The effectiveness of an integrated phonological awareness approach for children with childhood apraxia of speech (CAS).

B. C. McNeill[1], G. T. Gillon[2], and B. Dodd[3]

[1]HCD Division, School of Psychological Sciences,

University of Manchester,

UNITED KINGDOM

[2]College of Education

University of Canterbury

NEW ZEALAND

[2]Perinatal Research Centre

University of Queensland

AUSTRALIA

Address correspondence to: Doctor Brigid McNeill, HCD Division, School of Psychological Sciences, University of Manchester, Manchester M139PL, United Kingdom,

brigmoriarty@yahoo.co.nz

Background and Aim: This study investigated the effectiveness of an integrated phonological awareness approach for children with Childhood Apraxia of Speech (CAS). Change in speech, phonological awareness, letter knowledge, word decoding, and spelling skills were examined.

Method: A controlled multiple single-subject design was employed. Twelve children aged 4-7 years with CAS participated in two 6-week intervention blocks (2-sessions per week) separated by a 6-week withdrawal block.

Results: Nine children with CAS made significant gains in their production of target speech sounds and these demonstrated transfer of skills to connected speech for at least one speech target. Eight children showed significant gains in at least one target phoneme awareness skill, and these children demonstrated transfer of skills to novel phoneme awareness tasks. As a group the children with CAS demonstrated improvement in phonological awareness, letter knowledge, word decoding, and spelling ability.

Conclusions: An integrated phonological awareness programme was an effective method of simultaneously improving speech, phoneme awareness, word decoding, and spelling ability for some children with CAS.

Article word count (excluding references): 6.749 (includes tables, figures, and abstract)

Children with Childhood Apraxia of Speech (CAS) are renowned for the persistent nature of their speech impairment despite extended periods of intervention. Campbell (1999) reported that children with CAS require 81% more therapy than children with phonological impairment to produce a functional change in speech production. Preliminary research has also indicated that children with CAS are likely to experience severe written language deficits (i.e., reading and spelling deficits) (Gillon & Moriarty, 2007; Lewis, Freebairn, Hansen, Iyengar, & Taylor, 2004; McNeill, Gillon, & Dodd, in press). Despite the negative consequences of persistent oral and written language impairment and the financial cost of providing long periods of treatment, there is a scarcity of intervention studies for CAS. Current and novel treatment approaches for children with CAS must be rigorously investigated to direct treatment practices for this population.

CAS is a developmental speech sound disorder affecting the accuracy and consistency of speech production in the absence of neuromuscular deficits (American Speech-Language-Hearing Association, 2007). Commonly cited speech characteristics in the disorder include inconsistent speech errors, sound sequencing difficulty, vowel errors, articulatory groping, and prosodic disturbances (Davis, Jakielski, & Marquardt, 1998). Linguistic features associated with CAS include expressive and receptive language impairment, phonological awareness deficits, and written language disorder (Lewis *et al.,* 2004). The diverse nature of symptoms in CAS challenges clinicians to provide efficient and effective intervention targeting multiple skill areas. The majority of interventions described for CAS, however, are limited to remediation of speech production deficits (for review, see Morgan & Vogel, 2008). The written language development of children with CAS must also be fostered in intervention. The current study employed a controlled research design to explore the effectiveness of an approach designed to simultaneously target speech, phonological awareness, reading, and spelling for children with CAS.

Children with CAS present with multiple risk factors for reading and spelling disorder including genetic predisposition, persistent speech disorder, and poor phonological awareness (for review, see Gillon & Moriarty, 2007). Preliminary findings indicate that children with the disorder are more likely than children with other speech-language disorders to experience written language deficits (Lewis *et al.*, 2004; McNeill *et al.,* in press). McNeill *et al.* (in press) compared the phonological awareness, decoding, and letter knowledge ability of children with CAS (n = 12), children with inconsistent speech disorder without oro-motor impairment (n = 12), and typical speech-language development (n = 12). The CAS group exhibited inferior phonological awareness and had more participants performing below the average range on standardised letter knowledge and decoding measures than the comparison groups. Lewis *et al*. (2004) described the written language abilities of children with CAS (n = 10), children who displayed an isolated speech disorder (n = 15) and children who presented with a combined speech-language disorder (n = 14). These participants were assessed at age 4 to 6 years and again at age 8 to 10 years. The CAS group exhibited more severe decoding, spelling, and reading comprehension difficulties at follow-up than the two comparison groups

Phonological awareness deficits at phoneme, rhyme, and syllable levels appear to underlie the written language deficits of children with CAS. Marion, Sussman and Marquardt (1993) reported significant deficits in rhyme generation and identification in four children with CAS aged 5 to 7 years compared to their matched peers with typical speech and language development. Marquardt, Sussman, Snow and Jacks (2002) found severe deficits in syllable segmentation, phoneme identity, and manipulation tasks in three children with CAS aged 6 to 7

years included in their study. Moriarty and Gillon (2006) reported phoneme awareness deficits on a standardised measure in three participants with CAS who were aged 6 and 7 years.

Phonological awareness, reading, and spelling deficits in CAS appear to persist into adolescence irrespective of gains in speech production ability. Stackhouse and Snowling (1992) followed the phonological awareness, reading, and spelling development in two children with CAS aged 10;7 and 11 years over four years. The authors reported ongoing phoneme and rhyme awareness deficits and an inability to use phonological strategies in reading and spelling despite gains in speech production and intensive phonics training over the follow-up period. Similarly, the CAS group ($n = 10$) in the Lewis *et al*. (2004) sample exhibited reading and spelling deficits at follow-up (aged 8 to 10 years) when the speech production deficits of the group had largely resolved.

CAS Intervention Studies

Multiple interventions have been described for children with CAS including techniques based on imitation (Strand & Debertine, 2000; Strand, Stoeckel, & Baas, 2006), gestural, and tactile cueing for artciulatory position (Hayden & Square, 1994), and the use of melodic patterns to aid articulation (Helfrich-Miller, 1994). Traditional intervention approaches for CAS share some common intervention principals including: (1) use of multimodal cueing (auditory, visual, tactile) for articulatory placement; (2) use of drill based exercises; (3) use of imitation and (4) systematic progression from simple to more complex sound production (Marquardt & Sussman, 1991). However, many of the treatment approaches described for CAS are generally untested or evaluated by descriptive case studies employing limited experimental control (for review, see Morgan & Vogel, 2008). It is critical that interventions designed for children with CAS undergo more robust scrutiny.

One intervention that may be a promising method of simultaneously targeting speech, phonological awareness, and letter knowledge is an integrated phonological awareness approach (Moriarty & Gillon, 2006). The approach incorporates targeted speech production practice into phonological awareness activities and uses letters and phonological cues to prompt speech production. Moriarty and Gillon (2006) piloted an integrated phonological awareness approach on three children with a confirmed CAS diagnosis aged 6 and 7 years using a controlled multiple single subject design with repeated measures. The children received approximately seven hours of the research intervention in individual sessions over three weeks. The words used in the phonological awareness activities were based on the child's targeted speech error pattern. Two children significantly improved their targeted speech skills. All three children significantly improved their phonological awareness skills following the intervention with two children transferring these skills to an untrained non-word reading task.

