INT. J. LANG. COMM. DIS., MONTH 2008,
VOL. 000, NO. 000, 1–18

informa
healthcare

Phonological awareness and early reading development in childhood apraxia of speech (CAS)

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(*Received XXXX 2007; accepted XXXX 2008*)

Abstract

Background: Childhood apraxia of speech (CAS) is associated with phonological awareness, reading, and spelling deficits. Comparing literacy skills in CAS with other developmental speech disorders is critical for understanding the complexity of the disorder.

Aims: This study compared the phonological awareness and reading development of children with CAS and children with inconsistent speech disorder (ISD).

Method & Procedures: Participants included twelve children with CAS aged 4–7 years. Their performance was compared with twelve children with ISD (and normal speech motor planning) and twelve children with typical development on tasks measuring phonological awareness, letter–sound knowledge, real and non-word decoding, and access to underlying phonological representations of words. There was no significant difference in the age, gender, socio-economic status, and receptive vocabulary of the groups. The two groups with speech disorder were matched for severity and inconsistency of their speech impairment.

Outcomes & Results: The results indicated that the CAS group had inferior phonological awareness than the ISD and typical development groups. The CAS group had a greater proportion of participants performing below their expected age level than the comparison groups on phonological awareness, letter–sound knowledge and decoding tasks. There was no difference in the performance of the CAS and ISD groups on the phonological representation task.

Conclusions & Implications: Children with CAS are particularly susceptible to phonological awareness and reading delay. Intervention for children with CAS must facilitate skills underlying reading development in addition to resolving

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International Journal of Language & Communication Disorders
ISSN 1368-2822 print/ISSN 1460-6984 online
http://www.informahealthcare.com
DOI: 10.1080/13682820801997353

speech deficits in order to improve the spoke and written language outcomes of this population.

Keywords: childhood apraxia of speech (CAS), phonological awareness, inconsistent speech disorder.

What this paper adds

The literature suggests that children with childhood apraxia of speech (CAS) are more likely to experience phonological awareness and reading deficits than children with other types of speech–language impairment. It is unknown whether children with CAS remain at heightened risk when the receptive vocabulary and speech severity of comparison groups is controlled.

The current study found that children with CAS had poorer phonological awareness skills than children with inconsistent speech disorder with comparable receptive vocabulary and speech severity levels. The study highlights the importance of targeting oral and written language skills in children with CAS.

Introduction

The differential diagnosis of childhood apraxia of speech (CAS) from other speech–language disorders has been the focus of much debate (e.g., Shriberg *et al.* 1997a, b, 2003a, b, Davis *et al.* 1998, McCabe *et al.* 1998). Although some measures may distinguish a portion of children with CAS (e.g., Shriberg *et al.* 2003b), no single characteristic has been identified to differentiate CAS from other developmental speech disorders. Recent evidence suggests that children diagnosed with CAS have more severe written language deficits than other children with speech–language impairment (Lewis *et al.* 2004). This research is intriguing since it suggests that the symptoms that comprise CAS interfere with reading, spelling and phonological awareness development to a greater extent than heterogeneous groups of speech–language disorders.

One aspect of CAS that is not typically associated with specific speech and/or language impairment is speech motor planning difficulty (i.e., difficulty planning and producing the precise and timely movements of the articulators for speech). CAS is often defined as a disorder in speech motor planning characterized by inconsistent speech errors, sound sequencing difficulty, vowel errors, articulatory groping and prosodic disturbances amongst other symptoms (Davis *et al.* 1998). The complex nature of CAS makes it difficult to determine the influence of speech motor planning impairment on reading development, as other aspects associated with the disorder such as receptive vocabulary deficits, severe phonological speech errors are also associated with reading delay (Lewis *et al.* 2004). The current study aimed to extend previous research by comparing phonological awareness and early reading development in children with CAS to children who exhibit similar types of speech and language errors but do not display speech motor planning difficulties. Phonological awareness is the ability to consciously reflect on and manipulate the subunits of spoken language such as syllables, rhymes, and phonemes (Gillon 2004). This comparison will help to identify any negative influence of the motor planning difficulty characteristic of CAS on processes underlying reading development.

CAS and literacy development

Children with CAS are at high risk of persistent reading disorder (Stackhouse and Snowling 1992, Lewis *et al.* 2004, Moriarty and Gillon 2006). Although the evaluation of literacy outcomes in children with CAS has included relatively small samples, the available evidence indicates poor reading outcomes despite periods of intensive intervention (Stackhouse and Snowling 1992). Stackhouse and Snowling evaluated the literacy skills of two children with CAS in a longitudinal evaluation. The children were aged 10;7 (years;months) and 11;0 at initial assessment and 14;5 and 15;0 at follow-up assessment. Despite speech and language therapy support and participation in a phonics teaching programme throughout the study, the children with CAS presented with ongoing severe reading and spelling deficits. Reading age equivalence scores ranged between 7 and 8 years at initial and follow-up assessments, while spelling age equivalence scores ranged between 6 and 8 years at initial and follow-up assessments. The children also experienced continued difficulty grasping letter–sound correspondences.

