Deaf Children's Acquisition of Speech Skills: A Psycholinguistic Perspective through Intervention

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Abstract

This study set out to explore the nature of deaf children's lexical representations and how these may be updated as new speech skills are acquired, through an investigation of speech processing skills and responses to intervention in three deaf children. A computer-based psycholinguistic profiling procedure was developed to examine the relationships between input skills, lexical representations and output skills for a range of consonant contrasts, with the expectation that input skills were important in determining output skills. Using this procedure, consonants or consonant clusters that were not accurately realised by the participants were classified according to responses to real word and nonword input testing in audio-visual and audio-alone conditions. By comparing how the differently classified consonants responded to intervention, the role of input skills in the updating of lexical representations was discovered to be less important than other sources of information, including phonological awareness and knowledge of orthography and grapheme-phoneme links. There was some evidence that articulatory knowledge, acquired through phonetic instruction and tactile feedback, was enriching segments of input representations so that the corresponding segments became easier to detect in input tasks. This questions the assumption that output representations depend on input representations for their specification. Further intervention involving repeated practice of new motor patterns and use of feedback from the therapist to encourage motor planning facilitated generalisation of the acquired speech skills to a wide range of speaking tasks. There was evidence that one of the participants was accessing the orthography of what he was about to say in order to generalise his speech skills and that he could eventually do this, even when conversing at an acceptable rate of speech. The implications for combining the teaching of phonics with speech production training for deaf children are discussed.

Declaration

I declare that this thesis substantially represents my own work.

The project is based on my ideas. I designed the experiments, format of the tests and stimuli. I conducted most of the assessments and intervention. I analysed all the data collected, interpreted the results and wrote the thesis.

I was assisted in the following ways: Andy Faulkner (UCL) recorded the stimuli for the initial testing procedure, the Rees-Coleman Profiling Prodedure. Final year students assisted with the editing of these recordings and selection of items for test stimuli. Mike Coleman (UCL) designed the software for the procedure. Final year students from UCL used the Rees-Coleman procedure to assess individual deaf children as part of their own projects under my supervision. I used data that they collected as part of this project but either re-analysed it or analysed it in different ways. Two final year students conducted most of the intervention in Phase 2 under my supervision. A qualified speech and language therapist was paid to check 10% of my phonetic transcription.

Sources of written information are referred to in the text.

Signature:

Date:

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Chapter 1: A Psycholinguistic Approach to Investigating Deaf Children's Speech

Despite the recent growth in the provision of digital hearing aids and cochlear implants, a significant number of deaf children still have speech difficulties that may need investigation and intervention. This first chapter argues a case for developing a psycholinguistic approach to investigations of deaf children's speech. The nature of such an approach and its advantages are outlined. Evidence of what is already known about deaf children's speech processing is presented and discussed. The chapter concludes with a summary and implications for the design of a psycholinguistic profiling procedure that can be used with deaf children.

The Speech of Deaf Children

In Western countries one child in a thousand is born with a significant hearing loss and many of these children have speech that is difficult to understand (Murphy & Dodd, 1995). Although there are cases where profoundly deaf children do develop excellent and intelligible spoken language, most do not (Dodd, McIntosh, & Woodhouse, 1998). 78% of students with profound deafness are reported to have unintelligible speech (Murphy & Dodd, 2005).

Children with early onset deafness generally have significant delays in all areas involving speech: speech perception and production, oral language development, metaphonological abilities and reading and spelling (Leybaert, Alegria, Hage, & Charlier, 1998). This is not surprising as these areas are all related. The speech processing system is the foundation for written language development and so any fault in it is likely to influence literacy development (Stackhouse & Wells, 1997).

The primary cause of unintelligible speech in deaf children is the limited auditory input available to them. Because of this they have to depend on distorted speech and perhaps limited information from mouth movements (Massaro & Light, 2004). In general, as a hearing loss increases, the intelligibility of the child's speech decreases (Conrad, 1979). Conversely, it seems that children who perceive spoken words better are more likely to develop speech in a way that approximates to the typical development of oral language (Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000).

Most of the recent studies on the development and intelligibility of deaf children's speech have been conducted with children who have received cochlear implants (e.g. Svirsky et al. (2000); Calmels et al. (2004) and Horga & Liker (2006)). It seems that cochlear implants can increase a deaf child's speech intelligibility more than traditional hearing aids. Horga and Liker (2006) compared the speech of three groups matched in age: implant users, profoundly deaf children using traditional hearing aids and hearing controls. Acoustic analysis and perceptual assessment by phoneticians indicated that, for most variables tested, the implant users performed better that the children using traditional hearing aids. The implant users had better vowel intelligibility, word accent production and sentence stress. Both groups of deaf children had problems with voice onset time and closure durations of plosives with no significant difference between the two. However the voiced vs. voiceless distinction was perceived with more certainty in the implanted group. Using 7 point rating scales, voice and pronunciation quality of implant users was perceived as better than profoundly deaf hearing aid users.
It is interesting to consider how intelligible a deaf child's speech can become following implantation. Calmels et al (2004) conducted a longitudinal study following 63 congenitally or prelingually deaf children up to five years after implantation. Each child had received a nucleus multichannel cochlear implant before they were 10 years old. Speech intelligibility was measured at different time points using the Speech Intelligibility Rating (SIR) (Allen, Nikolopoulos, & O'Donoghue, 1998). This scale has five categories. Three months after implantation 61 of the 63 children were rated as having unintelligible connected speech (categories 1 and 2). Intelligibility gradually increased and five years after implantation 10 out of 29 children were rated with the highest fifth category ("connected speech is intelligible to all listeners"). Of these 29, nine were rated with the fourth category ("connected speech is intelligible to a listener who has a little experience of a deaf person's speech") and four with the third category ("connected speech is intelligible to a listener who concentrates and lip-reads"). The other six remained in the unintelligible categories.

Therefore it seems that, although recent advances in improving the auditory input received by deaf children has led to corresponding improvements in intelligibility, there are still a significant number of deaf children who have speech difficulties, even amongst the implanted group, and these difficulties could impact on their literacy development.

Limitations of Traditional Speech Assessments used with Deaf Children

Historically, investigations of deaf children's speech have focused on output, either taking a phonetic approach (Geffner, 1980) or combining this with a phonological approach (Abraham, 1989; Dodd, 1976). Presently in the United Kingdom, speech assessments used routinely by speech and language therapists with deaf children (e.g. Phonological Evaluation and Transcription of Audio-Visual Language (Parker 1999)) and others routinely used with hearing children (e.g. Phonological Assessment of Child Speech (Grunwell, 1985), South Tyneside Assessment of Phonology (Armstrong & Ainley, 1988) and Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd, Zhu, Crosbie, Holm & Ozanne, 2002)) give guidelines on how to elicit, describe and analyse a child's speech output. Some assessment procedures (e.g. DEAP) assess the child's ability to imitate sounds in isolation and in other phonetic contexts but they do not include assessments that look solely at a child's speech input processing skills. For both hearing and deaf children, the checking of input skills and motor execution skills tends to be done during the therapy, after sounds or contrasts have been selected as targets. Murphy and Dodd (1995) state that most phonological approaches to treatment involve checking that the sounds targeted for therapy are stimulable and can be perceptually discriminated. However, at the assessment stage, while it is possible to identify consonant contrasts that a deaf child has difficulty in producing, little is known about the underlying speech processing skills that may be causing these difficulties. For example, if a deaf child has difficulty in marking a /sm/-/m/ contrast because s/he is realising all words beginning with /sm/ as beginning with [m], it is not clear what may be causing this problem. S/he may have difficulty in discriminating /sm/ from /m/ in nonwords and/or words. S/he may have inaccurate phonological representations of words beginning with /sm/. S/he may have difficulty in the motor execution of /s/ or /sm/. A combination of these hypotheses may offer an explanation. It is difficult to generate any hypotheses that may explain speech difficulties if only naming is assessed.