The current study aims to extend the pilot study by evaluating the effectiveness of an integrated phonological awareness approach to improve the speech production, letter knowledge, and phonological awareness skills of 12 children with CAS and to examine the generalization of intervention targets to untrained items, spontaneous speaking contexts, and the reading and spelling process. The following hypotheses are tested:

Following participation in an integrated phonological awareness children with CAS will:

1. Suppress the use of targeted speech error patterns in trained and untrained words

2. Suppress the use of targeted speech error patterns during connected speech.

3. Increase the phonological awareness of trained and untrained words containing a target speech error pattern.

4. Increase letter-sound knowledge, real word and non-word decoding, and spelling ability.

METHOD

Research Design

The study employed a controlled multiple single-subject design with repeated measures, using an AB (baseline-intervention) format for each treatment goal.

Participant Selection Process

Speech-language therapists (SLTs) participated in a day-long workshop regarding CAS where an assessment battery for the diagnosis of the disorder was described. The assessment battery was based on Ozanne's (2005) model, (i.e., children must display impairment in the phonological planning, phonetic program assembly, and motor execution levels of speech production to be diagnosed with the disorder), and was piloted in Moriarty and Gillon (2006).

Following the workshop, 15 SLTs administered the assessment battery described in the workshop to children on their caseload aged 4-to-7 years with suspected CAS and who had no history of sensory, cognitive, or neurological impairment. 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 inbuilt stereo microphone) was used to record the assessment sessions. Assessment results were then forwarded to the researchers.

The battery included the following assessments:

Peabody Picture Vocabulary Test - III (PPVT-III) (Dunn & Dunn, 1997).

Bernthal-Bankson Test of Phonology (BBTOP) (Bankson & Bernthal, 1990).

Stimulability testing of speech sounds and clusters that were produced in error during the BBTOP was conducted informally for treatment selection purposes. If the child was unable to imitate the sound in isolation following three trials, it was considered unstimulable.

Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd, Hua, Crosbie, Holm, & Ozanne, 2006). The oro-motor and inconsistency subtests were administered.

Speech production analysis. The participants' responses from the BBTOP (Bankson & Bernthal, 1990) and the first trial of the 25-word consistency test (giving a sample of 105 words) were analysed with Profile in Phonology (PROPH) Computerized Profiling software (Long & Fey, 2005). The percent phonemes correct (PPC), percent vowels correct (PVC) and percent process usage (PPU) scores were collected.

Personal narrative language sampling Personal Narratives were collected following a standardized protocol (Westerveld & Gillon, 2002) in order to: (1) Informally evaluate of prosodic features (stress, loudness, resonance, pitch) during connected speech, (2) Compare the child's speech abilities in connected versus single-word contexts, and (3) Evaluate the presence of articulatory groping during connected speech.

CAS Identification

From the 44 children assessed, 12 children (3 females and 9 males), received a positive CAS diagnosis from the researchers. These participants were monolingual speakers of New Zealand English and attended schools in middle socioeconomic status areas as classified by the New Zealand Ministry of Education.

The inclusionary criteria were:

1. Standard score (SS) below 1.5 standard deviations of the mean on the BBTOP (Bankson & Bernthal, 1990).

2. Scored 40% or greater inconsistency on the inconsistency subtest of the DEAP (Dodd *et al.,* 2006).

3. Standard score within 1.5 standard deviations of the mean on the PPVT-III (Dunn & Dunn, 1997).

4a. Standard scores below 8 on all three oro-motor sub-tests of the DEAP <u>or</u>

4b. Standard score below 8 on the diadochokinetic subtest and presence of articulatory groping during connected speech.

Of the 32 children who were assessed for the study but did not match the CAS criteria, 12 children were excluded because of typical oro-motor performance, 9 children were excluded due to a PPVT (Dunn & Dunn, 1997) standard score below 77, 5 children were excluded due to a standard score within 1.5 standard deviations of the mean on the BBTOP (Bankson & Bernthal, 1990), and 6 children were under 40% inconsistent on the inconsistency subtest of the DEAP (Dodd *et al*., 2006).

CAS Assessment Data Verification

The first author reviewed all audio files (collected by the SLTs and the first author) and checked all scores following the assessment sessions to ensure accurate transcription and recording of assessment data. An independent examiner then re-transcribed 20% of the data. Mean inter-rater agreement was 84.4%.

Probes for Repeated Measures

Repeated assessment measures for speech production and phonological awareness were used to establish a stable or downward trend in the baseline phase for each child prior to the implementation of the intervention. These measures were re-administered during every second intervention session during the treatment block and again on three occasions post-intervention for trained items to evaluate intervention effects. The untrained probes were re-administered on three occasions at post intervention alone (and not during the intervention phase).

One speech error pattern was chosen to be targeted in each intervention block for each child. Selection of each child's targeted speech error patterns was based on (Crosbie, Holm, & Dodd, 2005; Hodson, 2006) speech target selection recommendations. Targeting speech error patterns was deemed appropriate, as the assessment data showed that all children presented with speech error patterns with at least 40% usage (Hodson, 2006). Thus, although the children presented with inconsistent speech errors in repeated productions of the same word, a hallmark symptom of CAS, there were identifiable speech error patterns that could be targeted. A long "cycle" of intervention was used for each speech error pattern (i.e., 12 sessions over 6 weeks), as evidence suggested that children with CAS are slow to progress during therapy and to ensure multiple productions of the target words.

Speech probes

The speech probes consisted of 10 trained words and 5 untrained words for each speech error pattern. Trained words consisted of items containing the target speech error pattern that were used as stimuli during intervention sessions. Untrained words consisted of items containing the target speech error pattern that were not used as stimuli during intervention sessions. The trained and untrained words were matched for phonological structure.

Speech probes were recorded via broad phonetic transcription and a percent suppression of speech error pattern score was calculated for trained and untrained items. For example, if a child suppressed his/her target speech error pattern in 2 out of the 10 trained speech probes, he/she would receive a percent suppression of speech error pattern score of 20%. Distortion errors were not counted as an 'incorrect' production.

Control probe

A further speech error pattern was selected from the children's PROPH analysis to act as a control probe. The children's target and control speech error patterns, the percentage usage of the speech error patterns, and stimulability of the sounds included in those speech error patterns are presented in Table 1.

Phoneme awareness probes

Different phoneme awareness tasks (phoneme segmentation and initial phoneme identity) were probed for children aged 4 years and 5 – 7 years to ensure the tasks were developmentally appropriate. The phoneme segmentation probe (participants aged 5-7 years) consisted of 10 trained and 5 untrained items where the child was required to segment the probe word into its constituent phonemes using coloured blocks. All the stimulus words for this phoneme segmentation task were taken from the child's target speech production words.

The initial phoneme identity probes (for participants aged 4 years) consisted of seven trained and five untrained words. The child was required to select one out of three words that started with a target sound that corresponded with the child's target speech error pattern.

A total percent phonemes correct score (PPC) was calculated for the trained and untrained phoneme segmentation probes. The percentage of correct responses was calculated for trained and untrained phoneme identity probes.

Measuring Generalization to Connected Speech

The personal narrative production was also used to evaluate the transfer of improved speech production to a connected and spontaneous speaking context. Children were required to produce at least 90% of words containing target sounds correctly to show transfer of speech goals to a connected context.

Table 1

Pre and Post Intervention Measures

Speech production measures. The items from the BBTOP (Bankson & Bernthal, 1990) and first trial of the inconsistency subtest of the DEAP (Dodd *et al*., 2006) were analysed to gain a PCC, PVC, and inconsistency score.

