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Title: Evaluation of Core Vocabulary Therapy for Deaf Children: Four Treatment Case Studies

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Abstract

This study evaluated whether core vocabulary intervention (CVT) improved single word speech accuracy, consistency and intelligibility in four 9-11 year-old children with profound sensori-neural deafness fitted with cochlear implants and/or digital hearing aids. Their speech was characterised by inconsistent production of different error forms for the same lexical item. The children received twice weekly therapy sessions for eight weeks. Fifty target words were drilled and changes in production assessed for accuracy and consistency. Generalisation of consistency and accuracy was assessed on non-targeted words. There were four assessment points: six weeks pre-therapy; immediately before therapy; immediately following therapy and six weeks post-therapy. In addition, ten unfamiliar listeners judged the intelligibility of audio recordings of the children's speech before and after therapy. The children's consistency and accuracy of single word production improved following CVT. Consistency generalised to untreated words. Sentence intelligibility ratings improved and more target words were identified after therapy. These case studies suggest that CVT merits further investigation as an effective intervention approach for deaf children, enhancing consistency, accuracy and intelligibility of speech.

KEY WORDS: *Core vocabulary therapy, hearing-impaired, deaf, speech intelligibility, speech consistency, listener feedback, intervention*

Introduction

Deaf students' speech intelligibility is crucial for oral communicative competence (Marschark, & Spencer, 2006) and social development (Most, 2007). However, few studies have evaluated specific interventions to enhance the speech intelligibility of children with prelingual, profound deafness. Some intervention approaches target impaired articulation at a phonetic level (e.g., electropalatography, Pantelemidou, Herman & Thomas, 2003; ultrasound, Bacsfalvi, 2010). Other studies focus on phonological knowledge that underpins the acquisition of both speech intelligibility and literacy (Thomson & Goswami, 2010; Leybaert 2005). Core vocabulary therapy (CVT), designed for hearing children making inconsistent speech errors, targets both articulatory and phonological aspects of word production (Dodd, Holm, Crosbie, & McIntosh, 2010). The case studies reported here evaluated whether the poor speech intelligibility of four children with cochlear implants and/or hearing aids would be enhanced by CVT.

Characteristics of deaf children's speech production skills

Since the days of early research characterising the effects of deafness on speech (e.g., Hudgins & Numbers, 1942), technological advances such as cochlear implants have lead to significant improvements in the intelligibility and language of deaf speakers (Marschark & Spencer, 2006). For example, Blamey et al. (2001) monitored the conversational speech of nine children from when they received their implants between 2-5 years until aged 6-11 years. The final assessment revealed that the number of intelligible words per utterance had increased from 3.6% to 80.8%, despite an increase in sentence complexity, reflecting great accuracy in the production of monophthongs, diphthongs and consonants. Although speech acquisition was incomplete six years post-insertion, indicating slow development, there was no evidence of a plateau in performance (ibid). Tobey, Geers, Sundarrajan and Shin (2011) assessed 110 adolescents with cochlear implants at 8-9 years and again at 15-18 years to identify factors influencing speech intelligibility. Participant, family, and performance measures at the first assessment predicted improvements in speech accuracy at the second assessment. The most important influences on adolescents' speech intelligibility were the extent to which participants' relied on oral communication and their use of shorter sentences (Tobey et al., 2011). A similar finding emerged from an investigation of the speech intelligibility of 17 children with cochlear implants, aged 4-11 years (Khwaileh & Flipsen, 2010). Single word and sentence level intelligibility were linked to the extent of cochlear implant use rather than age at implantation.

In contrast, De Raeve (2010) reported that the intelligibility of connected speech was related to age of cochlear implantation. Children receiving implants after 23 months had lower intelligibility than those implanted before 18 months. Marschark and Spencer's (2003) review concluded that receiving a cochlear implant at a younger age leads to higher levels of communication skills while a late age of implantation is associated with negative long-term speech and language outcomes.