For most deaf children on cochlear implant programmes, speech input skills as well as speech production skills are assessed. In order to measure the effects of implantation, studies assess speech perception at regular intervals using word recognition tests and minimal pair discrimination tests (Berguson, Pisoni, & Kirk, 2002; Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2002). Such tests are used to measure the development of speech perception and are not designed to locate the source of particular speech behaviours. Therefore the items in these tests are not matched to items used in speech production tests and so little is learnt about input processing skills for the contrasts or words elicited by the output tasks.

A Psycholinguistic Approach to Speech Assessment

Models of Speech Processing

One way of learning about how children are processing speech from hearing through to the motor execution of spoken words is to investigate their speech with reference to a psycholinguistic model. Baker, Croot, McLeod and Paul (2001) reviewed different types of psycholinguistic models and their application to the assessment and management of speech impairment in children. At the most basic level these models highlight three aspects of speech processing: the receptive processing of words, the storage or underlying representations of words (the lexicon) and the processes involved in production (Dodd, 1995a). Baker et al (2001) explain how more sophisticated models give more detail for each of these processes. Early box-and-arrow models represented the lexicon with one box (e.g. the model developed by Smith in 1973, cited in Baker et al, 2001). As early models had difficulty in accounting for the behaviours of children developing speech or children with disordered speech, models were revised and new ones were developed. For example, in 1990, Hewlett developed a detailed two-lexicon model that gave a better explanation of why children's production of words can vary and how representations are updated over time (Hewlett, 1990). He proposed that a child can access perceptual information from an input lexicon and send this to a motor programmer which devises a motor plan for production. As this system becomes more practised, its implementation can be increasingly delegated to the motor processing component so that the child can access articulatory-based information directly from an output lexicon, which already contains information on how to execute the word, built up by previously learned combinations of muscle commands. Hewlett (1990) suggested that representations are updated when all four of the following conditions apply for a child:
awareness of insufficiency of current production,
desire to change the production,
acquired knowledge of relevant articulatory targets,
sufficient motor dexterity to implement the sounds at speed in a variety of contexts.
These changes are thought to be facilitated by feedback and interaction between the various boxes within Hewlett's model. This model was successfully applied in a clinical setting by Williams and Chiat (1993). Williams and Chiat (1993) found that a group of

children with disordered phonology formed two subgroups: one that made significantly fewer errors on repetition tasks than naming tasks and the other that had equivalent error rates on both tasks. Using Hewlett's (1990) model, Willams and Chiat hypothesised that the subgroup with the consistent error rate had a problem with motor programming, whereas the other subgroup with the differing error rate had unstable underlying representations in their output lexicon.

Baker et al (2001) cite the case study of a child named Zoe (Stackhouse, 1997; Stackhouse et al., 1997) as "an excellent example" (page 691) of an investigation that has proven clinically useful. Stackhouse and Wells (1997) used their box-and-arrow single word speech processing model to generate alternative hypotheses which were explored by conducting a series of tests targeting various aspects of Zoe's input and output speech processing skills and phonological awareness skills. They then formulated post-assessment hypotheses about the loci of Zoe's speech and literacy difficulties. For example, when Zoe was 9;8 years, they noted that the major persisting locus of deficit was in motor programming. Although she also had some deficits in phonological recognition, phonological representations and motor programs, they were not as pervasive, but restricted to particular words or phonological oppositions.

The main clinical advantage of identifying the loci of speech difficulties is to inform any ensuing intervention. Decisions can be made, for example, on whether to focus on improving input discrimination, updating representations or improving motor execution skills. A psycholinguistic investigation with Robert, a 7-year-old boy with cerebral palsy, indicated different loci of breakdown across different words (Rees, 2001). Rees (2001) therefore suggested that, for some words, therapy aims would need to focus on auditory discrimination whereas, for other words, aims would need to focus on updating motor programmes and/or motor execution skills.

The Stackhouse and Wells speech processing model (Stackhouse et al., 1997) has been applied to the assessment of various groups of children with speech difficulties including children with epilepsy (Vance, 1997), children with word-finding difficulties (Constable, 2001; Constable, Stackhouse, & Wells, 1997) and children who stutter (Forth, Stackhouse, Nicholas, & Cook, 1996).
The model is depicted in Figure 1.

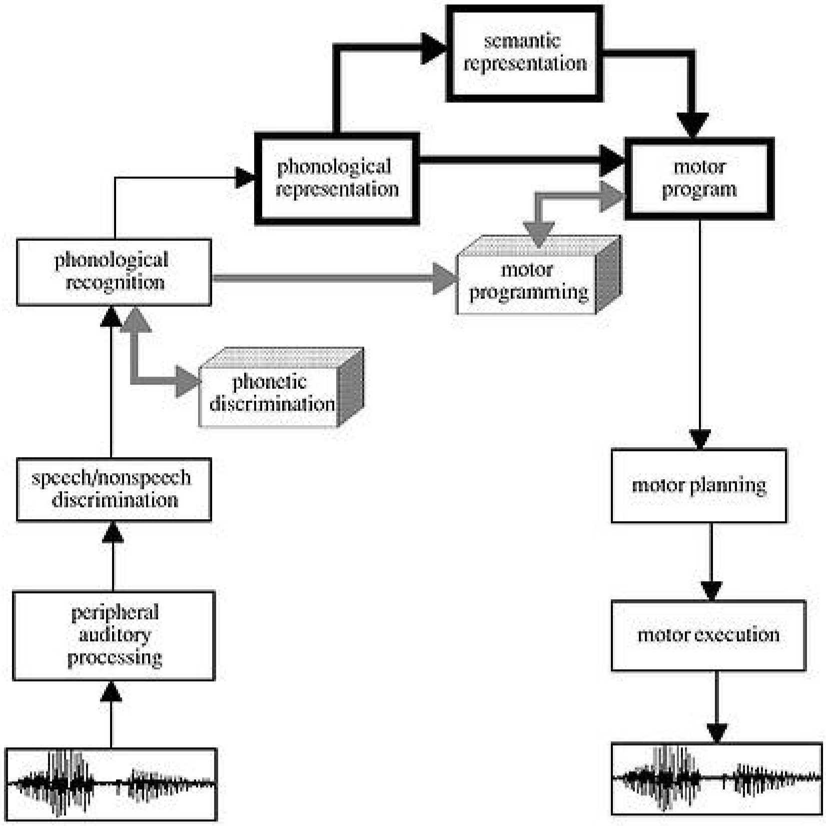

Figure 1 The Stackhouse and Wells speech processing model
From (Stackhouse et al., 1997)

Three emboldened boxes represent the child's stored knowledge about a word's form (*phonological representation*), its meaning (*semantic representation*) and the specific gestures required for its pronunciation (*motor program*). Input processes include *peripheral auditory processing*, *speech versus nonspeech discrimination* and *phonological recognition*, where speech is recognised as English and sent on for further decoding and comparison with stored phonological representations. Novel phonetic material can be recognised and learnt by an off-line level of processing called *phonetic discrimination*. The other offline process (also depicted with broad arrows and a shaded box) is *motor programming*, where new motor programs are created. Assembling motor programs into an utterance involves *motor planning*. The motor plan is executed and gives rise to an acoustic signal at the level of *motor execution*.

