It is worth noting here that group differences were not significant on all reading-related tasks: Children with speech difficulties performed similarly to the comparison group on RAN tasks. This finding is inconsistent with some previous studies of children with speech difficulties (e.g., Anthony et al., 2011; Leitao et al., 1997) though group differences on RAN tasks tend to be small and are not always significant (Raitano et al., 2004). As in the current study, Raitano et al. (2004) utilised object and colour naming tasks and, as those authors note, it may be that children with speech difficulties are more impaired on RAN tasks which utilize alphanumeric stimuli than they are on non-alphanumeric RAN tasks (Leitao et al., 1997).

We took a novel approach to examine the mechanism by which speech difficulties relate to learning to read by testing a theoretically motivated mediation model. In this model, word-level reading was predicted by measures of letter-sound knowledge, phoneme awareness and RAN. Performance on such tasks reflect aspects of phonological skills and are critical cognitive foundations of reading (Hulme et al., 2015). These skills in turn were related to speech difficulties, language and nonverbal IQ. As reported elsewhere (Hulme et al., 2015) there was a strong and significant relationship between language, early word reading, letter-sound knowledge, phoneme awareness and RAN. More critically, speech difficulties were directly associated with phoneme awareness and thereby were an indirect predictor of reading outcomes. This relationship was independent of language and nonverbal IQ. Thus, though comorbid language difficulties in children with speech difficulties are common and lead to poorer literacy outcomes than isolated speech-sound disorder (Hayiou-Thomas et al., 2017), speech difficulties at the outset of formal education are a unique (indirect) risk factor for later problems learning to read.

That the relationship between speech and reading was mediated by phoneme awareness, and not by letter-sound knowledge, is worth consideration given that children with speech difficulties showed impairments on this measure relative to the comparison group and that letter-sound knowledge is a strong predictor of reading. Though many earlier studies demonstrate weaknesses in letter-sound knowledge in children with speech difficulties (Bird et al., 1995; Raitano et. al., 2004) studies which control for language ability suggest that group differences in letter-sound knowledge are related to variations in language abilities rather than speech (e.g., Anthony et al., 2011; Rvachew et al., 2003). Our model is consistent with this in showing that language is a strong predictor of letter-sound knowledge, phoneme awareness and RAN whilst speech is a direct predictor only of phoneme awareness. Thus, letter-sound knowledge is more closely related to language skills than to speech skills.

That speech skills are closely tied to phonological and reading skills is not a new finding (Anthony et al., 2011; Bird et al., 1995; Eadie et al., 2004; Hayiou-Thomas et al., 2017; Raitano et al., 2004; Peterson et al., 2009; Nathan et al., 2004; DeThorne et al., 2006;

Snowling et al., 2000). However, most of what we already know about these relationships is drawn from highly selected, and often small, samples; very few studies have examined these questions in large unselected samples of children as we have done here (Beitchman et al., 1986; Eadie et al., 2015; Shriberg et al., 1999; Wren et al., 2013). Furthermore, our use of latent variable path models to test plausible relationships between different phonological skills, speech difficulties, and reading represents an important theoretical advance and clearly shows that phoneme awareness mediates the relationship between speech and reading.

It is worth highlighting here that children at the start of the current study were 5 years old and had recently started school. It has been noted elsewhere that speech problems which persist to the point of formal instruction in reading are particularly problematic (Bishop & Adams, 1990; Bird et al., 1995) and our results confirm this conclusion. The pattern of relationships we report here may not be true for children whose speech difficulties are diagnosed at an earlier age. For many children early speech difficulties resolve and the risk of poor long-term literacy outcomes appear to be small (Hayiou-Thomas et al., 2017).

Limitations

There are a number of limitations to this study. Firstly, the children in the current study were in the early stages of learning to read and our data can only speak to short-term effects of speech difficulties on reading development. Clearly, it is important for further work to examine whether such relationships between speech and reading are observed at later stages of reading development. Second, we measured reading ability by measures of decoding (single word/nonword reading tasks). However, recent research suggests that children with speech difficulties also have difficulties on broader literacy measures including spelling and reading comprehension tasks (Hayiou-Thomas et al., 2017). Finally, our measure of speech difficulties is based purely on a single task that examines the production of single words which is a relatively conservative measure (Eadie et al., 2015). It would be useful to use a broader range of measures including those derived from spontaneous speech to provide more detailed information on children's speech articulation skills. Longitudinal studies with longer term follow-up and a broader range of speech and literacy measures are needed to address these limitations.