Despite the benefits of cochlear implants for profoundly deaf children, Ouellet and Cohen's (1999) review emphasised great variability in post-implant performance for speech intelligibility, vocabulary and sentence structure. Factors affecting outcomes included age of onset, degree of hearing loss, extent of amplification experience and type of intervention (Khwaileh & Flipsen, 2010; Ouellet & Cohen, 1999). The data reviewed suggests that speech intelligibility remains an issue for some children with cochlear implants. The proportion of children having poorer outcomes after cochlear implantation, however, depends on the population studied. Children fitted with hearing aids alone also have a range of speech intelligibility outcomes, although these are typically less positive than those of children with cochlear implants (Lejeune & Demanez, 2006).

Interventions targeting speech

Traditional interventions to establish spoken language focus on the phonetic level, i.e. the articulation of single sounds, then on phonology, i.e. use of sounds contrastively in meaningful words (Ling, 1984). For example, four adolescents with moderate to severe deafness received 14 weekly, 30 minute, individual sessions using instrumental feedback. Treated consonant accuracy improved by 36% compared to 15% for untreated sounds. Speech intelligibility was not measured and no long-term follow-up data on maintenance of gains was reported (Bernhadt, Gick, Bacsfalvi & Ashdown, 2003). A single case study of an 18 year-old deaf client used electropalatography to target accurate alveolar plosive production (Martin, Hirson, Herman, Thomas & Pring, 2007). The statistically significant gains made, measured perceptually and instrumentally following six bi-weekly hour-long intervention sessions, were maintained and generalised to untaught words. A review of intervention focusing on phonetic targets using electropalatography and/or ultrasound, however, found the evidence base to be limited (Vuckovich, 2007).

An intervention targeting phonology (Massaro & Light, 2004) trained eight 6-10 year old deaf children to identify and produce 24 vocabulary items using residual hearing and lip-read cues presented by a computerised ‘talking head’. Students also read and wrote the words. The students received 18 twice weekly 30 minute sessions. Children learned 72% of the words receptively and 64% expressively, with learning retained four weeks after therapy ended. No measures of generalisation to speech intelligibility were made.Core vocabulary therapy (CVT) combines both phonological and articulatory cues to teach the intelligible production of words of high functional importance for children, their families and school classrooms. Clinical intervention trials indicate that CVT successfully targets inconsistent phonological disorder in hearing children. A review of the evidence for CVT with hearing children (Dodd, et al., 2010) included case studies, group comparison of children with different types of speech disorder (consistent and inconsistent errors) receiving different intervention programmes (CVT and phonological contrast) and a randomised control trial. The results indicate that an approach targeting both phonetic and phonological aspects of word production achieves intelligible speech, usually after eight hours of intervention (twice weekly, 16, 30-minute sessions). The long-term goal of therapy is to teach children to plan consistent production of the sequence of phonemes for specific lexical items. Children are taught a set of 50-70 target words selected for their functional value to the child, their family and school. Clinical research suggests that once a threshold level of words has been taught, consistency and accuracy of production generalises to untaught words (Crosbie, Holm & Dodd, 2005). The methods section details the components of CVT.

Experimental studies comparing hearing children who make inconsistent errors with those who make consistent errors indicated different profiles of speech processing strengths and weaknesses (Dodd, 2014). Children whose speech is characterised by non-developmental consistent errors do poorly on cognitive-linguistic tasks (e.g., phonological rule derivation, phonological awareness, literacy). In contrast, children making inconsistent errors appear to have a phonological assembly difficulty, i.e. in consistently selecting and sequencing the phonemes that make up a word. While the nature of inconsistency has been well described, both theoretically and clinically, little is yet known about the nature of inconsistency in children who are hearing impaired.