The model can be used to identify the levels in the speech processing system that are giving rise to a child's speech difficulties (Stackhouse & Wells, 2001). This kind of investigation involves comparing performance across more than one test. For example, if a child's performance on a nonword repetition task is better than his performance on a real word repetition task, it is likely that inaccurate lexical representations are interfering with the child's ability to repeat words accurately (as he could take the non-lexical route and bypass his representations when repeating nonwords).

Speech processing models can therefore be used to generate a range of hypotheses about children's speech processing skills, including those that refer to how children are discriminating speech, how they are updating representations and what levels in the system could be giving rise to speech difficulties.

Using Assessment to Evaluate Hypotheses

In order to permit evaluation of hypotheses about different levels in a child's speech processing system, a good assessment procedure must include tasks that enable us to consider all the levels. If, for example a procedure involves a naming task and a word repetition task, we can more easily evaluate hypotheses about lexical representations. If a child finds naming easier than word repetition this suggests input difficulties but if the child finds word repetition easier then this suggests problems with lexical representations. In investigating the speech processing skills of Robert, Rees (2001) was able to make useful post-assessment hypotheses concerning auditory discrimination, accuracy of phonological representations and motor programmes and motor execution skills by conducting the following range of tasks with matched stimuli:
naming
real word repetition
nonword repetition
auditory lexical decision tasks.
Pre-assessment hypotheses were formed by referring to the Stackhouse and Wells model (1997). By comparing performance across tasks with matching stimuli, post-assessment hypotheses were strengthened as alternative explanations for the difference in performance (e.g. fewer consonant clusters in the real word repetition list) were less likely (Stackhouse et al., 1997). Careful matching of items across tests has been used in many case studies, including others using the Stackhouse and Wells model (Constable, 2001; Dent, 2001). Case studies described by Constable (2001) and Dent (2001) provided insight into the source of particular speech behaviours by comparing performance across tests where items were matched.

Some tests that are used for psycholinguistic profiling are standardised or norm-referenced (e.g. The Auditory Discrimination and Attention Test (MorganBarry, 1989)).

It is important to use such tests when deciding whether a child has a general difficulty with an aspect of speech processing, such as speech discrimination or motor programming, in comparison with peers of the same age. However, tests that are standardised on hearing children are of limited value with deaf children who, because of their speech perception difficulties, cannot be expected to perform in similar ways. Standardising tests for deaf children and predicting performance at a given age is extremely difficult to do as deaf children form such a heterogeneous group. Paattsch, Blamey, Sarant, Martin and Bow (2004) discuss factors affecting the wide range of performance on speech perception tests amongst deaf children. Sarant, Blamey, Dowell, Clark and Gibson (2001) found that speech perception scores of 167 deaf children with cochlear implants were significantly affected by duration of deafness, mode of communication, and duration of implantation.

However, psycholinguistic investigations need not be concerned with age-appropriateness but more with investigating the nature of a speech difficulty experienced by an individual child. This difficulty is one that you would not expect in a child of the same age and may be very specific, such as difficulty with a particular group of words (e.g. the case of Michael, reported by Constable, 2001) or a particular set of consonant contrasts (e.g. the case of Paul, reported by Dent, 2001) . In such investigations the tests used may be designed to focus on a hypothesis that would explain a source of the speech difficulty. For example, Paul (Dent, 2001), aged nine, had difficulty in marking the /s/-/ʃ/-/tʃ/ contrasts in his speech output so that a listener would not be able to distinguish whether he was saying “sip”, “ship” or “chip”. In order to follow up the possibility that Paul may have inaccurate phonological representations of words beginning with /s/, /ʃ/ or /tʃ/ the auditory lexical decision task included pictures of words beginning with these consonants and the nonword stimuli for each picture began with one of the remaining two consonants. For example, Paul was shown a picture of a *shop* and asked “Is this a [sɔp]?” , “ Is this a [tʃɔp]?” etc. As all Paul’s responses in this test were correct the initial hypothesis could be rejected as his speech output difficulty could not be explained by inaccurate phonological representations. This kind of hypothesis-led psycholinguistic investigation may be particularly useful in learning about the nature of deaf children’s speech processing skills.

Deaf Children’s Speech Processing Skills

In order to develop psycholinguistic procedures for investigating deaf children’s speech processing skills, it is important to consider what is already known about the nature of these skills. Much of the previous research has focused on speech output and findings from some of these studies are presented, with the intention of identifying common difficulties and their nature. The roles of audition and vision in speech perception are discussed, both in relation to hearing and deaf people. Most assessment procedures designed to assess deaf children's input skills require them to access phonological representations. The possibility of investigating and contrasting lower level input skills and input skills that involve accessing representations is explored. Evidence suggesting the nature of deaf children's phonological representations is presented and discussed. Different ways of assessing the status of deaf children's phonological representations are suggested. This section ends with a description and discussion of a study that attempted to use a speech processing model to identify levels of breakdown for individual phonemic contrasts not marked in the speech output of a deaf child.

Deaf Children's Speech Output Difficulties

As previously discussed, the intelligibility of a deaf child's speech is heavily influenced by the degree of their hearing loss. Therefore, in reporting on the details of speech difficulties experienced by congenitally deaf children, particular attention will be paid to the severity of deafness in the participant group. Language studies providing information about deaf children often do not define how the hearing loss was classified. Classification systems do not vary greatly and so, as a guide for the reader, the classification recommended by the British Society of Audiology (www.thebsa.org.uk) in 2004 is shown in Table 1:

Classification of Hearing Loss	Average Pure Tone Loss over 250 Hz, 500Hz, 1000 Hz, 2000Hz and 4000Hz in dB (decibels)
Mild	20 – 40 dB
Moderate	41 – 70 dB
Severe	71 – 95 dB
Profound	95+dB

Table 1 Recommendation for Audiometric Descriptions of Hearing Impairment by the British Society of Audiology

(http://www.thebsa.org.uk/docs/RecPro/PTA.pdf) (2004):

The intelligibility of deaf children's speech is affected by both suprasegmental and segmental errors (Paatsch, Balme, & Sarant, 2001).

Osberger and McGarr (1982) reviewed the features likely to be impaired in the speech of severely and profoundly deaf children. Suprasegmental features included difficulties with rate and timing, intonation, overall pitch, pitch variability and voice quality (including degree of nasalization). However, it seems that many of these impaired features may be associated with severe to profound hearing loss. Elfenbein, Hardin-Jones and Davis (1994) studied a group of 40 deaf children with mild-to-severe hearing loss and rated their speech for hoarseness, nasality and pitch. The majority of the ratings fell in the normal range (51% for hoarseness, 69% for nasality and 80% for pitch).