Standardised phonological awareness measures. The rhyme awareness, alliteration awareness and phoneme identity subtests of the Preschool and Primary Inventory of Phonological Awareness (PIPA) (Dodd, Crosbie, MacIntosh, Teitzel, & Ozanne, 2000) were administered to children aged 4 years (*n*=5). The standard scores from these subtests were combined into a composite score for data analysis.

The Test of Phonological Awareness (TOPA) (Torgesen & Bryant, 1994) was administered to children aged 5 to 7 years (*n*=7). Raw scores were collected for data analysis while standard scores were used to determine performance within/below the expected range.

Letter knowledge measure. The letter-sound knowledge subtest of the PIPA (Dodd *et al.,* 2000) was administered to all participants. Standard scores were collected for children 6 years and under (to match the normative population) to determine performance within/below the expected range. Raw scores (out of 32) were collected for all participants for data analysis.

The following reading and spelling measures were administered to participants aged 6 years and older. These children had completed at least one year of formal literacy instruction.

Word decoding measures. The Burt Word Reading Test (Gilmore, Croft, & Reid, 1981) was used to measure real word decoding. An informal non-word reading task (Gillon, 2000) was used to measure non-word decoding. The percentage of phonemes correctly decoded for this task was calculated.

Informal spelling measure. Children spelt ten familiar (one to three syllable) words from the items sampled in the inconsistency subtest of the DEAP (Dodd *et al*., 2006). Responses were analysed for the number of graphemes represented correctly per attempt and combined into a percent graphemes correct (PGC) score.

Intervention

The first author instructed three SLTs and two student SLTs under clinical supervision in the implementation of the intervention for five of the participants. The first author administered the research intervention to the seven remaining participants. The content and materials used in intervention were standardised. All materials and the instruction manual were provided to the SLTs (Gillon & McNeill, 2006). The SLTs and student SLTs watched (and had continued access to) a demonstration video. To ensure treatment fidelity, SLTs were required to fill out a session completion worksheet after each session. SLTs were also required to elicit a minimum of 15 elicited productions of (any) trained speech target words in each activity. Productions were not required to be produced correctly to be counted as elicitations. Sessions were audio or videotaped for treatment fidelity analysis.

The research intervention had three aims:

1. Reduce target speech error patterns at the single word level and in connected speech

2. Improve phoneme awareness

3. Improve letter-sound knowledge.

Each child participated in 24 individual 45-minute intervention sessions over 18 weeks. The intervention scheduling was as follows: Intervention block one (12 sessions over 6 weeks, 2 sessions per week), followed by a 6-week withdrawal block without intervention, followed by a

second intervention block (12 sessions over 6 weeks, 2 sessions per week). Sessions were conducted in a quiet room in the child's home or school.

Structure of the Sessions

All sessions included the following types of phonological awareness tasks: letter-sound knowledge, phoneme identity, segmentation and blending, manipulation. Further description of the intervention tasks and resources may be freely downloaded at http://www.education.canterbury.ac.nz/people/gillon/resources.shtml. Tasks were presented as game activities with colourful pictures and toys.

Cueing for Correct Speech Production

The words used in the phonological awareness activities were the children's trained speech probe words. For example, if the child was working on suppressing the s-cluster reduction error pattern, he/she would be required to segment words that contained an s-cluster. Targeted speech production practice was required in all activities and all speech production practice occurred within the context of the phonological awareness activities. If a speech production error occurred, the child was cued by drawing their attention to the phonological structure of the word and/or using a letter or coloured block as a visual prompt for prompt speech production.

Reliability of Experimental Measures and Treatment Fidelity

An independent reviewer was used to verify the assessment data. Mean inter-rater reliability of non-word reading and spelling measures ranged from 88.2%-100% and 88.4%-100% respectively. Point by point analysis for (a) transcription of speech probes ranged from 78.8%-84.5% agreement, (b) phoneme awareness probes ranged from 82.1%-95.8% agreement, and (c) speech analysis of personal narratives ranged from 82.4%-88.3%.

Treatment fidelity. Twenty-nine sessions, (just over 20% of the total sessions), were randomly chosen for evaluation of treatment fidelity. An independent SLT recorded the presence or absence of the following treatment components: (1) Letter-sound knowledge, phoneme identity, segmentation, blending, and manipulation activities were required in each session. (2) A minimum of 15 elicited productions of trained words were required in each activity. (3) The sessions were required to exclude words from the participant's 'untrained' items, and (4) Cues were required to be given when the child produced a speech production error of a trained word. The majority of cues for were required to be limited to those giving information about the phonological structure of the word or those helping the child to use graphemes to direct speech production. Analysis showed that adherence to the above treatment fidelity measures was 96.6%.

RESULTS

Repeated Measures: Trained Items

The two standard deviation (2SD) band and the test of significance of the split-middle line methods were used to identify if variation between baseline and intervention phases were indicative of significant improvement across the phases for trained items (Portney & Watkins, 2000). The 2SD band method involves plotting the mean and two standard deviations above and below the mean of the baseline phase along the baseline and post-intervention phases. If two consecutive data points in the intervention phase fall outside the banded area, the change in performance is considered significant (Portney & Watkins, 2000).

The split middle line technique involves extending the trend line from the baseline phase through to the intervention phase. A one-tailed binomial test is then used to compare the number of data points in the intervention phase that are above and below the extended baseline trend line

(Portney & Watkins, 2000). It was required that both statistical methods denoted a significant result for the change to be considered significant.

An example of the graph used to analyse the trained speech production gains of one child via the two methods is presented in Figure 1. Given the number of graphs required for this analysis (four per child), the results for the trained speech production and phonological awareness probes of all participants are summarised in Figure 2.

The trained speech findings show that 9 of the 12 children showed improvement in trained speech probes for both targeted speech error patterns. One child improved in trained speech probes for one speech error pattern. Two children did not improve the speech production of trained probes. Analysis of the connected speech data showed that nine children were able to transfer their speech target from the first intervention block to a spontaneous speaking context, and five children were able to transfer their speech target from the second intervention block to a spontaneous speaking context.

The trained phonological awareness data are summarized in Figure 3. Five children improved improvement in probes from both targeted error patterns. Three children improved in trained phonological awareness probes for one error pattern. Four children did not improve their phonological awareness scores.

Figure 1

Figures 2 and 3

Repeated Measures: Untrained Items

An effect size appropriate for single cases (Apel & Masterson, 2001) was used to analyse the children's change in performance from pre to post-test on the untrained speech and phonological awareness probes (See Figures 4 and 5). The 15 untrained speech items (five words

elicited three times each at pre and post-intervention) were scored as 1 or 0 to indicate whether the targeted speech error pattern had been suppressed. The mean and standard deviation at pre and post-intervention was calculated.

The 15 phoneme identity probes were given a value of 1 or 0 to calculate the mean and standard deviation at pre and post-intervention. The 15 phoneme segmentation items were given a value indicating the number of phonemes correctly identified to calculate the mean and standard deviation at pre and post-intervention.

The untrained speech results show that three children had strong effect sizes (d = greater than 0.80) for both speech error patterns with a further three children exhibiting strong gains (although an effect size was undetermined due to a standard deviation of zero at pre-intervention). Two children had strong effect sizes for one speech error pattern. A further two children also exhibited strong gains in one speech error pattern (although no effect size could be calculated). Two children did not exhibit gains.

The untrained phonological awareness probes show that six children had strong effect sizes for both targets with a further two children exhibiting strong gains (although no effect size could be calculated). One child had a strong effect size for one target. Three children did not exhibit gains.