The trigger for the current study was provided by Speech and Language Therapists (SLTs) working in schools with provision for deaf students. They reported CVT was useful when working with children whose speech intelligibility had plateaued following therapy that adopted traditional approaches in targeting specific phonemes in isolation and in words (Martin, 2009, personal communication). The theoretical rationale for using CVT for this study is that prelingual deafness might lead to internal phonological representations of words that are incomplete or inaccurate. In addition, the ability to implement the phonetic plan for a word from an intact representation may be limited by poor self-monitoring of speech output. Inconsistent and/or erroneous word production would arise from both deficits. CVT targets the underlying phonological representation of words, ensuring that the client is aware of and can articulate all speech sounds in a specific word in the correct sequence, consistently. Once a word's best production has been elicited, it is drilled in single words, carrier phrases and sentences, developing the ability to assemble phonology and plan the phonetic program from a word's intact mental representation (e.g., Dodd et al., 2010). The importance of practice to automaticity has previously been emphasised by Perigoe and Ling (1986).

Research hypotheses

The research questions concern whether CVT can increase the accuracy of sounds in words in order to enhance the speech intelligibility of four deaf children. While the children attended the same school, they had different hearing histories, language exposure, communication methods and motivation.

It was hypothesised that there would be a significant increase from pre-therapy to post-therapy measures after CVT:

- In Percentage Consonants Correct (PCC) and Percentage Vowels Correct (PVC) for words targeted in CVT therapy, and
- For PCC and PVC in non-targeted therapy words in the Diagnostic Evaluation of Articulation and Phonology Inconsistency Subtest (DEAP: Dodd, Hua, Crosbie, Holm, & Ozanne, 2002);
- In consistency of production of single words targeted in therapy and a set of control words not targeted in therapy
- In the intelligibility of the children's speech, measured by listeners' identification of single word targets and listeners' comprehension of spoken sentences.

Method

Participants

Table 1 presents individual participant data. The children attended a mainstream primary school with a resource centre for deaf pupils. Total Communication (Sign Supported English and British Sign Language) was used consistently. Each child received weekly specialist speech and language therapy.

Insert Table 1 here.

Listeners

Ten listeners rated the participants' speech intelligibility. Three were male and seven were female with an average age of 22 years (range 13-29 years). None of the listeners knew the participants or had any training in phonetics or experience with deaf speakers.

Materials

1. All children were initially assessed on the Diagnostic Evaluation of Articulation and Phonology (Dodd, et al., 2002), administered and scored according the assessment's manual. Participants completed the diagnostic screen, which indicated whether they should receive the consistency and oro-motor subtests. All children had inconsistency scores of greater than 40% at that initial assessment. If a child's inconsistency score is 40% or more, they are diagnosed with inconsistent speech disorder based on inconsistency data from typically developing and undifferentiated speech disordered children. None of the participants performed poorly on the oro-motor assessment, indicating that no apraxic or dysarthric characteristics were present. Subsequent assessments included the consistency and phonology subtests from the DEAP to gain measures of both consistency and accuracy (PCC, PVC and percent phonemes correct (PPC). The four assessment points were: 1) six weeks prior to therapy, 2) immediately before therapy, 3) immediately following therapy and 4) six weeks post-therapy.

2. Therapy Resources. Each participant received a CVT homework book that listed current target words, represented in written words and pictures. The parents and class teachers were provided with their child's best production of each word, e.g. MA's best production of /rules/ was [ɹu], therefore the English spelling 'roo' was provided for ease of interpretation. A board game with dice, a counter and letter cards was used during the drilling sessions to encourage repetition of target vocabulary.

Parents and teachers completed a post-therapy questionnaire rating their experience of CVT including the amount of practice they had offered the children and the progress they observed.

Intervention procedure

Before the start of intervention, according to CVT protocol, approximately 85 words were collected from each child, their parents and teachers. Fifty were selected for targeting in therapy, ensuring inclusion of educationally and socially important vocabulary as well as words the children wanted to say better, enhancing motivation. The taught vocabulary contained a variety of phonemes, syllable shapes (CV, VC, CCVC, CVCC) and words of more than one syllable. Ten untreated probe words were matched to target words for syllable length and complexity to monitor consistency during intervention. Probe words were elicited three times in separate trials every second session. Children were presented with pictures of the probe words and had to name them. This occurred three times within the session, each occasion separated by another activity. Video recordings were made to ensure accurate transcription. These data were only analysed for consistency, not accuracy, to detect when generalisation of consistency occurred,