In listing segmental features likely to be impaired in the speech of severely and profoundly deaf children, Osberger and McGarr (1982) noted that fewer vowel errors were reported than consonant errors. In studying 13 orally-trained deaf children with moderate to profound hearing losses, Abraham (1989) found that initial consonant inventories ranged from 68% to 95% complete. All these inventories included the plosives /p/,/b/,/t/,/d/,/k/, the nasals /m/,/n/, the fricatives /f/ and /h/, the glide /w/ and the liquid /l/. Group means for accuracy of word-initial consonant production ranged from 35% for /z/ and /dʒ/ to 98% complete for /g/, /n/ and /h/. The consonants used less than 60% of the time were: /θ/, /s/, /z/, /tʃ/, /dʒ/ and /r/. Final consonant inventories ranged from 40% to 100% complete and only the nasals /m/ and /n/ were evident in all of the consonant inventories. Group means for accuracy of word-final consonant production ranged from 2% for /z/ to 81% for /p/ and /m/. The consonants used less than 60% of the time in this position in words were: /b/, /t/, /d/, /g/, /ŋ/, /v/, /θ/, /ð/, /s/, /z/, /tʃ/, /dʒ/ and /l/. Correct production of clusters in words ranged from 4% to 71%. Of the 364 cluster productions evaluated, 200 (55%) were produced incorrectly by the participants and 148 of these (74%) were reduced by one or two consonants. These large ranges noted by Abraham (1989) do indicate great variation from child to child but, none-the-less, some common difficulties emerge. For example, many of the children had difficulties in using affricates and alveolar fricatives and tended to reduce consonant clusters.

Stoel-Gammon (1983) also found that affricates and fricatives were produced least accurately and were generally realised as homorganic stops, particularly in initial position. This pattern occurred 30% of the time in the hearing impaired group (age range: 2;4 to 7;3) as opposed to 6% of the time in the younger hearing group (age range: 1;5 to 3;10). Nober (1967), cited in Abraham (1989), found that nasals and fricatives were produced less accurately and Geffner (1980) identified nasals and affricates as least correct.

Abraham (1989) suggested that these differences could partly be explained by differences in hearing levels. The children in Stoel-Gammon's study had similar hearing levels to Abraham's participants (moderate to profound). However Nober (1967), cited in Abraham (1989), and Geffner (1980) had participants with more severe deafness as most of the participants had deafness that fell in the severe to profound range. The acoustical properties of nasals are more congruous with residual hearing available to those with moderate – severe hearing losses (Abraham 1989). Elfenbein, Hardin-Jones and Davis (1994) also found that, for their 40 children with mild-to-severe hearing losses, affricates and fricatives were the classes of sounds most commonly misarticulated and they noted that even the mildest loss resulted in misarticulation of these classes.

The typical difficulties that deaf children have in using consonants do not necessarily resolve in time. As Abraham's participants included children up to the age of 15 years she concluded that:

> " --, unlike normal hearing children, the manner classes of fricatives and affricates appear to remain under-developed well into adolescent years for many hearing-impaired youngsters as indicated by findings from this study" (Abraham 1989, p. 607).

In summary, the speech difficulties experienced by deaf children are strongly associated with degree of hearing loss, but even children with mild hearing losses can have difficulties with the correct production of fricatives and affricates and the production of consonant clusters and these difficulties may not resolve spontaneously.

In considering how inaccurate productions of consonants affect intelligibility, it is important to consider which phonemic contrasts are lost or maintained. Deaf children may be marking phonological contrasts in other ways (Dodd, 1976; Higgins, McCleary, Ide-Helvie, & Carney, 2005; Parker, 1999; West & Weber, 1973; Oster, 1995). West and Weber (1973) describe a case study of a four year-old deaf child who was using vowel alterations to indicate the presence of a final consonant. Parker (1999) describes the case of a child who is realising /m/ as [ˬb] (prevoicing before release of [b]) in order to make a contrast with /b/, thus maintaining the /m/-/b/ contrast. These examples provide evidence that a linguistic contrast has been perceived and that the contrast is maintained in output, albeit in a different way. This difference from the normal way of marking a contrast may affect intelligibility somewhat but not as strongly as if the contrast were lost altogether. Also it provides some clues about how the child may be perceiving the contrast (e.g. visually).

How are deaf children's phonological systems different to the normal adult system? Are they following the same kind of simplification rules that are used by typically developing children? Dodd (1976) identified a set of phonological rules used consistently by two or more of a group of ten congenitally deaf children with an age range of 9-12 years. Abraham (1989) also identified phonological processes that were evident in a group of 13 deaf children. Her findings were similar to those of Dodd (1976), identifying the following processes as the most common: cluster reduction, deaffrication, deletion of final consonants and stridency deletion. For example, in the group of 10 children that Dodd (1976) studied, all 10 omitted /s/ from the /s/ clusters that were tested. Abraham (1989) also found cluster reduction to be one of the most common phonological processes employed. These phonological, rule-based processes led to systematic, patterned and predictable speech errors (Abraham, 1989). Thus some inaccurate realisations of particular phonemes in a deaf child's speech (e.g. /m/ realised as [b]) are likely to be consistent across words.

Murphy and Dodd (1995) describe how most of the rules reported to be used by deaf children (e.g. cluster reduction) are similar to those used by younger hearing children but a few are unusual (e.g. deaffrication and additions). These unusual rules could be evidence that there is a different combination of factors governing the acquisition of rules used by deaf children. Rules employed by deaf children (especially older deaf children) may be governed more by how individual contrasts are perceived. For example, some deaf children realise labio-dental fricatives as labio-dental plosives (Parker 1995). When hearing children are using the process of stopping, the labio-dental fricatives are typically realised as bilabial plosives. This difference in pattern may be a reflection on how the deaf child is perceiving the contrast: friction is often difficult to detect with a hearing loss, whereas the placement of /f/ and /v/ is clearly visible. This is one possible explanation amongst many. There are many conflicting theories that attempt to explain the phonological rules used by typically developing children including theories of auditory misperception, poor oromotor skills and cognitive-linguistic theories but in each case there is evidence to dispute a single theory (Dodd, 1995b). Dodd (1995a) concludes that a search for a single explanation is probably futile and that it is better to develop and use speech processing models that allow the identification of perceptual, motor and mental processes that contribute to the error patterns. Rather than grouping error patterns into phonological rules employed by typically-developing children (e.g. cluster reduction) it may be safer to treat each phonological contrast separately (e.g. /sp/-/b/, /sm/-/m/) as the rules used by deaf children seem to be different as they are likely to be governed by different combinations of factors.

Ebbels (2000) followed the Stackhouse and Wells (1997) model to profile a range of consonant contrasts not marked by TG, a 10-year-old deaf child, in order to identify the processes contributing to the error patterns. She found that profiles varied across contrasts, including those that fell into the /s/ cluster group. For example the profile for /sp/-/b/ was different to the profile for /sm/-/m/.

The Nature of Speech Perception

Early studies of speech perception assume it to be solely an auditory skill (Denes & Pinson, 1963). However there is now a growing body of literature on how speech perception is influenced by visual information from the speaker's face (Dodd & Campbell, 1987). It has long been established that the speech perception of hearing people can be improved in noisy environments by seeing the face of the talker (MacLeod & Summerfield, 1987) . More recently studies have shown that seeing the face of the speaker can also help hearing people to perceive speech when the auditory signal is clear (Arnold & Hill, 2001).