Clinical Implications

Notwithstanding these limitations, our study has a number of important implications. It is notable that only 5 out of 38 children in the speech difficulties group had been identified by their teachers as having difficulties with speech (a further 3 children in this group had been identified as having other forms of learning difficulty). Thus, the majority of children who met our criteria for speech difficulties were not recognised by teachers as having such problems, at least as indicated by our teacher reports. Potentially this suggests that, for children at this age, teachers view relatively moderate speech articulation errors as part of the normal course of development and do not necessarily regard them as a cause for concern.

However, our results suggest that speech difficulties at school entry are a relatively strong risk factor for broader oral language and reading difficulties. Our findings imply that any child who has a speech difficulty at school entry should be assessed and monitored by teachers and/or speech therapists both for broader oral language difficulties and for delays in reading development. Evidence-based interventions targeting oral language (e.g., Burgoyne, Gardner, Whiteley, Snowling, & Hulme, 2018; Fricke et al., 2017) and/or literacy and phoneme awareness (e.g., Hatcher, Hulme, & Ellis, 1994) should subsequently be put in place where necessary to support the development of these skills.

Conclusion

This study makes an important contribution to our understanding of speech difficulties and their relationship to language and reading development. This is one of only a few studies (Beitchman et al., 1986; Eadie et al., 2015; Shriberg et al., 1999; Wren et al., 2013) to examine speech difficulties in a population-based sample, and to consider outcomes in language and reading over time. We have shown that speech difficulties are associated with problems in the development of phoneme awareness which in turn is associated with difficulties in word-level reading. It is via this indirect relationship that speech difficulties at school entry place children at risk of later reading difficulties.

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Table 1

Means (standard deviations) for all study measures

Variable (max. score)	*N*	Reliability	Mean (*SD*)
Time 1			
Age (months)	569		63.86 (4.36)
Foundations of Reading			
Letter sound knowledge (17)	557	.91	10.40 (3.83)
Phoneme awareness (12)	541	.78	3.56 (2.30)
Reading			
Early word reading (30)	553	.95	6.60 (6.81)
Naming speed			
Rapid Automatized Naming Pictures Trial 1	544	.88[1]	0.79 (0.19)
Rapid Automatized Naming Pictures Trial 2	538		0.74 (0.21)
Rapid Automatized Naming Colours Trial 1	519	.92[1]	0.70 (0.21)
Rapid Automatized Naming Colours Trial 2	495		0.65 (0.20)
Language			
Expressive Vocabulary (54)	546	.84	19.02 (8.37)
Sentence Structure (26)	547	.72	16.16 (4.07)
Listening comprehension (8)	544	.40	2.43 (1.53)
Speech Articulation			
Percent Consonants Correct	552	.82	93.31 (5.48)
Non-Verbal IQ			
Ravens (12)	530	.85	7.17 (2.80)
Time 2			
Foundations of Reading			
Letter sound knowledge (32)	535	.87	27.55 (4.68)
Phoneme awareness (12)	536	.73	5.56 (2.49)
Reading			
Early word reading (30)	526	.94	17.20 (7.91)
Single word reading (60)	534	.94	11.03 (7.95)
Nonword reading (14)	492	.91	8.60 (4.66)
Naming speed			
Rapid Automatized Naming Pictures	518	.79[1]	0.88 (0.21)
Rapid Automatized Naming Colours	508	.79[1]	0.78 (0.23)
Language			
Expressive Vocabulary (54)	539	.74	23.43 (8.76)
Sentence Structure (26)	537	.61	19.02 (4.03)
Listening comprehension (8)	538	.45	3.24 (1.70)

Note. All reliability values are Cronbach's alpha unless otherwise stated; [1]alternate form reliability