Lewis *et al.* (2004) assessed the speech, language and literacy skills of ten children with CAS at age 4–6 years and again at age 8–10 years. The investigation also tracked children with an isolated speech disorder (n=15) and children with a combined speech–language disorder (n=14). Lewis *et al.* found that the CAS group had more severe real-word decoding, spelling, and reading comprehension difficulties than both comparison groups at school age. This comparison of literacy skills of children with CAS to other types of speech–language disorders was notable, as it began to address how reading deficits may be related to the nature of the speech disorder in children with CAS. However, the comparison groups employed were not equivalent, as the CAS group exhibited lower per cent consonant correct (PCC) scores and receptive language ability. The study, therefore, did not determine whether the inferior reading performance of the CAS group was due to the nature and/or severity of the speech disorder or the inferior receptive and expressive language ability of this group.

Inconsistent speech errors

Inconsistent speech errors have been identified as one of the hallmark characteristics of CAS (Davis *et al.* 1998, Marquardt *et al.* 2004), but inconsistent speech errors can also occur in the absence of speech motor control difficulties (Dodd *et al.* 1989, Holm *et al.* in press). An inconsistent speech error (also termed token to token inconsistency), occurs when a child produces different misarticulations upon repeated production of the same word. For example, in three trials of naming the picture ‘shark’, the child may produce /gak/, /sak/ and /sat/. Under Dodd’s (1995) classification system, inconsistency is evaluated by asking children to name the same 25 words on three occasions within a session. An inconsistent production is marked if the child produces at least two different forms for a word across the three trials. Children who exhibit 40% or greater inconsistency across the 25 items are considered to have ‘inconsistent’ speech errors. Inconsistent speech errors indicate pervasive speech processing difficulties that restrict categorical development of new phonemes (Forrest *et al.* 1997, Williams and Stackhouse 2000). Forrest *et al.* (2000) argued that the presence of inconsistent speech errors increases the likelihood that a child will experience persistent speech disorder.

Phonological awareness and inconsistent speech errors

Children with inconsistent speech errors, with or without speech motor planning difficulties, appear to have written language deficits (Lewis *et al.* 2004, Holm *et al.* in press) which are likely influenced by phonological awareness difficulties. Stackhouse and Snowling (1992) showed impaired phoneme identification, rhyme generation and rhyme identification skills in two children aged 10;7 and 11 years with CAS at initial assessment and at follow-up four years later. Marion *et al.* (1993) found severe deficits in rhyme generation and rhyme detection in four children aged 5–7 years with CAS compared with their peers with typical speech and language development. Similarly, Marquardt *et al.* (2002) found that the three children with CAS in their sample (aged 6–7 years), had severe deficits on a syllable segmentation task, and novel phoneme identity and phoneme manipulation tasks.

Holm *et al.* (in press) compared the syllable segmentation, rhyme awareness and alliteration awareness skills of preschool children with inconsistent speech disorder without speech motor planning difficulties (n=15) with other groups of speech disorder namely, phonological delay (n=46), consistent phonological disorder (n=17), and a control group of children with typical speech development (n=15). Children with inconsistent speech disorder performed poorly on the syllable segmentation task alone. Holm *et al.* also compared the performance of children with a history of inconsistent speech disorder (n=9) and children with a history of typical speech–language development in their third year of schooling (aged 7 years) on spelling, reading, phoneme awareness and rhyme awareness tasks. The children with a history of inconsistent speech disorder performed comparably to their peers with typical speech and language development on the phoneme awareness, rhyme awareness and reading tasks but performed less well on the spelling task.

Phonological representation deficit hypothesis of CAS

A phonological representation is an abstract concept describing the storage of speech sound information in long-term memory (Elbro *et al.* 1998). Access to distinct phonological representations of vocabulary items is thought to be critical for phonological awareness development. For example, to identify the final sound in a word, children must possess a segmental representation of the item in order to reflect on the smaller units (in this case the final phoneme) within the word. Some children with speech disorder have phonological representation deficits, performing poorly in comparison with children with typical speech and language development on tasks designed to measure this construct (Carroll and Snowling 2004, Sutherland and Gillon 2005).

A recent hypothesis accounting for CAS identifies deficits in phonological representation (as opposed to motor planning) as underlying the disorder. The theory posits that poor phonological awareness (particularly on receptive tasks) by children with CAS cannot be accounted for by motor speech planning difficulties alone (Marion *et al.* 1993, Marquardt *et al.* 2002). Rather, indistinct phonological representations and/or impaired access to phonological representations underlie the speech, language and literacy difficulties associated with CAS. Specifically, children are thought to lack quality phonological representations from which to direct motor performance (Marion *et al.* 1993). That is, a precise motor programme cannot be formed, as it is derived from an incomplete phonological template. Phonological

awareness, reading and spelling difficulties would also be predicted for those presenting with an impoverished phonological representation system (Sutherland and Gillon 2005).