It seems that visual information adds to auditory information and the combination results in greater accuracy than the sum of the two modalities presented alone (Massaro, 1998). The power of this combination is illustrated by the *McGurk effect* (McGurk & Macdonald, 1976).

> " For example, if the nonsense auditory sentence , *My bap pop me poo brive*, is paired with the nonsense visible sentence, *My gag kok me koo grive*, the perceiver is likely to hear, *My dad taught me to drive*."
> (Massaro & Light 2004, p. 305).

McGurk and Macdonald (1976) found that this effect was stronger in adults but that the fused response of perceiving da for ba-voice/ga-lips presentations, and perceiving ta for pa-voice/ka-lips presentations was also at a substantial level for the pre-school group (3-4y) and the school-aged group (7-8y).

Since this first study McGurk effects have been found with various populations including 5 month old infants (Rosenblum, Schmuckler & Johnson 1997, cited in Rosenblum 2005). The importance of this finding is that auditory and visual information about speech may be integrated at an age before phonetic categorisation. Also studies with adults suggest that information used to make a phonetic decision is derived from integrating audio and visual modalities (Summerfield, 1991). Such findings led Rosenblum (2005) to suggest that the basic process employed in speech perception is relatively independent of modality. However, it may be that "lower level" speech perception, necessary for discrimination without comparison to phonological representations, involves an integration of modalities but that the stored representations are more independent of modality. This issue is explored further in the section on deaf children's phonological representations.

Deaf Children's Speech Perception

The advantage of visual cues for the speech perception of deaf people has also been established (e.g. Walden, Grant & Cord 2001, Berguson, Pisoni & Davis (2001)). When integrating audio and visual information to make perceptual judgements, the least ambiguous source of information has the most influence (Massaro, 1998). Therefore deaf people often rely more on visual cues than hearing people because of a degraded auditory input. The additional use of these visual cues, provided by speechreading, can significantly improve speech understanding (Walden, Grant, & Cord, 2001). Walden, Grant and Cord (2001) found that, for 25 adults with acquired sensorineural deafness, both amplification and speechreading provided a significant improvement in consonant recognition. Speechreading provided mainly place-of-articulation information and amplification provided mainly information about place and manner of articulation as well as some voicing information.

Speech perception performance for deaf children is generally better under an audiovisual presentation compared with auditory-alone and visual-alone conditions (Berguson, Pisoni , & Davis, 2001). In the study conducted by Berguson et al. (2001) the children who were tested before and after cochlear implantation were divided into those from oral communication (OC) education backgrounds and those from total communication (TC) backgrounds. Testing these children in the audio-alone and audiovisual conditions allowed the authors to make some interesting findings. Before implantation both the OC and TC children performed at chance in the audio-alone speech perception tests but the OC children performed better than the TC children in the audiovisual condition. Three years post implantation the OC children performed better than the TC children in the auditory-alone condition. The auditory-alone scores for the TC children were not only consistently lower than the scores for the OC children but they improved more slowly over time. Berguson et al. (2001) implied that the children in the OC condition were more sensitive to the combination of audio and visual cues even before implantation and so this allowed them to make more use of this combination post implantation.

Assessing Deaf Children's Input Skills

In developing a psycholinguistic speech assessment procedure it is important to distinguish between tests where the child has to access lexical representations and those where the child is less likely to, and so depends more on lower level discrimination skills (Stackhouse et al., 1997). Selecting a picture from a closed set to match a spoken stimulus necessitates accessing representations. Repetition and discrimination of real words is very likely to involve accessing phonological representations and repetition and discrimination of nonwords is less likely to (Stackhouse et al., 1997). Comparing these kinds of tests can allow us to check hypotheses about a child's lower level auditory discrimination skills.

Many of the assessments used in investigations of deaf children's speech perception necessitate accessing phonological representations. For example the Berguson et al study (2001) used subtests of the Pediatric Sentence Intelligibility test (PSI) (Jerger, Lewis, Hawkins & Jerger 1980, cited in Berguson et al (2001)). These PSI subtests involved selecting one out of four pictures to match a word or sentence. This study also used the Phonetically Balanced Kindergarden (PBK) test (Haskins,1949) where the children had to repeat real words. Therefore the likelihood of accessing stored representations was high. None of the assessments involved nonwords to reduce this likelihood.

While it is useful to assess the way in which children compare stimuli to their phonological representations (and this is discussed in more detail in the following section) it is also useful to compare this to lower level input discrimination where children are less likely to access their lexicon. One way to do this is to compare tests with real words to tests using matched nonwords. Typically children find it easier to repeat words than nonwords and so, if a child's repetition of matched nonwords is better than their repetition of words, then this could indicate relatively good lower level input discrimination and articulatory skills but difficulties with lexical representations (Stackhouse et al., 1997). This scenario was found in a case study of DF (Bryan & Howard, 1992). Usually typically-developing children perform equally well on real and nonword input discrimination tasks (Stackhouse et al., 1997) and so, if nonword input discrimination is better than real word input discrimination, this could indicate relatively good lower level input discrimination and difficulties with phonological representations.

There are various ways of assessing auditory discrimination as described in a review by Locke (1980b; 1980a). A common way of assessing word and nonword input discrimination is by using a same/different design as in Wepman's Auditory Discrimination Test (Wepman & Reynolds, 1987) and tests used by Bridgeman and Snowling (Bridgeman & Snowling, 1988). An example item from the Wepman's Auditory Discrimination Test (Wepman et al., 1987) is where the tester presents, for example, *web-wed* and *lack/lack* and, in each case, the child has to say whether the two stimuli were the same or different.

In summary, when assessing deaf children's input discrimination skills, it is important to distinguish between lower level discrimination and discrimination where the child has to access phonological representations. Therefore it is useful to include nonword discrimination tasks using a method such as same/different.

Deaf Children's Phonological Representations

If deaf children are making use of vision to replace or supplement auditory information when distinguishing phonological contrasts it follows that their stored phonological representations of words may contain some visual information or, at least, information derived partly from vision. A study by Dodd suggested that lipreading may be a major input to the deaf child's phonological system (Dodd, 1976). In the first experiment of this study the spontaneous speech of ten deaf children was analysed and a list of phonological rules was extracted. The second experiment investigated the predictive values of these rules by asking another group of ten deaf children to lipread and read nonsense words that contained the phonemes affected by the rules. Phonemes that were difficult to lipread were affected by the change of input from lipreading to reading. For example, the children were more likely to produce /k/ and /g/ in their speech when reading than when lipreading. The older children's treatment of /k/ and /g/ in the lipreading condition was similar to that of the younger children in their spontaneous speech. Dodd (1976) interpreted these findings as suggesting that deaf children use information from lipreading and from written representations to form the phonological systems that influence speech output.