Table 2

Pearson correlations among speech articulation, oral language and reading related tasks (simple correlations below the diagonal; partial correlations controlling for age above the diagonal).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Time 1																		
1. LSK	-	.47**	.71**	.34**	.28**	.22**	.17**	.15**	.24**	.58**	.42**	.64**	.62**	.39**	.35**	.23**	.20**	.16**
2. PA	.52**	-	.46**	.23**	.32**	.31**	.06	.20**	.17**	.34**	.46**	.38**	.44**	.32**	.18**	.23**	.25**	.16**
3. EWR	.71**	.53**	-	.36**	.28**	.20**	.12*	.13*	.22**	.41**	.39**	.65**	.75**	.33**	.27**	.23**	.15**	.17**
4. RAN Average	.40**	.32**	.40**	-	.18**	.12*	.19**	.13*	.18*	.27**	.36**	.46**	.43**	.33**	.79**	.25**	.16**	.08
5. Ex. Vocab.	.36**	.33**	.32**	.23**	-	.42**	.29**	.14*	.14*	.19**	.23**	.26**	.29**	.16**	.15**	.75**	.42**	.30**
6. Sen. Struc.	.33**	.37**	.26**	.21**	.45**	-	.25**	.11	.22**	.18**	.24**	.25**	.20**	.14*	.07	.43**	.53**	.32**
7. List. Comp.	.30**	.18**	.22**	.25**	.40**	.33**	-	.05	.07	.07	.11	.09	.10	.06	.19**	.35**	.31**	.41**
8. PCC	.25**	.23**	.20**	.15**	.20**	.17**	.13**	-	.10	.18**	.16**	.22**	.20**	.15**	.11*	.25*	.16**	.10
9. NVIQ	.30**	.23**	.25**	.19**	.20**	.30**	.13**	.09*	-	.24**	.31**	.28**	.23**	.20**	.15*	.19**	.23**	.10
Time 2																		
10. LSK	.63**	.40**	.42**	.30**	.30**	.32**	.23**	.23**	.24**	-	.41**	.65**	.56**	.47**	.27**	.21**	.18**	.19**
11. PA	.51**	.56**	.46**	.40**	.27**	.32**	.21**	.24**	.31**	.51**	-	.57**	.59**	.51**	.33**	.26**	.28**	.17**
12. EWR	.71**	.50**	.68**	.47**	.34**	.36**	.22**	.29**	.31**	.70**	.64**	-	.86**	.53**	.41**	.29**	.24**	.22**
13. SWR	.64**	.54**	.74**	.44**	.34**	.32**	.22**	.24**	.29**	.57**	.65**	.87**	-	.52**	.34**	.32**	.23**	.20**
14. NWR	.40**	.37**	.35**	.32**	.18**	.17**	.10**	.16**	.19**	.51**	.52**	.55**	.54**	-	.27**	.20**	.15**	.13*
15. RAN Average	.39**	.24**	.31**	.77**	.20**	.15**	.22**	.14**	.16**	.32**	.37**	.42**	.37**	.28**	-	.18**	.12*	.04
16. Exp. Vocab.	.33**	.30**	.28**	.27**	.77**	.45**	.41**	.18**	.26**	.32**	.33**	.38**	.37**	.25**	.22**	-	.47**	.38**
17. Sen. Struc.	.26**	.29**	.18**	.20**	.44**	.55**	.35**	.18**	.31**	.29**	.31**	.30**	.28**	.20**	.15**	.51**	-	.35**
18. List comp.	.23**	.22**	.19**	.12**	.36**	.33**	.43**	.12**	.15**	.27**	.26**	.27**	.27**	.20**	.12**	.41**	.40**	-
19. Age	.21**	.22**	.27**	.17**	.18**	.19**	.17**	.05	.16**	.14**	.10*	.15**	.14**	.05	.14**	.18**	.16**	.08

Notes. LSK: letter sound knowledge; PA: phoneme awareness; EWR: early word reading; RAN: rapid automatized naming; Ex. Vocab: expressive vocabulary; Sen. Struc: sentence structure; List. Comp: listening comprehension; PCC: percentage consonants correct; NVIQ: nonverbal intelligence; NWR: nonword reading * $p < .05$; ** $p < .01$