Figures 4 and 5

Pre and Post Measures

A descriptive analysis of PPU on the items from the BBTOP and the first trial of the inconsistency test show that in general the gains in the targeted speech error pattern were greater than those achieved in the control pattern for children that responded to the intervention (see Table 2). This conclusion is confirmed by statistical analysis with paired *t-tests* showing a

significant increase in suppression of speech error patterns for target one (T (11) = 7.01, $p <$ 0.001) and target two (T (11) = 5.47, $p < 0.001$), but no significant change in the suppression of control speech error patterns (T (11) = 1.93, $p = 0.08$).

Table 2

A paired *t-test* was used to evaluate change over the intervention period in the pre and post measures. The results (Table 3) indicate that the children made a significant improvement in all the pre-post measures except for the Burt Word Reading Test over the intervention period. There was, however, a large effect size for the Burt reading measure indicating a clinically significant effect.

Table 3

DISCUSSION

This study employed a controlled multiple single subject design to evaluate the effectiveness of an integrated phonological awareness intervention for 12 children with CAS aged 4 to 7 years. The intervention aimed to improve speech, letter sound knowledge, and phoneme awareness skills. The effects of the intervention on the children's speech, reading, and spelling ability were monitored.

Speech

The first hypothesis tested was that the research intervention would suppress the use of targeted speech error patterns in trained and untrained words. This hypothesis was supported by the data for the majority of participants. Nine of the twelve participants suppressed the use of speech error patterns in trained words for both targets while six children also suppressed the use of speech error patterns in untrained words for both targets. In general, the suppression of speech

error patterns was greater for targeted than control patterns for those children who made speech gains.

The second hypothesis tested was that participants would suppress the use of targeted speech error patterns during connected speech. This hypothesis was supported partially by the data. Nine participants generalised gains in the first speech target to the connected speaking context, whereas four participants generalised gains in the second speech target to the connected speaking context. The low number of children who generalised their second speech target is likely due to the administration of the connected speech probe immediately post-intervention giving less time for generalization of the second target.

The increased accuracy of trained speech items is consistent with that reported in the pilot study (Moriarty & Gillon, 2006). The results also extend the pilot results by demonstrating the generalization of speech gains to untrained items and a connected speaking context for some participants. The generalisation of speech gains in the current sample is contrary to reports that children with CAS struggle to transfer gains to other linguistic contexts and may be due to the nature of the research intervention. The integrated approach targeted speech error patterns rather than drilling certain words or phrases which may be more likely to create widespread change in children's phonological systems. Although intervention based on speech error pattern suppression has been contraindicated by some authors for children with CAS who do not identify a phonological component to the disorder (e.g., for review see Pannbacker, 1988), its use is appropriate if the child presents with delayed or disordered speech error patterns as exhibited by the current sample (Velleman & Strand, 1994).

The improvement in speech production skills achieved by the children with CAS is also contrary to reports indicating that children with CAS are particularly slow to progress in therapy

(e.g., Campbell, 1999). The average PCC gain of 12.4% achieved over the four month intervention period is similar to that reported in treatment studies for children with other developmental speech sound disorders with integrated goals over similar intervention periods. For example, Gillon (2000) reported that 20 hours of integrated phonological awareness approach over 4.5 months produced an average PCC gain of 13.2% in 23 participants aged 5;6 to 7;6 with spoken language impairment. Tyler, Lewis and Welch (2003) reported that 24 weeks of morphosyntactic and phonological intervention (one individual and one group session per week) produced an average PCC gain of 13.1% for participants aged 3;0 – 5;11.

The speech gains exhibited by the participants may be related to the selection of treatment targets for participants. Eight of the twelve participants were stimulable for at least one of their targeted speech error patterns. The intervention approach may thus be more suitable for children with CAS who can produce some sounds in isolation but are struggling incorporating those sounds into syllables and words. Three children, however, who were unstimulable for either targeted speech error pattern made strong gains in speech production. The role of stimulability in speech target selection is an ongoing debate in the developmental speech disorder literature (e.g., Morrisette & Gierut, 2002; Rvachew & Nowak, 2001). Further research is needed to determine applicability of the research intervention for children with CAS who are unstimulable for speech targets.

Receptive vocabulary level may also influence children's ability to benefit from the integrated programme. The two children who made the least progress in their speech development over the intervention presented with receptive vocabulary standard scores between 80 and 84 (i.e., just below the typical range). Intervention tasks may need to be adjusted for children that present with co-occurring language difficulties.

Phoneme Awareness

The third hypothesis tested was that participants would increase the phonological awareness of trained and untrained words containing a target speech error pattern. The data supported the hypothesis for the majority of the participants.

Five children showed significant improvement in trained and untrained phonological probes for both targeted error patterns while a further three children showed significant improvement in trained and untrained phonological awareness for one targeted error pattern. One child showed strong gains in untrained but not trained probes. Three children did not show phonological awareness gains.

The findings are consistent with results from the pilot study demonstrating it is possible to teach phoneme awareness in an integrated framework to children with CAS (Moriarty & Gillon, 2006). The results are also consistent with previous research demonstrating that phoneme identity skills can be enhanced in 4 year old children with speech impairment (Gillon, 2005; Hesketh, 2007). The single-subject design also drew attention to three participants who did not benefit from the phonological awareness training, two of whom were the two youngest children in the sample (who also presented with the most severe speech difficulty) and one school-aged child. 'Treatment resisters' have been described in other phonological awareness intervention studies (Gillon, 2005; Hesketh, Dima, & Nelson, 2007) and require further investigation.

Letter Knowledge, Reading, and Spelling

The fourth hypothesis tested was that participants would increase their letter knowledge, decoding, and spelling skills. The data supported this hypothesis with the children learning an average of 8.5 letter-sound combinations during the intervention. Participants made significant gains in all literacy areas except for real word decoding. The non-significant change in real word

decoding may be explained by the nature of the assessment which included many items which could not be decoded phonetically (e.g. some, one etc.). The reading task in the intervention program (i.e. manipulation with letter tiles) focused on decoding phonetically regular real and non-words alone. Further, the small number of children aged six years and older in the CAS sample made it more difficult to detect statistically significant results. Overall the findings suggest that an integrated approach benefits phonological awareness development in children with CAS. Further, the integration of letter knowledge into phoneme awareness tasks facilitates the transfer of improved phonological awareness skills to the reading and spelling process (Hulme, Goetz, Gooch, Adams, & Snowling, 2007).

Theoretical Principles behind an Integrated Phonological Awareness Approach

It is useful to discuss the findings in relation to the theoretical principles behind an integrated approach to intervention. Integrated phonological awareness intervention focuses on improving accessibility and specificity of phonological representations and providing targeted speech production practice to simultaneously improve speech and phonological awareness. The approach is consistent with recent research highlighting the importance of visual-verbal paired associated learning (i.e. the ability to learn that a particular shape corresponds with a particular verbal response) and phoneme awareness for reading development (Hulme et al., 2007). Hulme *et al*. (2007) found that visual-verbal learning and phoneme awareness were independent correlates of reading ability in a sample of children aged 8 to 11 years with typical reading development. Visual-verbal learning was more strongly correlated with reading ability than visual-visual (i.e. learning that two shapes go together) and verbal-verbal learning (i.e. learning that two words go together). In line with the above findings, the integrated approach facilitates

the development of visual-verbal learning (e.g. letter-sound knowledge training, using letters to prompt speech production) and phoneme awareness.