Deficits in phonological representation may also disrupt lexical development which depends on the storage of increasingly segmental items to reduce memory demands and aid word finding (Marion *et al.* 1993). For example, Constable *et al.* (1997) described a 7-year-old boy with severe word-finding difficulty whose assessment profile indicated the deficit was due to poor phonological representations. The child performed poorly on a lexical decision task that included words he had difficulty naming (although no difficulty comprehending). The authors concluded that the patterns of results indicated the child had poor phonological representations for words that were difficult to retrieve in spoken production. Despite the formation of the phonological representation deficit view of CAS, the quality of phonological representations has been minimally assessed in this population. Stackhouse and Snowling's (1992) assessment of two children aged 10;7 and 11;0 included a lexical decision task that involved indicating whether matched words produced by an examiner were real or non-word productions (e.g., *black–brack*). This task taps the children's underlying representations of the target words. The participants performed inferiorly to reading age-matched controls on the task. Further evaluation of the phonological representation skills of children with CAS is required to examine the hypothesized deficit underlying CAS. This study compares the performance of children with CAS and inconsistent speech disorder on a receptive phonological representation task.

Recent advances have been made in the assessment of phonological representations in children with speech disorder that do not require verbal output. Sutherland and Gillon (2005) trialled three receptive phonological representation measures (phonological representation judgement, non-word learning task and receptive gating tasks) on nine children with moderate–severe speech disorder and 17 children with typical speech–language development aged 3–5 years. In the phonological representation judgement task children were asked to indicate the 'correctness' of the pronunciation of familiar multisyllabic words with and without vowel errors by pointing to a happy face or a red cross. In the non-word learning task participants were taught a non-word as the name of a picture. Following structured teaching of the non-word and its referent, children were asked to judge the correctness of the non-word's pronunciation with or without production errors (pointing to a green tick or a red cross to indicate correctness). The authors reported that the phonological representation judgement and non-word learning tasks were appropriate measures that distinguished between groups of children with and without speech disorder and were moderately correlated with phonological awareness skills.

The current study

Although evidence (Marion *et al.* 1993, Marquardt *et al.* 2002, Lewis *et al.* 2004) suggests that children with CAS are more likely to experience phoneme awareness and reading difficulty than children with inconsistent speech disorder, a direct comparison of these groups has not been conducted. Such a comparison (particularly when there is no significant difference in speech severity and receptive

vocabulary ability in the groups), will provide insight into how the presence of speech motor planning difficulties in CAS may impact reading and phonological awareness development. Further, an evaluation of the phonological representation skills of the groups will give insight into processes underlying each group's phonological awareness abilities.

The following hypotheses were tested:

- Children with CAS will perform more poorly than children with inconsistent speech disorder on phonological awareness, letter knowledge and reading tasks (despite both groups exhibiting comparable performance on speech and receptive vocabulary measures).
- Children with CAS will perform more poorly than children with inconsistent speech disorder on a receptive phonological representation judgement task.

Method

Study design

The study employed a comparative group design to evaluate the phonological awareness and early reading development of the three groups.

Participant selection process

Speech–language pathologists (SLPs) employed by the New Zealand Ministry of Education participated in a day-long workshop regarding CAS where an assessment battery for the diagnosis of the disorder was described. The workshop was presented in six areas across the country. The assessment battery was based on Ozanne's (2005) model (i.e., children must display impairment in the phonological planning, phonetic programme assembly and motor execution levels of speech production to be diagnosed with the disorder), and was piloted in an earlier research study evaluating an intervention approach for three children with CAS (Moriarty and Gillon 2006). Table 1 outlines characteristics at each level of impairment in Ozanne's model.

Following the workshop, SLPs administered the assessment battery described in the workshop to children on their caseload aged 4–8 years with suspected CAS and who had no history of sensory, cognitive or neurological impairment. All children assessed for the study were viewed as potential CAS participants by their SLP.

Table 1. Levels of impairment and associated characteristics in the Ozanne diagnostic model.

Level	Characteristics
Phonological planning	Vowel errors, greater errors on multisyllabic words and during connected speech, poor phonotactics, inconsistent speech errors, sound sequencing errors, prosodic deficits
Phonetic programming	Articulatory groping during speech production, high rates of consonant deletion, voluntary speech performance poorer than involuntary speech performance
Motor programming	Slow diadochokinetic rates, sequencing errors during diadochokinetic tasks, voicing errors, resonance inconsistencies

Children were assessed in a quiet room at their school or home over two sessions of one hour. The Olympus DS-2 digital voice recorder (with in-built stereo microphone) was used to record the assessment sessions. Assessment results were then forwarded to the researchers. The first author reviewed all audio files (collected by the SLPs and the first author) following the assessment sessions to ensure consistent transcription and recording of assessment data.

The battery included the following assessments:

- Peabody Picture Vocabulary Test — III (PPVT-III) (Dunn and Dunn 1997).
- Bernthal–Bankson Test of Phonology (BBTOP) (Bankson and Bernthal 1990). All responses were transcribed via broad transcription. If a spontaneous response could not be elicited by the picture, delayed imitation was employed to gather a response from the child.
- Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd *et al.* 2006), which consists of four subtests: articulation assessment, phonology assessment, oro-motor assessment and inconsistency assessment. The oro-motor and inconsistency subtests were administered. The oro-motor subtest consists of three components: isolated movements (e.g. lateral tongue movement), sequenced movements (e.g. blow and then put your tongue up), and diadochokinetic testing (elicit multiple trials of 'pat-a-cake', which were rated on sound sequencing, intelligibility and fluency). A standard score is calculated for each component (i.e., isolated movements, sequenced movements and diadochokinetic testing) to indicate performance within/below the expected range. The three standard scores from each component were also added together to compare the overall oro-motor performance of the two groups.