Table 3

Language and literacy outcomes (t1-t2) for children with speech difficulties (t1 DEAP scores <=85) (z-scores standardised relative to sample mean)

	N	**Mean (min-max)**	*SD*	*t*	*df*	*p*
		Time 1				
Expressive vocabulary	36	-0.53 (-2.03 to 1.07)	0.84	3.30	531	.001
Sentence structure	36	-0.22 (-2.50 to 1.68)	1.00	1.37	532	.170
Listening comprehension	36	-0.10 (-1.59 to 2.34)	1.01	0.61	529	.541
Phoneme awareness	35	-0.53 (-1.55 to 1.06)	0.81	3.23	527	.001
Letter sound knowledge	38	-0.47 (-2.71 to 1.20)	1.10	3.02	550	.003
RAN	31	-0.28 (-1.97 to 1.62)	0.95	1.72	539	.086
Early word reading	35	-0.39 (-0.97 to 1.23)	0.61	3.65[1]	47.72	.001
		Time 2				
Expressive vocabulary	35	-0.41 (-1.99 to 1.44)	0.83	2.56	514	.011
Sentence structure	35	-0.47 (-3.48 to 1.48)	1.25	2.90	512	.004
Listening comprehension	35	-0.19 (-1.91 to 1.63)	0.97	1.21	513	.228
Phoneme awareness	35	-0.58 (-2.27 to 1.81)	0.90	3.54	511	.001
Letter sound knowledge	35	-0.47 (-3.11 to 0.95)	1.22	2.40[1]	37.31	.021
RAN	35	-0.22 (-2.01 to 2.54)	0.99	1.43	502	.154
Early word Reading	37	-0.66 (-2.18 to 1.11)	0.91	4.24	500	.000
Single word reading	35	-0.52 (-1.39 to 1.76)	0.71	4.25[1]	44.65	.000
Nonword reading	26	-0.20 (-1.85 to 1.16)	0.97	1.01	469	.313

Notes. RAN: rapid automatized naming; [1]*equal variances not assumed*

Table 4

Spearman correlations among the latent variables in Figure 2

	t1 Letter Sound Knowledge	t1 Rapid Automatized Naming	t1 Language	t1 Phoneme Awareness	t1 Reading	t1 Nonverbal IQ	t2 Reading
1. t1 Speech Difficulties	-0.14**	-0.07	-0.13*	-0.21**	-0.11*	-0.15**	-0.14**
2. t1 Letter Sound Knowledge	-	0.46**	0.56**	0.74**	0.79**	0.38**	0.77**
3. t1 Rapid Automatized Naming		-	0.38**	0.46**	0.47**	0.28**	0.53**
4. t1 Language			-	0.65**	0.45**	0.45**	0.53**
5. t1 Phoneme Awareness				-	0.71**	0.43**	0.76**
6. t1 Reading					-	0.34**	0.72**
7. t1 Nonverbal IQ						-	0.38**

Note. * $p < .05$; ** $p < .001$.

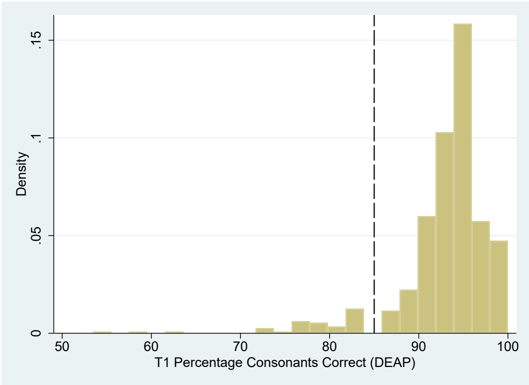

Figure 1. Histogram displaying distribution of t1 DEAP Percentage Consonants Correct (PCC); the vertical dashed line shows the cut point adopted for identifying a child as having a speech difficulty