This approach is also consistent with theoretical accounts of the disorder emphasising disordered representational and motor processes in those affected. Marquardt *et al.* (2002, 2004) pinpoint an underdeveloped phonological representation system and unstable motor programs for speech production as the underlying impairment in CAS. Performing phonological awareness tasks on a target speech word may increase the specificity of the phonological representation of that word and provide a more stable motor program to direct speech production. The bidirectional links between phonological representation, phonological awareness and speech have also been highlighted in other types of phonologically based speech disorder (Leitao & Fletcher, 2004; Rvachew, 2006; Sutherland & Gillon, 2007).

Clinical Implications

The findings show that it is possible to simultaneously target speech production, phonological awareness, letter knowledge, reading, and spelling skills in children with CAS. The results are particularly important considering previous research demonstrating that speech production difficulties in CAS tend to minimise over time while language, reading, and spelling deficits persist (Lewis *et al*., 2004).

There has been a widespread impetus for SLTs to incorporate evidence based practice into clinical work which has been difficult to achieve for children with CAS given the lack of intervention studies for this population. The current study is a first step in demonstrating treatment effectiveness for a comparatively larger number of children with CAS compared to previous studies via a controlled intervention design. The data also indicated that the integrated

approach is an efficient use of intervention resources with some participants making rapid gains in speech and phoneme awareness skills.

Table 1: Target speech error pattern and control probes for all participants

P	Age	PCC	Target 1	% Usage	Stim?	Target 2	% Usage	Stim?	Control Pattern	% Usage	Stim?
1	87	69.5	S-cluster reduction	86%	Yes	Tri-cluster reduction	100%	No	Gliding	52%	Yes
2	64	54.3	Velar fronting	56%	Yes	S-cluster reduction	100%	No	Deaffrication	30%	No
3	53	52.5	Velar fronting	67%	No	S-cluster reduction	100%	No	Early stopping	58%	No
4	53	54.8	Velar fronting	63%	No	S-cluster reduction	100%	No	Early stopping	52%	No
5	90	71.7	Velar fronting	78%	Yes	Palatal fronting	44%	Yes	Gliding	24%	No
6	87	57.5	Velar fronting	44%	Yes	S-cluster reduction	86%	Yes	L-clusters	90%	Yes
7	51	19.2	Final consonant deletion	95%	No	S-cluster reduction	100%	No	Velar fronting	44%	No
8	92	81.7	Syllable reduction	56%	Yes	S-cluster reduction	66%	Yes	L-clusters	33%	Yes
9	79	76.4	S-cluster reduction	86%	No	Palatal fronting	60%	Yes	Gliding	60%	No
10	55	42.3	S-cluster reduction	100%	Yes	Velar fronting	63%	No	Early stopping	37%	Yes
11	51	13.9	Initial bilabial deletion	62%	No	Final consonant deletion	95%	No	Deletion of clusters	90%	No

| 12 | 60 | 24.6 | Final consonant deletion | 80% | Yes | S-cluster reduction | 100% | Yes | Liquid deletion | 100% | Yes |

Note: P = participant, PCC = percent consonants correct, target 1 = speech error pattern targeted in the first intervention block, target 2 = speech error pattern targeted in the second intervention block, % usage = percent usage of the speech error pattern according to the child's PROPH analysis, Stim? = was the speech pattern stimulable or not
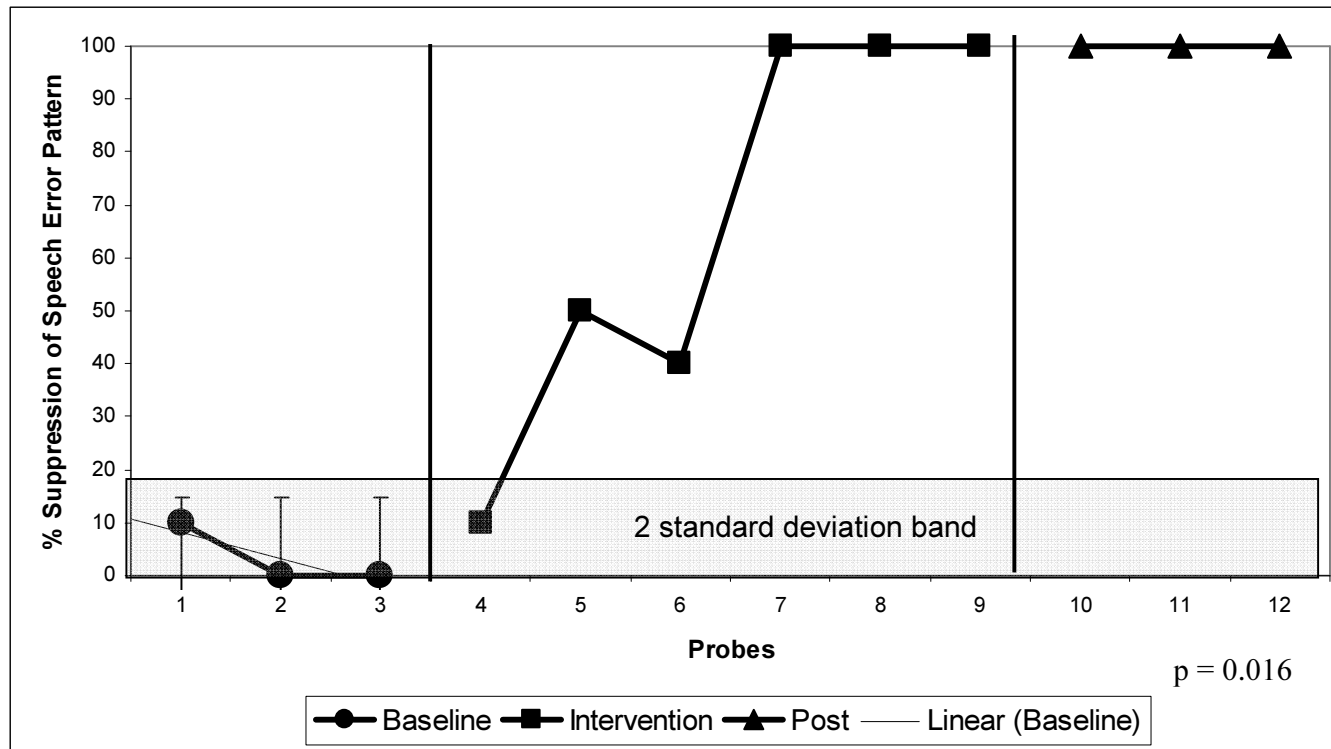
Figure 1. Baseline, intervention and post-intervention performance for trained speech probes during block two (palatal fronting) for participant 9.