In the inconsistency subtest, participants are required to articulate a set of 25 words three times within a session with an activity between each trial. A production is marked as inconsistent if the same item is articulated differently on two or three of the three trials. Children who are 40% and over inconsistent (i.e., produce an inconsistent error on ten or more of the 25 items) are deemed to have inconsistent production. All responses were transcribed via broad transcription. If a spontaneous response could not be elicited by the picture, delayed imitation was employed to gather a response from the child.

Multisyllabic real and non-word repetition task (Larrivee and Catts 1999). This task was employed to evaluate single-word articulation in spontaneous versus imitation contexts.

Standardized personal narrative sampling (Westerveld and Gillon 2002). This task enabled the informal evaluation of prosodic features (stress, loudness, resonance, pitch) during connected speech. Results also were employed to compare the child's speech abilities in connected versus single-word contexts and to evaluate the presence of articulatory groping during connected speech.

Participants

Forty-four children were assessed for participation in the project by 20 SLPs and the first author with twelve children receiving a positive CAS diagnosis and a further twelve children matching an inconsistent speech disorder profile (Dodd 2005). 4

Inclusionary criteria for the CAS group and inconsistent speech disorder (ISD) group

A standard score (SS) below 1.5 standard deviations of the mean (i.e., SS<77) on the BBTOP (Bankson and Bernthal 1990). This criterion was used so that children with moderate to severe speech production difficulties were included in the study.

Forty per cent or greater inconsistency on the inconsistency subtest of the DEAP (i.e., a whole-word inconsistency measure) (Dodd *et al.* 2006). This criterion was used because inconsistent speech is a hallmark characteristic of CAS and ISD.

A standard score within 1.5 standard deviations of the mean (i.e., SS>77) on the PPVT-III (Dunn and Dunn 1997). This criterion was used so that the poor phonological awareness of participants could not be attributed to significant receptive vocabulary deficits.

CAS group

- Standard scores below 8 on the three oro-motor subtests of the DEAP (i.e., isolated movements, sequenced movements and diadochokinetic).
- Or a standard score below 8 on the diadochokinetic subtest and presence of articulatory groping during connected speech (i.e., noted during the child's personal narrative production). Oral (along with verbal) apraxia is present in only a portion of children diagnosed with CAS (Davis *et al.* 1998).

ISD group

A standard score of 8 and above on the three subtests of the DEAP (Dodd *et al.* 2006) and no evidence of articulatory groping during speech production.

A cross-comparison of the linguistic profiles of each child in the CAS and ISD group to the group of CAS differential diagnostic characteristics identified by Davis et al. (1998) is presented in Tables 2 and 3. The comparison shows that CAS diagnosis via the two methods corresponded well.

Table 2. Comparison of CAS group to Davis *et al.* (1998) diagnostic symptoms

	Child											
Characteristic	1	2	3	4	5	6	7	8	9	10	11	12
Limited phonemic repertoire	+	+	+	+	+	+	+	+	+	+	+	+
Omission errors	+	+	+	+	+	+	+	+	+	+	+	+
Vowel errors	+	+	+	+	+	+	+	+	+	+	+	+
Inconsistent errors	+	+	+	+	+	+	+	+	+	+	+	+
More errors on longer units	+	+	+	n	n	n	+	+	+	+	+	+
Altered suprasegmentals	−	+	+	n	n	n	+	+	+	−	+	−
Uses simple syllable shapes	+	+	+	+	+	+	+	+	+	+	+	+
Oral apraxia	−	+	+	+	−	−	−	+	+	+	−	+
Expressive–receptive gap	+	+	+	+	+	+	+	+	+	+	+	+
Diadochokinetic difficulties	+	+	+	+	+	+	+	+	+	+	+	+

+, Characteristic present, −, characteristic absent; n, characteristic unable to be assessed (due to a lack of production of multisyllabic words and/or connected speech).

Table 3. Comparison of ISD group to Davis *et al.* (1998) diagnostic symptoms.

	Child											
Characteristic	1	2	3	4	5	6	7	8	9	10	11	12
Limited phonemic repertoire	+	+	+	+	+	+	+	+	+	+	+	+
Omission errors	+	−	+	+	+	−	+	+	+	+	+	+
Vowel errors	−	−	+	−	+	+	−	−	+	+	−	−
Inconsistent errors	+	+	+	+	+	+	+	+	+	+	+	+
More errors on longer units	n	+	+	+	n	+	+	+	+	+	+	+
Altered suprasegmentals	n	−	−	−	n	+	−	−	+	−	−	−
Uses simple syllable shapes	+	+	+	+	+	+	+	+	+	+	+	+
Oral apraxia	−	−	−	−	−	−	−	−	−	−	−	−
Expressive–receptive gap	+	+	+	+	+	+	+	+	+	+	+	+
Diadochokinetic difficulties	−	−	−	−	−	−	−	−	−	−	−	−

+, Characteristic present, −, characteristic absent; n, characteristic unable to be assessed (due to a lack of production of multisyllabic words and/or connected speech).

Negative diagnoses

Twenty children were assessed as for the study but did not match criteria for either group. Of those children, nine children achieved a PPVT (Dunn and Dunn 1997) standard score below 77, five children achieved a standard score within 1.5 standard deviations of the mean on the BBTOP (Bankson and Bernthal 1990), and six children were under 40% inconsistent on the inconsistency subtest of the DEAP (Dodd et al. 2006).