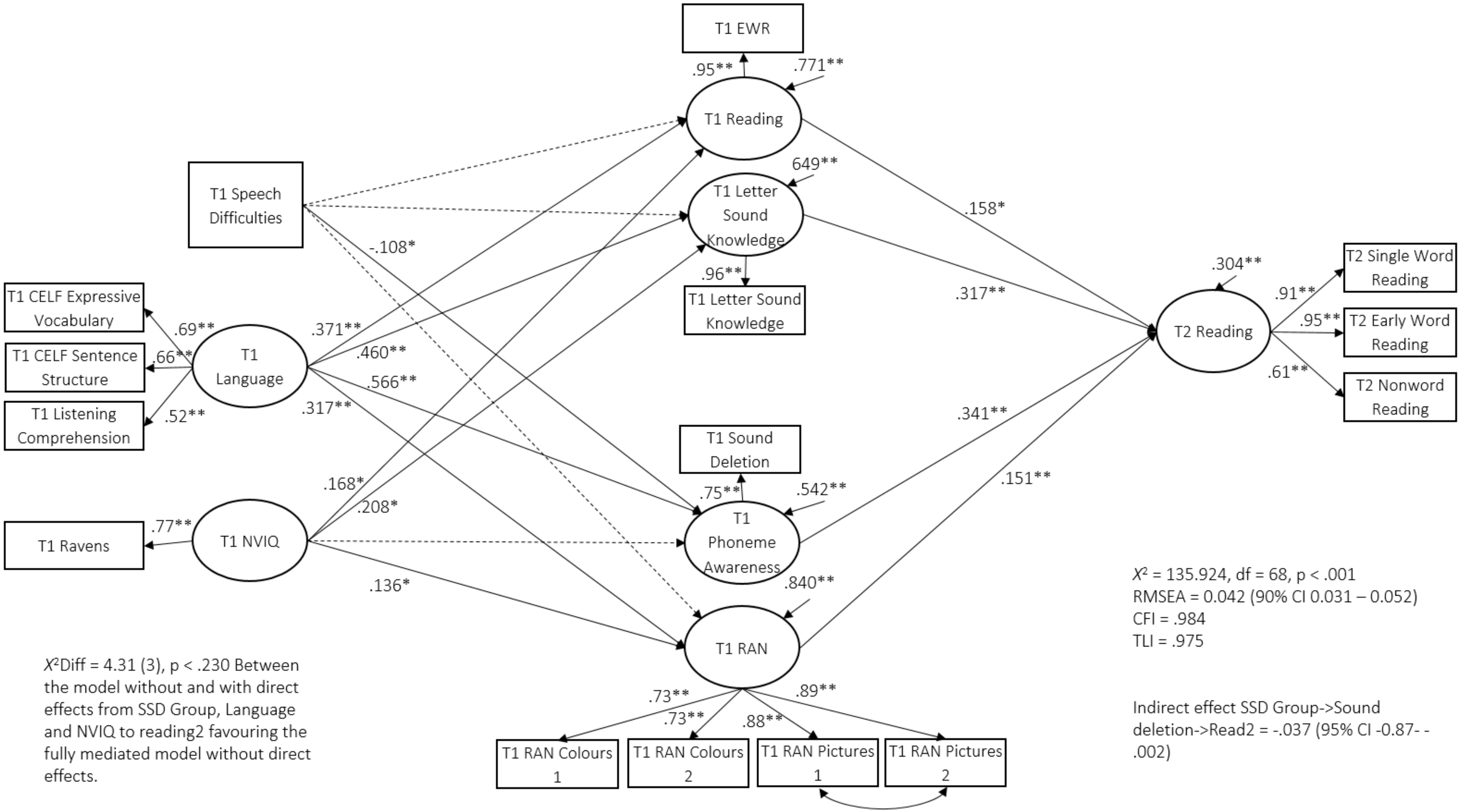

Figure 2. Latent variable path model showing longitudinal predictors of reading. Twin headed arrows represent correlations between variables. One headed arrows represent regression paths; non-significant paths are represented by dashed lines. Both correlations between speech difficulties, language and

nonverbal IQ and between the residuals of t1 reading, letter-sound knowledge phoneme awareness and RAN were estimated but are not shown in the diagram for reasons of simplicity. All parameters are standardized. * $p < .05$, ** $p < .001$