Participants were offered 16 twice weekly 45 minute therapy sessions during the course of the study. In the first weekly session, each child randomly selected 10 target words for that week from a box containing all 50 targets. The child’s best production was elicited for each of these 10 words by breaking the word down into separate syllables, and syllables into separate sounds. The aim was not the accurate adult production of each word but the child’s best possible production. When the correct production could not be elicited for a sound, a developmental error used by typically developing children was accepted, e.g. [t] for /k/; [b] for /bl/; [w] for /r/. Cued Articulation (Passy, 1990) was sometimes used to elicit participants' best productions of words as it had been used in previous therapy with these participants. CVT allows the use of any cues (e.g. Prompt, finger spelling, written letter sequences, cued articulation) to elicit a child's best production, irrespective of whether a child is hearing or hearing impaired. Best productions were identified and transcribed, then practised in games to establish consistency. This is a crucial component of CVT. When the best production is not used, listeners (clinician, parent, teachers) say "That is not the way we say it. Remember?" If it is still not produced, then cues are given about the phonological structure of the word (e.g. number of syllables, the sounds in the first syllable, and other syllables. When a child uses their best production, they should receive positive feedback, that is, specific about the word's structure, e.g., "You said that word just right. It had a 's' at the beginning and a 'n' at the end. People would understand you when you said it." There was an emphasis on the child actively remembering the production pattern, rather than imitating words.

In the second weekly session, selected words were drilled in games. Children consistently produced their 'best production' of each target word at least 20 times. Once they could produce a particular word consistently (tested at different points throughout the session), the word was allocated to a "Words I can say well" pile on a visual chart. Words produced inconsistently were allocated to a "Words I need to practise" pile. Words that had been drilled were revisited the following week to review their consistency: any words that children struggled to say consistently were placed back into the 'word box' to be targeted another week. At the start of therapy, children were asked what they wanted to receive as a reward and were reminded of this during therapy. Children received their reward once therapy was completed.

The implementation of CVT with deaf participants presented a number of challenges. The student therapists carrying out the intervention used basic SSE to support the children's understanding of the presented activities. In addition, visual explanations using pictures demonstrated what was expected. Due to limitations in staff availability it was not possible to have an experienced signer or Teacher of the Deaf (TOD) attend therapy sessions.

Homework carried out by parents and teachers

Homework sheets and class-work sheets were used to liaise with families and teachers. It was essential for children to practise their words outside the therapy sessions to develop consistency of word productions and promote generalisation. Traditional CVT has included the parent/carer being present at every session. However, in the current study, this was not possible for parents. The homework sheets provided a detailed breakdown about how to carry out CVT homework practice with their child. Parents were advised to help children practise for at least 10 minutes every day. The sheets also provided a checklist for parents to mark off when they had finished practising each week and they were encouraged to provide feedback or make comments on their child's production of the target words. Where parents were unable to support their child, another family member was enlisted.

Teachers were familiar with the use of Cued Articulation and had received training from the SLT in its implementation. The class sheets contained information on the specific cues used in the session and advised teaching staff to encourage the child by using cues that helped to elicit their best production of the target words. Children practised their words at least three times a week during literacy lessons with support staff.

Listener ratings

For the purposes of listener intelligibility ratings, a 30 minute audio recording was presented individually to 10 unfamiliar listeners. It comprised 80 sentences, 10 spoken by each of the four participants on two occasions, before and after CVT. The last word of each carrier sentence was a word targeted in therapy (see Table 2). The order of sentences and of the children producing them was randomised. The listeners could only hear the children speaking; no visual clues (signs or lip patterns) were provided. All recordings were made in a quiet room using identical recording conditions. Each sentence was presented twice and listeners could request a third presentation. The listeners were asked to a) identify and write down the last word in each sentence (1 = correct identification of whole word, 0 = incorrect), and b) rate the overall intelligibility of each sentence on a four point scale of understanding (1= nothing; 2= part; 3= most; 4= entire sentence).