Control group: children with typical speech and language development (TD)

Twelve children with typical speech–language development were included as a peer comparison group. Teachers from two primary schools and one kindergarten in middle socio-economic areas were asked to refer monolingual children of New Zealand–European descent with average literacy/language skills and no history of speech or language disorder. Participants in the comparison group exhibited speech and language skills within the expected range (as measured by the PPVT-III and BBTOP) and were monolingual English speakers. Assessment data for the three groups can be viewed in Table 4.

Demographic information

All children were from middle socio-economic areas and were monolingual English speakers of New Zealand–European descent. Socio-economic status was measured according to the 'decile' ranking given to the school. In New Zealand a decile ranking indicates the degree to which a school obtains its pupils from low socio-economic areas. Decile one schools are the 10% of schools with the greatest percentage of pupils from low socio-economic areas, while decile ten schools are the 10% of schools with the lowest percentage of pupils from low socio-economic areas (Ministry of Education 2007). The decile ranking of participants in the study ranged from four to seven indicating middle socio-economic status. There were nine males and three female participants in each group and all children were aged 4–8 years.

Table 4. Assessment data for the three groups

	CAS (n=12)		ISD (n=12)		TD (n=12)				
Group	Mean	SD	Mean	SD	Mean	SD	F	p	F
Age (months)	68.5	17.1	61.2	8.2	73.4	15.3	2.37	0.11	
PPVT-III[1]	91.3	6.4	97.1	8.6	97.2	8.5	3.04	0.06	0.42
PCC[2,a]	51.6	22.6	52.5	18.7	97.6	1.8	28.6	<0.00	1.32
PVC[3,b]	83.7	15.1	92.4	4.8	99.9	0.2	9.86	<0.00	0.77
Inconsistency per cent (DEAP[4])[a]	58.9	17.7	56.7	13.3	2.0	4.0	71.6	<0.00	2.08
Oro-motor[c]	14.0	4.2	27.3	2.4					

[1]Peabody Picture Vocabulary Test — III (Dunn and Dunn 1997).
[2]Per cent consonants correct.
[3]Per cent vowels correct.
[4]Diagnostic Evaluation of Articulation and Phonology (Dodd et al. 2006).
[a]**TD group performance significantly above comparison groups.
[b]**CAS group performance significantly below comparison groups.
[c]**Significant difference between the CAS and ISD groups.

Per cent consonants correct (PCC) and per cent vowels correct (PVC) analysis

Per cent consonants correct (PCC) and per cent vowels correct (PVC) analyses were completed by analysing participants' responses from the BBTOP and the first trial of the 25-word consistency test (giving a sample of 105 words) with computerized profiling software (Long and Fey 2005).

Assessment data for the three groups (CAS, ISD and TD) are presented in Table 4. A single-factor analysis of variance (ANOVA) revealed no significant group effect in age [$F(2, 33)=2.37$, $p=0.109$] or receptive vocabulary [$F(2, 33)=3.04$, $p=0.062$]. Further analyses revealed a significant group effect for PCC [$F(2, 33)=28.6$, $p<0.001$], inconsistency [$F(2,33)=71.6$, $p<0.001$] and PVC [$F(2,33)=9.86$, $p<0.001$] scores. Post-hoc pair-wise comparisons using Bonferroni tests showed the TD group had a higher PCC and more consistent speech productions than the CAS and ISD groups. The TD group had significantly higher PVC scores than the CAS group but not the ISD group. The only significant difference between the CAS and the inconsistent group was oro-motor performance [$t(22)=-4.267$, $p<0.001$]. Oro-motor performance was not calculated for the TD group. The effect size index f (appropriate for ANOVA; Portney and Watkins 2000) was also calculated for all statistically significant comparisons (Table 4). The effect size was interpreted as follows: 0.10=small, 0.25=medium, and 0.40 and above=large (Portney and Watkins 2000).

Procedure and material

The participants from the three groups were administered phonological awareness, letter–sound knowledge and reading tasks. All assessments were conducted individually in a quiet room in the children's home or school.

Standardized phonological awareness assessment

The Test of Phonological Awareness (TOPA; Torgesen and Bryant 1994) was used for children aged 5–8 years (n=7 for the CAS group, n=7 for the ISD group, and

n=8 for the TD group). This assessment provides a receptive measure of phoneme awareness. Responses to test items are made by participants marking one of four picture boxes. The test has two forms: (1) a kindergarten version for children aged 5 and 6 years that measures initial phoneme identity; and (2) an elementary version for children aged 7 and 8 years that measures final phoneme identity. The TOPA has strong psychometric properties with internal consistency reliability, test–re-test reliability, and inter-scorer reliability of r=0.80 or above across all ages. Standard scores were collected for analysis.

Preschool Inventory of Phonological Awareness (PIPA) (Dodd *et al.* 2000) was used for children aged 4 years (n=5 for the CAS group, n=5 for the ISD group, and n=4 for the TD group). The rhyme awareness, alliteration awareness and phoneme identity subtests were administered. The standard scores from each subtest were added to form a composite score for analysis. The administered subtests have strong psychometric properties with test–re-test reliabilities of r=0.870, 0.803 and 0.949, respectively, and internal consistency reliability coefficients from r=0.83 to 0.92.