Dodd (1976) also discussed the possibility that when auditory and/or visual information is in long-term phonological storage it may be independent of modality. This hypothesis was originally proposed by Morton (1970), cited in Dodd (1976). As discussed earlier, Rosenblum (2005) suggested that processes involved in speech perception may be independent of modality. However, lower level input skills may be dependent on modality. As Dodd (1976) suggested, it may be at the storage phase that modalities become more independent. This idea of abstract representations common to both auditory and visual speech information has been developed in the context of hearing people (Summerfield, 1991; Rosenblum, 2005) and in the context of deaf people, where visual experiences such as speechreading, fingerspelling and reading undoubtedly contribute to the development of phonological representations (Alegria, Charlier, & Mattys, 1999; Leybaert, 2000). In the context of deafness, speechreading frequently refers to the combination of visual and acoustic speech information. If the acoustic information is very limited, as it is for many profoundly deaf people, there will be more reliance on visual input. Unfortunately, many phonemes share the same place of articulation and many syllables are articulated at the back of the mouth. These ambiguities mean that only part of the message (perhaps 30%) can be conveyed by speechreading alone (Leybaert, 2005). Consequently many phonological representations developed by deaf children are incomplete, inaccurate and underspecified (Leybaert, 2005).

One group of profoundly deaf children who do have access to all the phonemes in their spoken language are those whose parents use Cued Speech (Cornett, 1967). This is a system of hand shapes and hand placements that are designed to be used alongside speech, to disambiguate or fully specify the phonology of a spoken language (Leybaert, 2005). Research with profoundly deaf, French-speaking children who are exposed to Cued Speech at an early age at home and at school (CS-Home) demonstrated phonological abilities and written language abilities that were comparable to hearing peers (Leybaert, 2000). Leybaert (2000) suggested that this group of CS-Home children were able to develop complete phonological representations because of their access to the full version of spoken French, where every phoneme could be identified. As Leybaert (2000) emphasised, phonological representations must be defined as being made up of linguistic, abstract units, rather than sounds. The modality-free phonological representations developed by the CS-Home group had allowed them to develop age-appropriate literacy skills. Moreover, this CS-Home group were better able to produce phonologically accurate spellings than a matched group who had been exposed to Cued Speech later and only at school (CS-School group). The spelling of the CS-School group seemed to indicate underspecified phonological representations. Examples of spelling errors in this group were TIGARETTE for *cigarette* and ESCORLE for *escalier* (Leybaert, 2000). Most children are not exposed to Cued Speech (Transler, Gombert, & Leybaert, 2001) and so are relying on incomplete auditory information and limited visual information in order to develop phonological representations.

In conclusion, for many deaf children, phonological representations of spoken words are likely to be made up of abstract units that have been laid down as a result of perceiving a combination of auditory and visual information. At least some of these phonological representations are likely to be underspecified, unless the children have been exposed to adequate auditory cues (due to amplification/implantation) and/or enhanced visual cues (Cued Speech).

It is therefore important to investigate the integrity of phonological representations as part of a psycholinguistic assessment procedure.

Assessing the Integrity of Deaf Children's Phonological Representations

It is difficult to assess the exact state of a child's representation of a particular word. The way a child spells a word does give some indication (as in the examples from the CS-School group (Leybaert 2000)). Another way of investigating the phonological representation is to use a procedure where the child has to access his/her phonological representation of a word and compare it to different spoken stimuli (Locke, 1980b). To do this successfully the child's phonological representation must contain enough phonological information to identify the word uniquely (Stackhouse et al., 1997). For example, the child could be asked to look at a picture of a *sock* and asked if the following spoken stimuli were correct labels for the picture: *sock, tock* etc. Using a picture would ensure that the child was accessing his/her phonological representation and the response would necessitate him/her using input discrimination skills to make comparisons. Commonly, when this procedure is used, the child is confronted with his/her incorrect production of a word as the tester is hypothesising that the production error is reflecting the way in which the phonological representation is underspecified. This method was first described by Locke (1980b) and used by Ebbels (2000) when she discovered that TG was able to reject [dʌn] as a label for *sun* but was not able to reject [dɪp] as a label for *zip*, indicating an inaccurate phonological representation of *zip*. TG produced both [dʌn] and [dɪp] for the words *sun* and *zip* respectively and so using these allowed Ebbels to tap the part of the phonological representation that was likely to be underspecified.

In using input testing in this way, it seems appropriate to use the input channel that was used to acquire the phonological representations, the audiovisual channel, using any usual aids to hearing and any visual system that has been used to enhance speechreading. In order to investigate the degree to which the child relies on vision it would be useful to compare tests in the audiovisual condition to those in an auditory alone condition.

A Psycholinguistic Investigation of a Deaf Child's Speech

Studies with deaf children described above have investigated some aspects of deaf children's speech processing. None of these studies, however, have attempted to assess a range of levels of speech processing for the same aspect of speech in order to identify loci of speech difficulties. This was attempted by Ebbels in 2000. As previously stated, she used the Stackhouse and Wells model (1997) to examine the speech processing abilities of TG, a 10 year-old child with severe deafness. One of the aims of this study was to identify the precise level of breakdown for individual phonemic contrasts not marked consistently in the child's speech output (e.g. /s/-/d/, /t/-/k/, /sp/-/b/, /sm/-/m/). The same items were used across a range of live speech tests such as naming, real word repetition, lexical decision tasks and same/different discrimination tasks. This allowed for some interesting observations about the level of breakdown for particular contrasts. For example, *sun* was named as [dʌn], but repeated as [sʌn], suggesting relatively good input skills for /s/-/d/ in words, the potential to execute /s/ at the beginning of words, but an inaccurate lexical representation of *sun*. /dʌn/ (spoken by the tester) was rejected as a label for the picture *sun*, indicating an accurate phonological representation of *sun*, despite an inaccurate motor programme. Patterns varied across the contrasts tested suggesting different loci of difficulty for different contrasts.

Summary and Implications

Despite recent advances in the provision of digital hearing aids and cochlear implants, there are still a substantial number of deaf children whose speech is not fully intelligible. Presently most of the speech assessments used by speech and language therapists working with deaf children only investigate speech output difficulties. There is a need for a psycholinguistic approach to assessment in order to learn more about deaf children's speech processing skills and to identify levels in the speech processing system that are giving rise to particular speech behaviours.

Previous psycholinguistic investigations with hearing children have indicated the value of using theoretical models to generate hypotheses and then checking them out by comparing a range of tasks (e.g. naming, real and nonword repetition and auditory lexical decision tasks) with matched items.

Previous investigations into the nature of deaf children's speech output indicate that there are some common difficulties e.g. with realisations of affricates, fricatives and consonant clusters. Studies indicate a degree of consistency in particular speech errors. Although there is evidence that deaf children use some of the phonological rules/processes employed by hearing children, there is also evidence that the rules used by deaf children may be different in nature and, at least partly dependent on how phonological contrasts are perceived. Error patterns seem to vary across phonemic contrasts indicating that psycholinguistic investigations should focus on profiling individual contrasts rather than particular words or phonological processes.

Research into deaf children's speech perception indicates that, as with hearing children, this group are integrating auditory and visual information, with sometimes more reliance on visual information. Therefore, when assessing deaf children's input skills it is important to use an audiovisual condition as well as an audio condition. It is also useful to use assessment procedures that would differentiate between lower-level input skills and input discrimination involving comparisons to phonological representations. As deaf children have less access to the auditory channel and the visual information provided by lipreading is limited, they sometimes develop stored phonological representations that are incomplete and/or inaccurate. There is evidence to suggest that, although auditory and visual information are processed during input tasks, the stored representations are independent of modality and made up of abstract linguisitic units.