Insert Table 2 here

Reliability

Reliability of coding was assessed by two raters independently phonemically transcribing the 50 words from video of the DEAP phonology assessment for each participant. If the phonetic variation was within the phonemic category of the target phoneme, the realisation was counted as correct. The transcriptions were compared for number of correct consonants and vowels present in relation to the target word. Transcriptions were highly correlated (0.939, $p<0.001$) indicating high inter-rater reliability.

Results

The quantitative and qualitative data collected were used to evaluate the effectiveness of CVT for the children's speech intelligibility, consistency and generalisation of therapy. Below we present the study findings at each of the four assessment points.

Baseline comparisons

Table 3 presents the scores obtained for the two DEAP assessments carried out at the two pre-therapy assessment points. All children had more accurate vowel than consonant production and exhibited inconsistency at a level indicative of inconsistent speech disorder. SI and DB had the highest levels of inconsistency while SI and MA made more consonant and vowel errors. DK achieved the highest PCC and PVC scores and also had the lowest level of inconsistency. All children showed small positive changes at the second assessment point, with the mean difference scores for consonants being +6%; for vowels +3.5%; and for inconsistency -15%. These changes probably reflect increased familiarity with assessors, procedure and stimulus items.

Insert Table 3 here

Comparing pre and post-therapy scores

To investigate whether or not therapy was effective, the mean of the two DEAP pre-therapy scores for each of PCC, PVC and inconsistency were compared to the immediate post-therapy scores (see Table 4). All children showed positive changes post-therapy, with the mean difference scores for consonants being +10.3%; vowels +10.8%; and inconsistency -19%.

Insert Table 4 here

Individual differences were apparent. SI increased consistency of word production by 28% but accuracy changed little. MA improved his vowel accuracy by 20% and consistency by 24%. DK's consistency increased by 20% but accuracy gain was limited. DB gained only 14% in consistency but accuracy improved for both consonants (17.5%) and vowels (17%). Given that core vocabulary primarily targets consistency of production, it is not surprising that all four children showed gains post-therapy that exceeded their pre-therapy change.

Maintenance of therapy

To explore whether benefits from therapy were maintained after therapy had ceased, a comparison was made of the immediate post-therapy DEAP scores and those obtained 6 weeks later (see Table 5). By the maintenance assessment point, the mean positive difference score for consonants was +4.2% and for vowels +5.5, indicating that speech accuracy was maintained. Change in inconsistency varied: one child became 8% less consistent, one made no change, one improved consistency by 12% and one by 32%. Two of the children had consistency below the diagnostic criterion of 40% of the DEAP (Dodd, et al., 2002). For the group the mean decrease in inconsistency between the combined pre-therapy assessments and the final follow-up assessment was 30.5% (range 20-46%). Although statistical analyses should be treated with caution for such a small clinical sample, a paired t-test was significant ($t(2) = 7.1813$, $p < 0.02$).

Insert Table 5 here

Generalisation to untaught words during therapy

Every second week, children named ten untaught words matched for phonological complexity to ten of their target words. There was a 30% decrease in inconsistency between sessions three and seven for two of the children: SI from 80% to 50%; MA from 70% to 40%. Consistency data for the other two children were unavailable as one student mislaid her data. PCC accuracy improved between sessions three and seven for three of the four children: MA 25%; DK 31%; DB 15%, but there was no change for SI with a 3% gain.

Listener ratings

Results of listener ratings of sentence intelligibility and listener identification of target words are presented in Table 6. Paired t tests showed that sentence intelligibility ratings ($t(9)= 8.44$, $p=<0.001$) and word identification ($t(9)=5.10$, $p=0.001$) were significantly higher post-therapy.

Insert Table 6 here

Parent and teacher questionnaires

All four class teachers reported that they had practised three times per week with each child. They noted that children showed benefits by becoming more intelligible in class and more confident when speaking or reading aloud at school. One teacher mentioned that she now felt more confident in her ability to correct children's speech errors appropriately following the intervention.