Letter–sound knowledge assessment

The Letter Knowledge task from the PIPA (Dodd *et al.* 2000) was administered to all children. This task requires the child to name the sound associated with 32 letters, digraphs, blends and vowels. Raw scores (out of a total of 32) were collected for analysis.

Phonological representation assessment

A phonological representation judgement task (Sutherland and Gillon 2005) was administered to all participants. This receptive task requires the child to judge the correctness of 25 multisyllabic words articulated by a New Zealand speaker by pointing to a tick or a check. Some items were produced correctly and others were produced with vowel errors. Five training items were included to familiarize the participants with the task. This task has high internal consistency with a coefficient alpha of 0.835 (Sutherland and Gillon 2005). Full details about the development of this task are included in Sutherland and Gillon (2005). Raw scores (out of 25) were collected for analysis.

Additional measures were administered to children aged 6 years and older (n=5 for the CAS group, n=5 for the ISD group, and n=6 for the TD group). New Zealand children begin formal education at five years, meaning all children who completed the reading measures had received at least one year of literacy instruction.

Word decoding assessment

Burt single-word reading test New Zealand revision (Gilmore et al. 1981). This task requires children to read a series of real words that are graduated for difficulty. Raw and age-equivalence scores were collected from this assessment. Raw scores were used for data analysis as this assessment does not present standard scores. This assessment provides normative data for children from 6 to 13 years.

Informal non-word reading task (Calder 1992). This test requires children to decode 30 non-words. The per cent phonemes read correctly were calculated for analysis. For example, if a child read 'vab' as 'vob', he/she would be awarded two-thirds phonemes read correctly.

Reliability

Speech data

In addition to the first author reviewing all audio samples collected by SLPs, transcription reliability was determined for a second independent transcription conducted by an experienced SLP on eight participants (just over 20% of participants). Mean inter-rater agreement was 88.19% with a range of 78.4–97.3%. Any differences between the transcribed and the reviewed responses were resolved by the reviewers reaching consensus following repeatedly listening to recordings.

Non-word reading data

An independent reviewer analysed and scored the non-word reading responses of eight participants (just over 20% of participants). Mean inter-rater agreement was 93.4% with a range of 87.7–100%.

Results

Multiple ANOVAs were employed to compare each group's performance on phonological awareness, reading and phonological representation measures. The effect size index *f* was also calculated for all statistically significant comparisons (Portney and Watkins 2000).

Phonological awareness

An ANOVA performed on TOPA scores (used for participants aged 5 years and older) revealed a significant group effect [$F(2,21)=11.69$, $p<0.001$; large effect size $f=0.88$]. Post-hoc pair-wise comparisons using Bonferroni tests revealed the TD group had significant higher scores than the ISD and CAS groups. Further, the ISD group had significantly higher scores than the CAS group.

An ANOVA performed on PIPA scores (used for participants aged 4 years) revealed a significant group effect [$F(2,10)=6.456$, $p=0.016$; large effect size $f=1.14$]. Post-hoc pair-wise comparisons using Bonferroni tests revealed the TD and ISD groups had significantly higher scores than the CAS group. There was no significant difference between the PIPA performance of the TD and ISD groups.

Letter knowledge

An ANOVA performed on letter knowledge raw scores revealed a significant group effect [$F(2,33)=3.827$, $p=0.032$; large effect size $f=0.49$]. Post-hoc pair-wise comparisons using Bonferroni tests revealed the TD group had significantly higher

scores than the CAS and ISD groups in the letter knowledge task. There was no significant difference between the performance of the CAS and ISD groups.

Phonological representation

An ANOVA performed on phonological representation scores revealed a significant group effect [$F(2,33)=25.838$, $p<0.001$; large effect size $f=1.25$]. Post-hoc pair-wise comparisons using Bonferroni tests revealed the TD group had significantly higher scores than the CAS and ISD groups. There was no significant difference between the performance of the CAS and ISD groups.

Non-word reading

The Burt reading and non-word reading results were analysed qualitatively due to the small number of participants aged six years and above in each group. The five children with CAS aged 6 years or over (i.e., had received at least one year of formal reading instruction) were compared with the five children with ISD who had received a year of schooling and six children with TD. The CAS group appeared to have difficulty with the non-word reading task in comparison with children in the TD and ISD groups. The range of per cent phonemes correct (PPC) achieved by the CAS group was 0–38% compared with 15–52% and 43–81% achieved by the ISD and TD groups, respectively. Four of the five participants in the CAS group achieved a PPC score below 13%. This result should be interpreted cautiously, however, as participants in the ISD group are generally younger than the CAS and TD groups.

Comparison with norms

The percentage of participants in each group that were performing within or above normal limits on the phonological awareness, letter knowledge and Burt word-reading assessments are shown in Figure 1. A standard score of 85 or above on the TOPA or standard scores over 7 on at least two of the three administered subtests of the PIPA was the criterion for phonological awareness within/above normal limits. A standard score over 7 on the letter–knowledge subtest was the criterion for letter–knowledge skills within/above normal limits. The letter knowledge subtest is normed for children aged 3–6 years so only eight, twelve and eight children from the CAS, ISD and TD groups who were within this age range were compared with the norms. An age equivalence score within/above that expected for a child's age was the criterion for single-word reading (Burt assessment) within/above normal limits. The Burt word reading test is normed for children aged 6–12 years so only five, five, and six children for the CAS, ISD and TD groups who were within this age range were compared with the norms, respectively.