It would be useful to develop a psycholinguistic profiling procedure that could provide more information about deaf children's speech processing of individual consonant contrasts that are not marked appropriately in speech output. In developing such a procedure it is important to refer to a theoretical model and to use a range of tasks that tap different levels of processing. To reflect the nature of how deaf children may perceive speech it is important to include an audiovisual condition for the relevant tasks. When interpreting results, it is also important to consider the possibility that stored representations are modality-independent.

Chapter 2: The Development of the Rees Coleman Profiling Procedure

The previous introductory chapter argued the need for a psycholinguistic approach to the investigation of deaf children's speech. It drew on what has been learnt from psycholinguistic investigations with hearing children and what is already known about deaf children's speech to form suggestions for developing a new psycholinguistic profiling procedure. This second chapter outlines a new procedure that has incorporated these suggestions. It has been developed by the author of this thesis (Rees) with the assistance of a computer programmer at the department of Human Communication Science at UCL, Mike Coleman. The development of the procedure, including a check of its robustness, is explained. This chapter also describes in detail how the procedure was used with a deaf child, AE, to form a profile of her underlying speech processing skills for two contrasts (/st/-/d/ and /sk-/g/), not marked during naming. Other profiles that have been formed by using the procedure with five other deaf children are presented to highlight the kind of differences in speech processing that can be revealed. Finally, the procedure is reviewed and a description of necessary amendments is described. These amendments were made before the procedure was used with participants in the main study involving intervention.

Development Version 1 of Rees-Coleman Profiling Procedure

The development of this procedure was guided by the Stackhouse and Wells speech processing model (1997). It was predicted that careful matching of items across tests in the procedure would enable the tester to track the precise level/s of breakdown for consonant contrasts not marked during spontaneous naming. It was also predicted that the level(s) of breakdown would vary across the different contrasts tested.

As the procedure needed to include a series of auditory discrimination tests for consonant contrasts it was felt that the assessment was more suitable for children from 6 years of age with mild to severe deafness. As the aim of the procedure was to profile particular contrasts (eg /st/-/d/) that are not marked during single word naming it was designed for deaf children who were producing some speech errors in naming. Following the Stackhouse and Wells model (1997), possible loci of breakdown for a particular contrast (e.g /st-/d/) include:

1. Lower level auditory discrimination (e.g. of /st/-/d/ in minimal pairs of nonwords and words)

2. Integrity of phonological representations of words containing the consonant or consonant cluster not realised correctly (e.g. ***st****ar*)
3. Integrity of motor programs of words containing the consonant or consonant cluster not realised correctly (e.g. ***st****ar*)
4. The forming of new motor programs with the consonants in the contrast (e.g. /**st**ɑʊ/)
5. Motor execution of words including the consonants in a known or unknown word (e.g. ***st****ar*)

If a contrast, such as /st/-/d/, is not marked in naming, because /st/ is consistently realised as [d], we can conclude that the motor programs of the words incorrectly pronounced are inaccurate. However, unless further testing is conducted, we do not know whether there are any other loci of breakdown. As discussed in Chapter 1, comparing the results of a series of tests with matched items should allow us to track the root of the speech errors.

Therefore, for each contrast tested in the procedure, there were the following six tests with matched items:

1. Nonword Discrimination (NWD) (e.g. /stɑu/-/dau/)
2. Real Word Discrimination (RWD) (e.g. *steep/deep*)
3. Picture Yes/No Judgement (PYNJ) (e.g. picture of *star*– "Is this right? ---- /dɑ/, /stɑ/ etc.)
4. Naming (e.g. *star, stamp, steep*)
5. Real Word Repetition (RWR) (using words from naming test)
6. Nonword Repetition (NWR) (e.g. /stɑu/, /stɪmp/, /stik/)

All the tests were presented on a Pentium III, Dell Latitude CP*X* laptop, attached to two 6W powered Zodiac Mutimedia loudspeakers. It was decided to use soundfield presentation of the spoken stimuli, with participants using their own hearing aids at the recommended volume settings. The aim was to provide a closer reflection on how the participants heard speech from day to day than would be provided by other forms of presentation. It was also important that the loudness level of the auditory signal gave the child a good opportunity for any potential for speech discrimination, thus creating optimum listening conditions in realistic circumstances. If the auditory stimuli in the tests were comparable to the best listening environments that the child encountered from day to day, then performance in the tests would be a better reflection on how the child could discriminate speech in these conditions.

It was also important that the loudness level was consistent across tests in order to make comparisons. Therefore the following procedures were put in place. The children were always tested in a quiet room with no others present. Although the testing rooms in the different schools varied in terms of reverberation, this variation was small and all the rooms had soft furnishings. The loudspeakers and laptop screen were always placed approximately 70 cms away from the child's head. The volume control on the laptop and the dial on the loudspeakers were set to the midpoint as the tester judged the loudness level of this setting to be greater than conversational voice, without sounding distorted.

As discussed in Chapter 1, it was considered important to assess the integration of auditory and visual information and to compare this to information received only through the audio channel.

Therefore, for all tests (except naming), there were two conditions:

- Audio-visual (AV) where items were presented as audio clips played while matching video clips in a blue box appeared on the computer screen and
- Audio-alone (AA) where items were presented as audio clips played while a blue box (with the same dimensions as in the AV condition) framing a blank white speech bubble appeared on the screen (see Figure 2).

The blue boxes appeared only for the duration of the spoken stimulus.

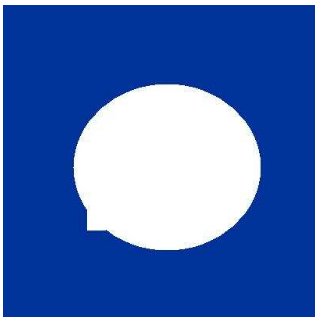

Figure 2 Blue box for AA condition in Rees Coleman Profiling Procedure

Selection of Contrasts

Many successful case studies that have identified levels of breakdown in a child's speech processing system have included assessment procedures that are tailored to the individual child (Ebbels, 2000; Dent, 2001; Constable, 2001). Ebbels (2000) designed tests for consonants and consonant contrasts that TG was not marking. The aim of the Rees Coleman Procedure was to begin to produce a bank of tests that could provide a resource when conducting a hypothesis-led investigation for a particular child. It would not have been possible to produce tests for every consonant contrast in every syllable and word position and so it was decided to concentrate on contrasts commonly not marked by deaf children and to begin with the syllable-initial position in single-syllable words. Previous studies, described in Chapter 1, have indicated some groups of sounds that deaf children commonly have difficulty with. Studies conducted with children with mild to severe deafness have identified fricatives, affricates and consonant clusters as commonly causing difficulties (Abraham 1989; Stoel-Gammon 1983). As discussed in the introduction to Chapter 1, the difficulties that deaf children have with speech are changing over time due to the provision of digital hearing aids and cochlear implants. Therefore it was decided that the selection of consonants and contrasts should be based on the results of recent assessments. A brief study was conducted with ten children aged 6-11 years with mild-severe deafness attending a unit for hearing impaired children. All these children had completed a speech output test (Phonological Evaluation and Transcription of Audio-Visual Language (Parker,1999)) during the last 6 months and the results of the naming tests for each child were examined for incorrect realisations of consonants and consonant clusters. The ten contrasts selected were those that were most commonly not marked appropriately. These were:

/p/-/b/, /m/-/b/, /s/-/d/, /ʃ/-/tʃ/, /sp/-/b/, /sm/-/m/, sw/-/w/, /sn/-/n/, /st-/d/, /sk/-/g/.