Intervention phase data must contain at least two consecutive points above the two standard deviation band and be significantly greater than baseline phase data according to binomial testing.
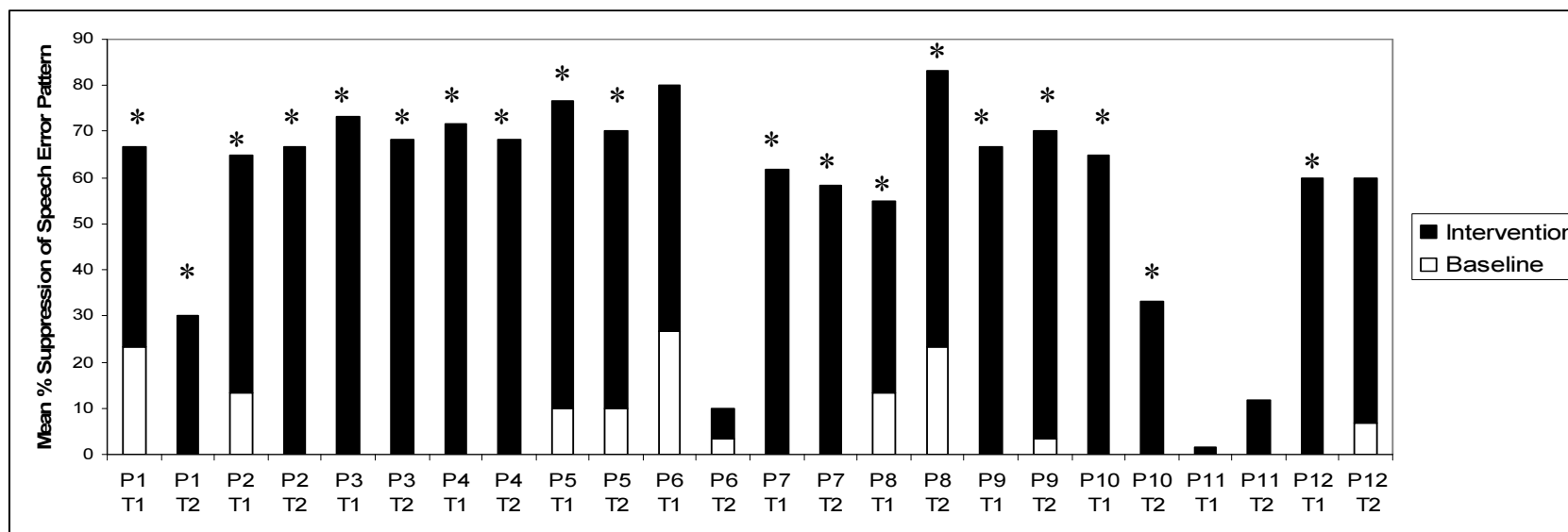
Figure 2. Average percent suppression of targeted speech error patterns in baseline and intervention phases.

Note: an entirely black bar indicates 0% suppression of the error pattern during the baseline phase, P = participant, T1 = speech target from the first intervention block, T2 = speech target from the second intervention block, * = significant increase across the phases according to the binomial and two standard deviation band analysis methods.
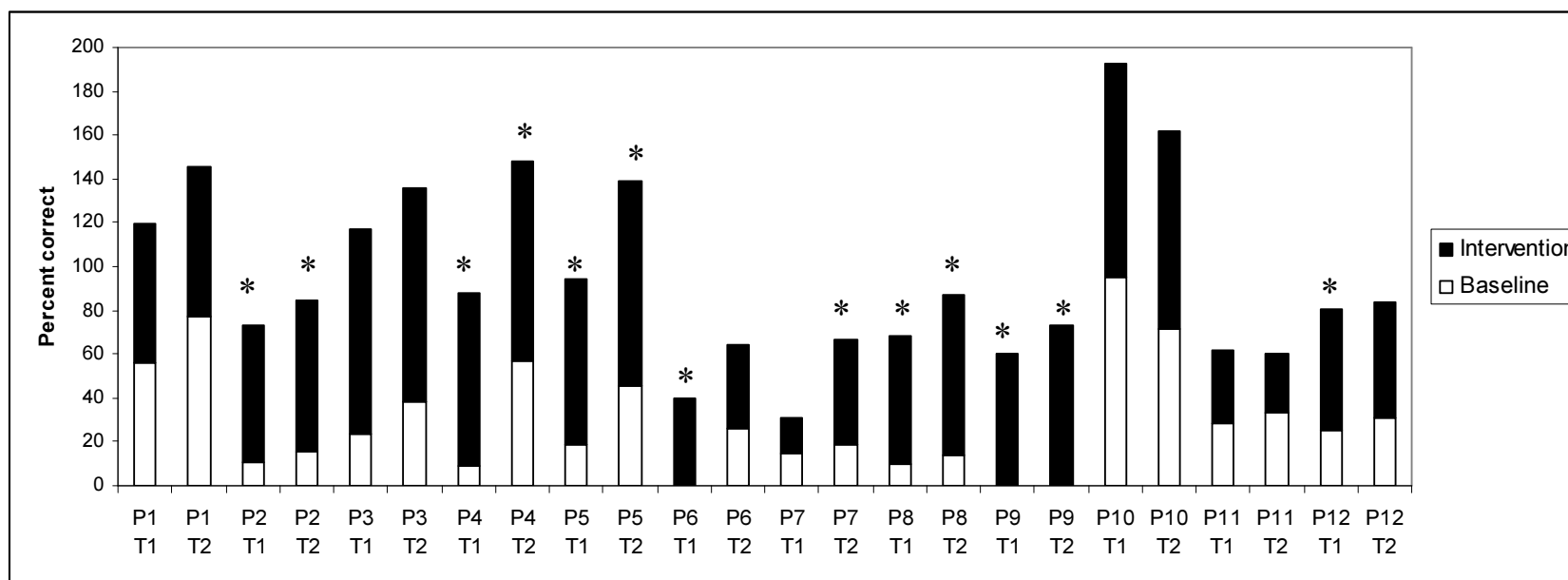
Figure 3. Average percent correct for targeted phonological awareness probes in baseline and intervention phases.

Note: an entirely black bar indicates 0% percent correct during the baseline phase; P = participant, T1 = target from the first

intervention block; T2 = target from the second intervention block; * = significant increase across the phases according to the

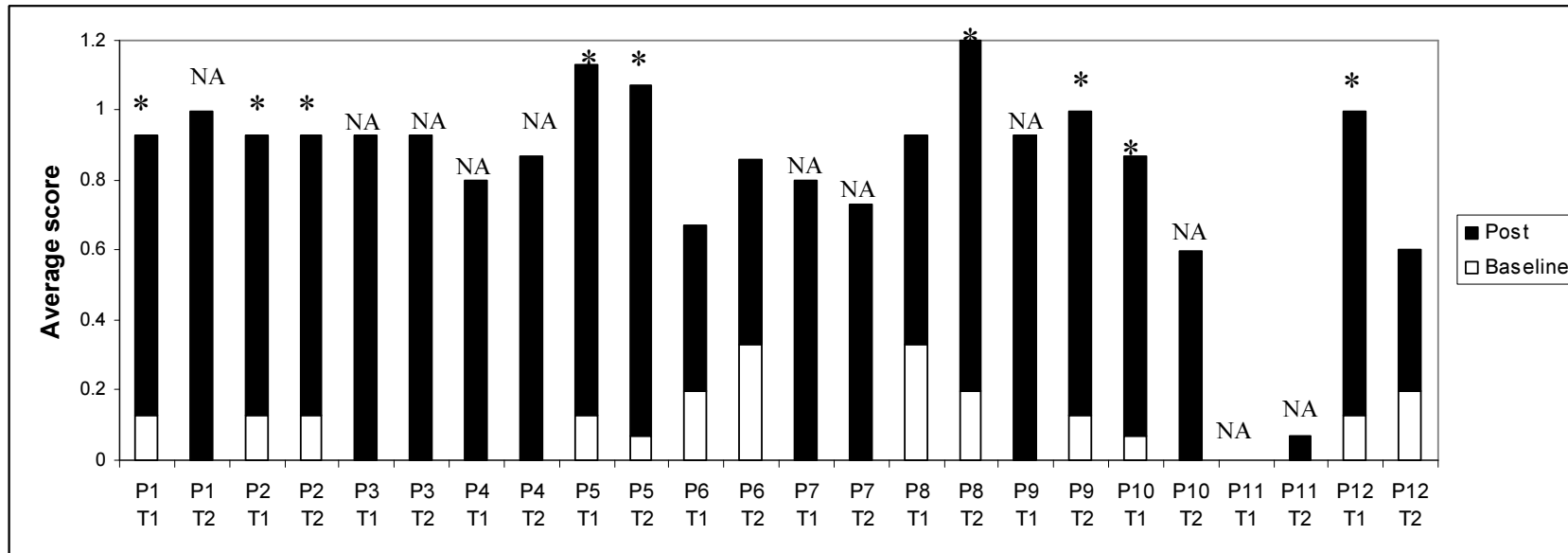binomial <u>and</u> two standard deviation band analysis methods.