These results show that the CAS group have fewer participants performing within/above normal limits than the ISD and TD groups in phonological awareness, letter knowledge and word reading. The ISD group also has a greater proportion of participants than the TD group performing below normal limits in all areas. Two children in the TD group performed below normal limits on the letter knowledge task. This may have been due to the whole language focus in the New Zealand

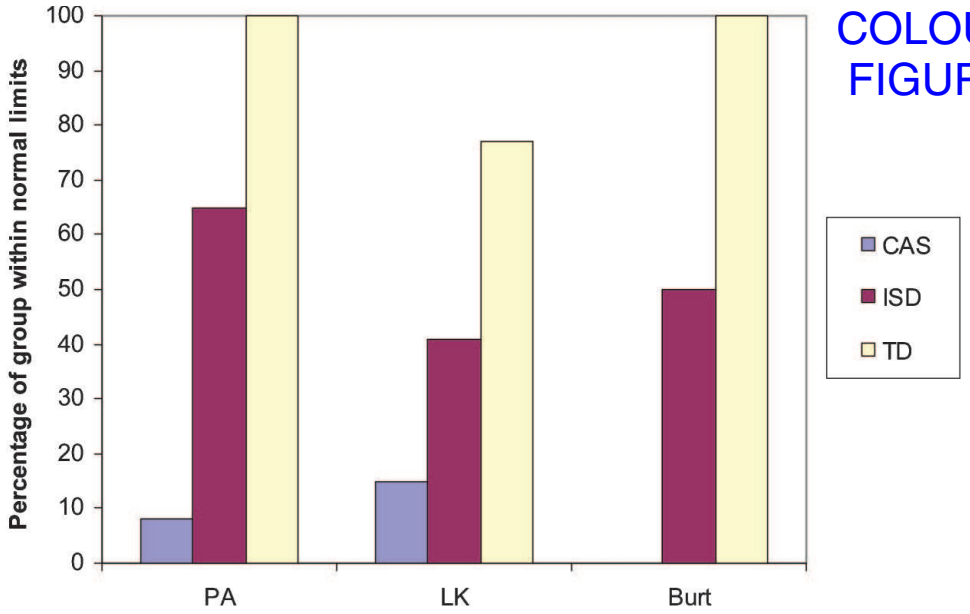

Figure 1. Percentage of children in each group within or above normal limits in phonological awareness, letter knowledge and word reading ability. PA=phonological awareness (n=36) (Preschool and Primary Inventory of Phonological Awareness (PIPA) performance for children aged 4 years; Test of Phonological Awareness (TOPA) performance for children aged 5–8 years); LK=letter–sound knowledge (n=36); Burt=Burt word reading test (n=16); CAS=Childhood Apraxia of Speech group; ISD=inconsistent speech disorder group; TD=typically developing group.

curriculum where letter–sound correspondences are not overtly instructed. These children named all letter names correctly but had difficulty labelling the corresponding sound especially for digraph, clusters and vowels.

Discussion

This study compared the phonological awareness, letter knowledge, reading, and phonological representation ability of children with childhood apraxia of speech (CAS), children with inconsistent speech disorder, and children with typical speech–language development. The first hypothesis tested was that children with CAS would perform more poorly than children with inconsistent speech disorder on phonological awareness, letter knowledge, and reading tasks (despite both groups exhibiting comparable speech severity and receptive vocabulary levels). This hypothesis was supported partially by the data. The children with CAS exhibited poorer phonological awareness scores than the inconsistent speech disordered group, but no difference was found between the groups on the letter knowledge and reading measures.

The finding that children with CAS performed more poorly than the inconsistent group on the phonological awareness measures supports previous research indicating that children with CAS are likely to experience more severe phonological awareness deficits than children with other types of speech–language impairment (Lewis *et al.* 2004). The finding also extends this research by demonstrating that children with CAS continue to perform more poorly despite the comparison group presenting with similar speech error types, receptive vocabulary ability, and speech severity. The result is further consistent with previous

research demonstrating that children with inconsistent speech disorder have an isolated difficulty in syllable awareness (Holm *et al.* in press), with this group performing well on the receptive phonological awareness measures used in the current study that did not contain a syllable awareness component.

The real word and non-word reading performance of the groups was analysed qualitatively due to the small number of participants over six years in each group. The analysis indicated that participants in the CAS group performed inferiorly on the reading tasks in comparison with children of a similar age with inconsistent speech disorder and typical speech–language development. The CAS group appeared to have particular difficulty with the non-word reading task. This finding is expected given the group's poor phonological awareness, as non-word reading requires the use of phonological information in the reading process (Gillon 2004). Results also indicated that the children with inconsistent speech disorder performed more poorly on the reading tasks than the children with typical development. These results must be interpreted cautiously however as raw scores were compared for the reading measures (rather than the standard scores compared for the phonological awareness measures). Although there was no significant difference in the ages of the groups, the CAS group had more 7-year-old participants than the inconsistent group, meaning that the raw scores may not have provided a fair comparison of the reading abilities of both groups given the variability in exposure to formal reading instruction.