Parental feedback questionnaires were returned by two of the four children's parents. One mother reported that she had practised three times per week with her child. The other parent had only practised at weekends. Both reported satisfaction with the therapy their child had received and felt that there were noticeable improvements in their children's speech. One parent requested that further CVT therapy should be offered. For another child (DB), it was evident from speaking to him that although he had practised his target words regularly at school, practice at home had been sporadic.

Discussion

Clinical trials indicate that CVT is an effective intervention for hearing children who make inconsistent speech errors (Dodd et al., 2010). The evidence base includes case and group studies, as well as a randomised control trial. This paper presents the first evaluation of CVT with a small group of deaf children, the first step of the development of an evidence base for a particular approach to intervention (Robey & Shultz, 1998). All children made significant improvements in their speech intelligibility post-therapy. In addition, change was evident when measured by listener ratings of intelligibility and word identification and more informally from parent and teacher report.

Importantly, there was evidence of generalisation to untaught words and gains made were maintained six weeks after therapy had ended. The CVT described in this study specifically targeted single word speech accuracy. Nevertheless, the higher ratings of sentence intelligibility post-therapy using listeners who were unfamiliar with deaf speech are indicative of gains extending beyond the single word level.

Speech characteristics prior to therapy

Initial DEAP assessment results indicated that all children made inconsistent speech errors. They had been referred specifically because they had reached a plateau in their speech development with traditional therapy, suggesting their speech was resistant to change. The four children's inconsistency scores were surprisingly high (range 40-80%) for a group of children with hearing impairment who had received intervention over many years. Although the second pre-therapy assessment showed some decrease in inconsistency, all four children's scores met criteria for a diagnosis of inconsistent speech disorder (Dodd et al., 2002).

It is surprising that inconsistent speech production of the same lexical item has not previously been reported in the literature for deaf children (e.g., Tobey, et al., 2011). Indeed, descriptive studies usually report deaf children's speech errors to be systematic (Parker & Rose, 1990) and to respond best to phonological rather than phonetic intervention approaches when these have been compared (Paatsch, Blamey & Sarant, 2001). The current results indicate that even at the single word level, many lexical items were pronounced differently on repeated production, affecting listeners' ability to learn how a child says a particular word. It may be that the inconsistent speech of these children is atypical of primary school deaf children fitted with cochlear implants. Alternatively, given that most speech assessments only require children to say each test item once, consistency of word production is not often tested and may have been overlooked due to the use of assessment measures that focus on phonetic repertoires and severity measured by counting errors.

Vowels were less prone to error than consonants, reflecting previous research on phonological acquisition of deaf children (e.g. Hudgins & Numbers, 1942). The percentage of consonant errors made by the four children studied varied: two were in the severe range with fewer than 50% correct consonants, one moderate – severe (50-64%), and one moderate (65-85%) according to Bowen's (2013) criteria. The wide variation shown in only four children probably reflects variation in factors such as age, language learning background (two were bilingual), age at implantation, means of communication at home and school, and support in the use of hearing aids and cochlear implants (Marschark & Spencer, 2006).

Response to CVT

The results indicated a reduction in inconsistency with three children attaining scores at or below the threshold of 40% criterion for diagnosis of inconsistent speech disorder. One child, who continued to show 56% inconsistency, may benefit from further therapy focusing on consistency of production given that he was absent for three sessions. CVT not only reduced inconsistency in the participating deaf children's word production, but also led to improvement in consonant accuracy although the mean improvement between the combined pre-therapy assessments and the final follow-up assessment was limited (15%) compared to that of three hearing children (33%) (McIntosh & Dodd, 2009). Nevertheless, by the final assessment, one child could be classed as mild and one as moderate and even the two whose accuracy remained in the severe category showed improvements of 14% and 15% in PCC. Vowel accuracy remained relatively constant across assessments, with severity of impairment in the mild to moderate range.

The improved intelligibility ratings and identification of target words in sentences suggest that the impact of CVT on communication was greater than might be predicted by consistency and accuracy scores. Perhaps the acceptance and reinforcement of developmental speech errors aided listener comprehension despite words not being accurate. This intervention strategy might have contributed to maintenance and a trend for continuing improvements at the final follow-up assessment.