Figure 4. Mean scores in untrained speech probes during baseline and intervention phases.

Note: An average score of 1 denotes 100% suppression of the speech error probe. Pre and post scores are the mean of the 15 items (five words probed on three occasions); P = participant, T1 = target from the first intervention block; T2 = target from the second intervention block * = large effect size ($d => 0.80$); NA = effect size unable to be calculated as the standard deviation of pre-intervention phase is zero
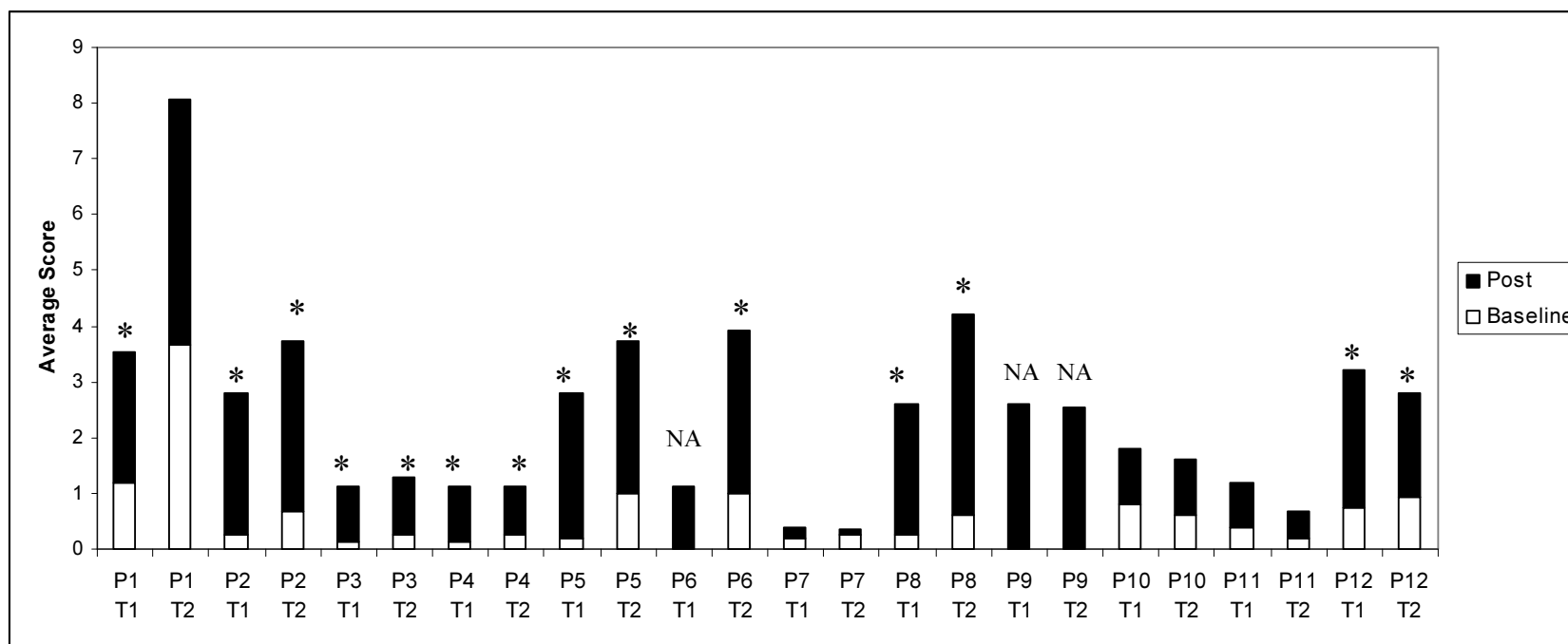
Figure 5. Mean scores in untrained phonological awareness probes during baseline and intervention phases.

Note: Pre and post scores are the mean of the 15 items (five words probed on three occasions); A score of 1 or 0 was given in phoneme identity probes (children aged 4 years). A score corresponding to the number of phonemes identified correctly was given for phoneme segmentation probes (children aged 5 years and older). P = participant, T1 = target from the first intervention block; T2 = target from the second intervention block * = large effect size (d = > 0.80); NA = effect size unable to be calculated as the standard deviation of pre-intervention phase is zero

Table 2. Change in percent process usage (PPU) of targeted and control speech error patterns

P	Target pattern 1	Target pattern 2	Control pattern
1	-57%	-20%	-12%
2	-56%	-71%	-15%
3	-67%	-71%	-8%
4	-43%	-100%	-22%
5	-60%	-39%	-8%
6	-4%	-0%	-6%
7	-85%	-70%	+31%
8	-33%	-37%	+5%
9	-57%	-45%	-14%
10	-25%	-56%	-18%
11	-21%	-15%	-8%
12	-77%	-24%	-20%

Note: P = participant, Target pattern = speech error pattern targeted in the intervention blocks, control pattern = speech error pattern not targeted throughout the intervention, scores are change in percent process usage.

Table 3: Change in pre and post measures

	Pre	Post	T	p	d
	Mean (SD)	Mean (SD)			
PCC	51.6 (22.5)	64.0 (20.5)	-8.1	0.000**	3.3
PVC	83.7 (14.9)	92.9 (9.4)	-2.4	0.034*	1.0
Inconsistency%	58.7 (18.1)	43.0 (21.8)	4.0	0.002*	1.6
TOPA (n =7)	6.3 (3.1)	11.1 (2.6)	-3.8	0.009*	2.0
PIPA (n = 5)	21.4 (0.5)	31.4 (12.0)	-1.9	0.136	1.2
LK	8.3 (9.6)	16.8 (9.6)	-4.9	0.000**	2.0
Burt Reading (n = 6)	14.2 (10.8)	23.0 (7.8)	-2.2	0.078	1.3
NWR (n = 6)	8.9 (15.0)	49.3 (19.5)	-8.1	0.000**	4.7
Spell (PGC) (n = 6)	20.1 (12.8)	51.7 (9.2)	-5.0	0.007*	3.2

Note: PCC = percent consonants correct, PVC = percent vowels correct, TOPA = Test of Phonological Awareness raw score (Torgesen & Bryant, 1994), PIPA = Preschool and Primary Inventory of Phonological Awareness combined standard scores from rhyme awareness, alliteration awareness and phoneme identity subtests (Dodd *et al.*, 2000), LK = letter-sound knowledge raw score, NWR = non-word reading percent phonemes correct, PGC = percent graphemes correct, ** = significant difference at .001 level; * = significant difference at .05 level

References

American Speech-Language-Hearing Association. (2007). *Childhood Apraxia of Speech: Technical Report*, from http://www.apraxia-kids.org/atf/cf/%7B145BA46F-29A0-4D12-8214-8327DCBAF0A4%7D/CAS_TECHNICAL_REPORT.pdf

Apel, K., & Masterson, J. J. (2001). *Theory-Guided Spelling Assessment and Intervention: A Case Study* (080 Journal Articles; 143 Reports: Research).