To control for the use of raw scores in the reading and letter knowledge measures, participants' scores were compared with the expected range and the proportion of participants in each group who were performing within/above the typical level was calculated. A greater proportion of children in the CAS group performed below the expected range than the inconsistent and control groups in all measures. In fact, all children in the CAS group performed below the expected level in the reading measure. These findings are consistent with previous investigations indicating that children with CAS are likely to experience severe phonological awareness and reading deficits (Stackhouse and Snowling 1992, Marion *et al.* 1993, Marquardt *et al.* 2002, Lewis *et al.* 2004), and that children with CAS are more likely to experience more deficits in these areas than children with other speech–language disorders (Lewis *et al.* 2004). The finding also extends previous research by demonstrating that a greater proportion of children with CAS perform below typical range on letter knowledge and reading measures than a speech disordered comparison group despite the comparison group presenting with similar speech error types, receptive vocabulary ability, and speech severity.

Despite the inconsistent group having a greater proportion of children than the CAS group performing within the expected range on the phonological awareness and reading measures, this group had a greater proportion of children under-performing than the control group. This result conflicts with previous findings that children with inconsistent disorder are at risk for spelling rather than reading difficulties (Dodd 1995, Holm *et al.* in press). However, the reading and letter knowledge measures required verbal output which may have confounded the results in these tasks given the multiple speech errors exhibited by the CAS and inconsistent groups.

The second hypothesis tested was that children with CAS would perform more poorly than children with inconsistent speech disorder and children with typical speech–language development on a phonological representation judgement task.

The data did not support the hypothesis with both the CAS and inconsistent groups performing below the control group on this task. The inferior performance of the CAS group is consistent with previous research that concluded children with CAS have deficiencies in their phonological representational systems, due to this population's poor performance on receptive phonological tasks (Marion *et al.* 1993, Marquardt *et al.* 2002).

One explanation for the unexpected result is that children with inconsistent speech disorder have a deficit in their phonological representation system. Alternatively, the poor performance of the CAS and inconsistent groups may be due to different causes. Dodd (1995) argues that children with inconsistent speech disorder have an isolated deficit in phonological assembly (the creation of phonological plans for speech production). Phonological assembly deficits are hypothesized to disrupt the translation of words into phonological working memory. It follows that the inconsistent group's performance on the phonological representation judgement task may be impeded, as they are required to compare the clinician's pronunciation to a potentially distorted assembled target in working memory. Thus, difficulty with the task could stem from underspecified phonological representations of words in long term memory or impaired phonological assembly for working memory.

Phonological awareness findings in the current study support differing causes of impaired performance in the phonological representation judgement task for the experimental groups. The performance of the CAS group was inferior to that of the inconsistent group on the receptive phonological awareness measure, whereas the performance of the two groups was comparable on the phonological representation task. The completion of phonological awareness tasks is thought to necessitate reflection on the phonological representation of a word in long term memory (Elbro *et al.* 1998). Thus, the phonological awareness results indicate that the group with inconsistent speech disorder presented with stronger representational abilities than the CAS group. In contrast, there was no difference in the groups' performance on the phonological representation judgement task, which may indicate that the inconsistent group's performance was hindered by poor phonological assembly while the CAS group's performance was hindered by their underspecified representational systems.

The above findings must be interpreted with caution, however, as the phonological representation judgement task employed was developed for children aged 4–5 years (Sutherland and Gillon 2005). The task may not have been sufficiently sensitive to detect differences in the phonological representation abilities of the CAS and inconsistent speech disordered groups. Further, the raw scores gathered from the phonological representation judgement task are subject to the same possible age effects outlined for the reading and letter knowledge measures. There is a need for future research that explores the development and assessment of phonological representation of older children with and without speech disorder.

Theoretical implications

The current study supports the theoretical view that children with CAS have a diminished phonological representation system (Marion *et al.* 1993, Marquardt *et al.* 2002). Further investigation is required to determine whether the phonological

representation and phonological awareness abilities of children with CAS are different to children with other types of speech or language impairments. Future studies should focus on developing tasks that can differentiate phonological assembly and phonological representation in children with speech disorder. Such research will help to determine if children with CAS have a particular deficit in this area.

The findings provide further evidence that the deficits experienced by children with CAS are not limited to verbal motor planning but include reading and representational deficits. It is not clear, however, if the linguistic and representational features of the disorder are causal, consequent, or co-occur with verbal motor planning difficulties.

Clinical implications

The study provides further evidence that intervention for children with CAS should not be limited to the remediation of verbal motor planning difficulties. Children with CAS present a challenge for clinicians due to the severity and diversity of speech and language difficulties in the disorder. The use of integrated treatment models that simultaneously target speech, phonological awareness and reading is critical to ensure treatment is efficient and effective in improving these children's oral and written language development.

Acknowledgements

The authors would like to acknowledge the children and families who participated in the study. Grateful thanks are expressed to the kindergartens, schools and speech–language pathologists from the New Zealand Ministry of Education who contributed to the study. The authors would also like to thank the New Zealand Tertiary Education Commission for financial support.

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International Journal of Language & Communication Disorders lcd149522.3d 9/4/08 15:11:37
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