CVT is inherently motivating because children, their parents and teachers play an active role in selecting the target vocabulary and in practising outside of therapy sessions. All children practised their target words regularly in school and enjoyed the therapy sessions, particularly when they became aware of the improvements in their speech and when others commented on their progress. However, outside school, regular practice was only confirmed for 1 child, was occasional for 2 children and information was missing for the fourth child, whose parents spoke little English. Nevertheless, observable progress was made by all participants. By drilling a substantial number of words intensively to achieve each child's best production, children's phonological representations were stabilised and their intelligibility improved. The progress made, then, might be considered clinically significant. Even in the absence of large gains in consonant accuracy, consistency of word production allows listeners to learn how children say particular words, enhancing communication (Bernstein-Ratner, 2006).

Implications

In hearing children, inconsistent speech errors in the absence of childhood apraxia of speech are attributed to an impaired ability to assemble a phonological plan (the sequence of phonemes to be uttered) from an intact mental phonological representation of a word (Dodd et al., 2011). The cause of inconsistent errors in deaf children may differ. Should future research indicate that inconsistent production of the same lexical item is prevalent in this population, it would need to be explained. One plausible account would be that children learning to use information provided by a cochlear implant take time to build complete and accurate underlying phonological representations for words. These representations are thought to underpin both speech intelligibility and literacy (Leybaert 2005). An incomplete representation (e.g. /m-æ-plosive/ for 'mat') would result in a variety of different spoken realisations ([mæt]; [mæp]; [mæk]; [mæs]; [mæd], etc.) as well as an impaired ability to map between written words, phonology and meaning, affecting literacy.

The identification of inconsistent speech errors among a small group of deaf participants with persistently poor intelligibility suggests that clinicians need to consider the impact of inconsistency on speech and literacy and the implications for intervention. CVT was successful in achieving significant speech improvement. Nevertheless, there is a need for the intervention to be better adapted for this population. Future research might establish the prevalence and nature of inconsistency in the speech of deaf children to better inform the development of CVT for deaf children.

Research has noted the variability in outcomes following cochlear implantation (Marschark & Spencer, 2006). Of the four children referred, three used cochlear implants either alone or in addition to a digital hearing aid. In view of their poor speech intelligibility, they may be considered to be relatively unsuccessful implant users. One explanation for this may be the timing of implantation. In all cases, implantation or activation of the implant occurred between the ages of 3 and 5 years, which is considered late by current standards (Marschark & Spencer, 2006). Interestingly it was the participant who used only digital hearing aids (DK) who presented with the best speech. A further participant (SI) presented with additional difficulties, having been diagnosed with autism and a speech-language disorder. Nonetheless, he made significant improvement. Further research is needed to evaluate the usefulness of CVT therapy for children with impaired hearing whose speech is characterised by inconsistent errors. Case studies would build evidence concerning which children respond positively to CVT. Experimental studies exploring the intactness of phonological representations and phonological assembly skills would allow better understanding of how CVT affects the speech processing skills of hearing impaired children.

Conclusion

This study has identified a small group of deaf children who made inconsistent speech errors. For these children, CVT was an effective intervention approach, enhancing consistency, accuracy and intelligibility of speech. Clearly caution is needed in drawing conclusions from four individuals. Nevertheless, despite widely differing profiles and differences in initial speech ability, the results indicated the usefulness of CVT for all children. Further research is needed on larger numbers of participants, at different ages and from different language learning contexts. That research might explore ways in which CVT can be better adapted for deaf children, to determine the potential of CVT to enhance real world communication.