Bankson, N. W., & Bernthal, J. E. (1990). *Bankson-Bernthal test of phonology*. Austin, Tex.: Pro-Ed.

Campbell, T. F. (1999). Functional treatment outcomes in young children with motor speech disorders. In A. Caruso & E. Strand (Eds.), *Clinical management of motor speech disorders in children* (pp. 385-396). New York: Thieme Medical.

Crosbie, S., Holm, A., & Dodd, B. (2005). Intervention for children with severe speech disorder: A comparison of two approaches. *International Journal of Language and Communication Disorders, 40*, 467-491.

Davis, B. L., Jakielski, K. J., & Marquardt, T. P. (1998). Developmental apraxia of speech: determiners of differential diagnosis. *Clinical Linguistics and Phonetics, 12*(1), 25-45.

Dodd, B., Crosbie, S., MacIntosh, B., Teitzel, T., & Ozanne, A. (2000). *Preschool and Primary Inventory of Phonological Awareness (PIPA)*. London: Psychological Corporation.

Dodd, B., Hua, Z., Crosbie, S., Holm, A., & Ozanne, A. (2006). *Diagnostic Evaluation of Articulation and Phonology (DEAP)*. San Antonio: Psychological Corporation.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test - III*. Circle Pines, Minnesota: American Guidance Service.

Gillon, G. T. (2000). The efficacy of phonological awareness intervention for children with spoken language impairment. *Language, Speech and Hearing Services in Schools, 31*, 126-141.

Gillon, G. T. (2005). Facilitating phoneme awareness development in 3-and 4-year-old children with speech impairment. *Language, Speech, and Hearing Services in Schools, 36*, 308-324.

Gillon, G. T., & McNeill, B. C. (2006). *Integrated Phonological Awareness: An intervention program for preschool children with speech-language impairment*. Christchurch: Department of Communication Disorders, University of Canterbury.

Gillon, G. T., & Moriarty, B. C. (2007). Childhood apraxia of speech: Children at risk for persistent reading and spelling disorder. *Seminars in Speech and Language, 28*, 48-57.

Gilmore, A., Croft, C., & Reid, N. (1981). *Burt Word Reading Test. New Zealand Revision*. Wellington: NZCER.

Hayden, D., & Square, P. (1994). Motor speech treatment hierarchy: A systems approach. *Clinics in Communication Disorders, 4*, 162-174.

Helfrich-Miller, K. (1994). Melodic intonation therapy and developmentallly apraxic children. *Clinics in Communication Disorders, 4*, 175-182.

Hesketh, A., Dima, E., & Nelson, V. (2007). Teaching phoneme awareness to pre-literate children with speech disorder: a randomized controlled trial. *International Journal of Language and Communication Disorders, 42*, 251-271.

Hodson, B. (2006). *Evaluating and enhancing children's phonological systems: research and theory to practice*. Greenville, SC: Thinking Publications.

Hulme, C. K., Goetz, D., Gooch, J., Adams, J., & Snowling, M. (2007). Paired-associated learning, phoneme awareness, and learning to read. *Journal of Experimental Child Psychology, 96*, 150-166.

Leitao, S., & Fletcher, J. (2004). Literacy outcomes for students with speech impairment: long-term follow-up. *International Journal of Language & Communication Disorders, 39*(2), 245-256.

Lewis, B. A., Freebairn, A., Hansen, A. J., Iyengar, S. K., & Taylor, H. G. (2004). School-age follow-up of children with childhood apraxia of speech. *Language, Speech and Hearing Services in Schools, 35*(2), 122-140.

Long, S., & Fey, M. E. (2005). Computerized Profiling (Version 9.7.0). Cleveland, OH: Case Western Reserve University.

Marion, J., Sussman, H. M., & Marquardt, T. P. (1993). The perception and production of rhyme in normal and developmentally apraxic children. *Journal of Communication Disorders, 35*(1), 31-49.

Marquardt, T. P., & Sussman, H. M. (1991). Developmental apraxia of speech: Theory and practice. In D. Vogel & M. Cannito (Eds.), *Treating disordered speech motor control* (pp. 341-390). Austin, TX: Pro-Ed.

Marquardt, T. P., Sussman, H. M., Snow, T., & Jacks, A. (2002). The integrity of the syllable in developmental apraxia of speech. *Journal of Communication Disorders, 35*(1), 31-49.

McNeill, B. C., Gillon, G. T., & Dodd, B. (in press). Phonological awareness and early reading development in children with childhood apraxia of speech (CAS). *International Journal of Language and Communication Disorders*.

Morgan, A. T., & Vogel, A. P. (2008). Intervention for childhood apraxia of speech. *Cochrane Database of Systematic Reviews, 3*, 1-19.

Moriarty, B. C., & Gillon, G. T. (2006). Phonological awareness intervention for children with childhood apraxia of speech. *International Journal of Language & Communication Disorders, 41*, 713-734.

Morrisette, M. L., & Gierut, J. (2002). Lexical organization and phonological change in treatment. *Journal of Speech, Language and Hearing Research, 45*, 143-159.

Ozanne, A. (2005). Childhood Apraxia of Speech. In B. Dodd (Ed.), *Differential Diagnosis and Treatment of Children with Speech Disorder.* (2nd ed., pp. 71-82). London: Whurr.

Portney, L. G., & Watkins, M. P. (2000). Foundations of Clinical Research - Application to Practice. In (2nd ed., pp. 710-711). Upper Saddle River, NJ: Prentice Hall.

Rvachew, S. (2006). Longitudinal predictors of implicit phonological awareness skills. *American Journal of Speech-Language Pathology, 15*, 165 - 176.

Rvachew, S., & Nowak, M. (2001). The effect of target-selection in phonological learning. *Journal of Speech, Language and Hearing Research, 44*, 610-623.

Stackhouse, J., & Snowling, M. (1992). Barriers to literacy development in two cases of Developmental Verbal Dyspraxia. . *Cognitive Neuropsychology, 9*(4), 273-299.

Strand, E., & Debertine, P. (2000). The efficacy of integral stimulation intervention with developmental apraxia of speech. *Journal of Medical Speech-Language Pathology, 8*, 295-300.

Strand, E., Stoeckel, R., & Baas, B. (2006). Treatment of severe childhood apraxia of speech: a treatment efficacy study. *Journal of Medical Speech-Language Pathology, 14*, 297-307.

Sutherland, D., & Gillon, G. T. (2007). Development of phonological representations and phonological awareness in children with speech impairment. *International Journal of Language and Communication Disorders, 42*, 229-250.

Torgesen, J., & Bryant, B. (1994). *Test of Phonological Awareness*. Austin, Texas: PRO-ED Inc.

Tyler, A. A., Lewis, K. E., & Welch, C. M. (2003). Predictors of phonological change following intervention. *American Journal of Speech-Language Pathology, 12*, 289-308.

Velleman, S. L., & Strand, K. (1994). Developmental verbal dyspraxia. In J. Bernthal & N. Bankson (Eds.), *Child phonology: Characteristics, assessment, and intervention with special populations* (pp. 110-139). New York: Thieme Medical Publishers.

Westerveld, M., & Gillon, G. T. (2002). *Language sampling protocol*. Christchurch: University of Canterbury.