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Table 1. Participant information

Name Age gender	Diagnoses	Amplification	Background information	Speech production / discrimination	Sessions attended
SI 11;3 Boy	PBSNHL ASD (at 5 years) SLD	Unilateral CI activated at 3 years Contralateral digital HA Consistent use at school and home.	Only deaf member of family Parents & SI communicate using SSE + basic BSL.	Low speech intelligibility Highly inconsistent on unfamiliar vocabulary Not stimulable for production of velar consonants [g, k, ŋ] Imitated a range of syllable structures and vowels accurately	13/16 Technical fault with CI affected 2 sessions, away ill for 1 session
MA 9;0 Boy	PBSBHL	Unilateral CI activated at 5 years Contralateral digital HA Consistent use at school and home.	Only deaf member of family. English and Senegalese spoken at home. Parents & MA communicate using SSE + basic BSL.	Severely reduced speech intelligibility. Highly inconsistent productions affecting vowels & consonants Consonants /v, n, ŋ/ were not stimulable Poor discrimination of consonant contrasts.	16/16
DK (9;6) Girl	BSNHL (profound on left / severe-profound on right) Pendred Syndrome	Bilateral digital HA Consistent use at school and home	Hearing family except for one of her three siblings Parents & DK communicate using SSE + some BSL	Discriminated syllable structures, vowel contrasts and many consonants by listening alone. Unable to discriminate: /t, k/, /d, g/, /ʃ, tʃ/ and /z, d/ Often omitted WFC reducing speech intelligibility	16/16
DB (10;9) Boy	PBSNHL	Unilateral CI activated at 4 years Consistent use at school but inconsistent at home.	Hearing family except for DB's only sibling English and Vietnamese spoken at home Parents & DB communicate using basic English	Discriminated syllable structures and vowel contrasts by listening alone. Difficulty discriminating most consonant contrasts Severely reduced speech intelligibility	16/16

PBSNHL: profound bilateral sensori-neural hearing loss; ASD: autistic spectrum disorder; SLD: speech and language disorder; CI: cochlear implant; HA: hearing aid; WFC: word final consonants.

Table 2. Treated words included in pre- and post-therapy sentences for listener ratings

SI	MA	DK	DB
World	Beautiful	Phone	Zoo
Cinema	Love	Shy	Music
Mosque	Mirror	Multiply	Sunny
Lion	January	Picture	Bright
Sun	Noodles	Watch	Upstairs
Socks	Pasta	Calculator	Happy
English	Homework	Sad	September
Chocolate	Rules	Cake	Homework
Chair	Assembly	Saturday	Play
Calculator	Dress	Gloves	Shopping

Table 3. DEAP assessment scores at pre-therapy assessment points 1 and 2: PCC and PVC and percentage inconsistency scores

Child	PCC1	PCC2	PVC1	PVC2	Inconsistency 1	Inconsistency 2
SI	26%	35%	55%	57%	80%	64%
MA	24%	26%	37%	43%	72%	56%
DK	75%	85%	90%	92%	56%	40%
DB	59%	62%	67%	71%	80%	68%

Table 4. DEAP pre and post-therapy assessment scores: PCC and PVC and percentage inconsistency scores.

Child (age)	PCC1/2	PCC3	PVC1/2	PVC3	Inconsistency 1/2	Inconsistency 3
SI (11;3)	30.5%	37%	56%	58%	72%	44%
MA (9;0)	25%	34%	40%	60%	64%	40%
DK (9;6)	80%	88%	91%	97%	48%	28%
DB (10.9)	60.5%	78%	69%	86%	74%	60%

Table 5. DEAP assessment scores at two post-therapy assessment points: PCC and PVC and percentage inconsistency scores.

Child	PCC3	PCC4	PVC3	PVC4	Inconsistency 3	Inconsistency 4
SI	37%	44%	58%	58%	44%	52%
MA	34%	40%	60%	72%	40%	40%
DK	88%	90%	97%	99%	28%	16%
DB	78%	80%	86%	94%	60%	28%

Table 6. Mean listener sentence intelligibility ratings (N=10) and word identifications pre- and post-therapy

	Pre-therapy rating	Post-therapy rating	Pre-therapy identification	Post-therapy identification
Minimum	59	91	7	12
Maximum	102	121	15	23
Mean	78.5	98.8	9.4	14.9
Std. Deviation	13.4	11.2	2.37	3.03