With the exception of /ʃ/-/tʃ/, the first consonant or consonants of the pair were mostly realised as the second consonant of the pair (eg /st/→[d], /sk/→[g]). For /ʃ/-/tʃ/, incorrect realisations were more inconsistent and could be in either direction: /ʃ/→/[tʃ] and /tʃ/ → [ʃ] .

Selection of Stimuli

All the stimuli were single-syllable words or nonwords. It was decided to avoid connected speech as the same-different discrimination tests involve holding the stimuli in working memory in order to make a judgement and the demands on working memory are increased if more syllables are added to the stimuli compared (Rees, 2001a). However, tests using single words do not provide information on the acoustic and visual cues provided by the phonetic environment when the words tested are embedded in an utterance.

One of the aims in developing the tests was to match items across tests as closely as possible. Therefore it was decided to use previously recorded speech rather than live speech. This meant that the same audio recording of a word or nonword could be used in both the audio and audio-visual condition and across tests. Also it gave the opportunity for the “same” pairs (e.g. *school – school* or /skil/ - /skil/) to be truly identical. This avoided the possibility of the participants judging that a same pair were different because of phonetic differences in either condition or differences in facial movements in the audio-visual condition. As the purpose of the assessment was not to examine the effect of specific acoustic cues, it was decided not to use synthetic speech but to record live speech where care was taken to keep the non-tested variables constant. (For further details see description of recording at the end of this section.)

Real words were based on the list used in the naming test of the Phonological Evaluation and Transcription of Audio-Visual Language (Parker, 1999) as this test is frequently used by speech and language therapists specialising in deafness in the UK and so the computer tests could easily complement this test if they were used in clinical practice. For the naming and real word repetition there were 4 words for each consonant or pair of consonants in the pair (e.g. for/ st/-/d/, the words were: *stamp, star, stairs, steep* and *dog, duck, deep, door*). In each group of eight words there was at least one minimal pair that could be used for real word discrimination (eg *steep/deep*). Since two minimal pairs of real words were used in the real word discrimination test, if the naming and real word repetition tests only included one pair, then another pair was used (e.g. for /st/-/d/: *store/door* was used). This second pair often included words that were less frequent and difficult to illustrate and therefore not used for the naming test.

Nonword stimuli for the nonword discrimination and nonword repetition tests were created by altering the vowel of the real words used in the naming test (eg /stæmp/ → /stɪmp/). Wherever possible the length of the vowel was maintained. However, in some cases it was not possible to create a pair of nonwords by following these two rules and so similar alternatives were chosen. Locke (1980b) recommends that three types of stimuli are chosen for Yes/No picture tests. These are the adult form, the form including the child’s error and a form including a control consonant. As these tests are designed to be used by a large number of children, it was not possible to choose an alternative to the adult form that would correspond to all children’s errors. Therefore the error most commonly used by the participants in the pilot study was chosen. The control item acted as a distractor item to ensure that the child understood the test and was not responding indiscriminately. Therefore those chosen were not perceptually similar to the adult form and had different lip patterns. For example the stimuli of the Yes/No picture test for /st/-/d/ included a picture of a star and the spoken stimuli: /stɑ/ (the target), /dɑ/ (the most common realisation) and /bɑ/ (the control item). Rejection of the distractor was not scored, but, if the child accepted the distractor, then this would be taken as evidence that the child was having difficulty in understanding and/or paying attention to the input tests.

In the input tests the order of items and number of same and different pairs or right or wrong versions were balanced and the order was randomised for presentation. Each test required 24 responses from the child. In the output tests each word or nonword was elicited twice, so that the total number of items in each test was 16.

Tables 2 and 3 show the stimuli used in each test for the /st/-/d/ contrast and the /sk/-/g/ contrast respectively.

For all contrasts, except /ʃ/ - /tʃ/, the Picture Yes/No Judgement task (in both audio and audio-visual conditions) used two words beginning with the first consonant/s in the pair (e.g. pictures of *skate* and *school* for the contrast /sk/ - /g/), as the first consonant/s in the pair tended to be realised as the second (e.g. /sk/ → [g]). For /ʃ/ - /tʃ/ there were two Picture Yes/No Judgement tasks: one using pictures of words beginning with /ʃ/ (*ship* and *shop*) and one using pictures of words beginning with /tʃ/ (*chair* and *chip*). This was because participants had difficulty with both the phonemes in this pair, realising /ʃ/ as /tʃ/ or another sound and realising /tʃ/ as /ʃ/ or another sound.

The spoken stimuli were recorded in a sound-isolated room, using a Canon XL-1 digital camcorder and Bruel and Kjaer 2231 sound level meter equipped with a type 4165 microphone cartridge. Care was taken to keep nonsegmental features (e.g. intonation) and facial movements as neutral and consistent as possible during the recording. Stimuli were recorded in sets of three, and repeated at least three times in a different order each time:

e.g. /stɑ/, /stɑ/, /dɑ/
/dɑ/, /stɑ/, /stɑ/
/dɑ/, /dɑ/, /stɑ/

This was done to ensure that “list intonation” did not consistently influence the production of any items.

Using a Pinnacle DV500 card, the video was copied, in digital format to a computer, where it was edited to produce individual video clips of each item. Examples of each word or nonword were compared on the basis of how alike they looked and sounded.

For each pair of different stimuli (e.g. stɑ/dɑ) a pair was chosen that were the most alike. Same pairs were then created by repeating the relevant stimulus from this pair and the same stimulus was used for the single item tests.

The pictures used in all relevant tests were downloaded from www.arttoday.com.

Nonword Discrimination (NWD) - Audio-visual version (NWDAV) and audio- alone version (NWDAA)	
stɜk/dɜk x 3 dɜk/stɜk x 3 stɜk/stɜk x 3 dɜk/dɜk x 3	stɑp/dɑp x 3 dɑp/stɑp x 3 stɑp/stɑp x 3 dɑp/dɑp x 3
Real Word Discrimination (RWD) - Audio-visual version (RWDAV) and audio- alone version (RWDAA)	
store/door x 3 door/store x 3 store/store x 3 door/door x 3	steep/deep x 3 deep/steep x 3 steep/steep x 3 deep/deep x 3
Picture Yes/No Judgement (PYNJ) - Audio-visual version (YNJAV) and audio-alone version (YNJAA)	
Picture of *star* stɑ x 6 dɑ x 6 bɑ x 2 (not scored)	Picture of *steep* stip x 6 dip x 6 bip x 2 (not scored)
Real Word Repetition (RWR) - Audio-visual version (RWRAV) and audio- alone version (RWRAA) and Naming	
stamp x 2 star x 2 stairs x 2 steep x 2	dog x 2 duck x 2 deep x 2 door x 2
Nonword Repetition (NWR) - Audio-visual version (NWRAV) and audio-alone version (NWRAA)	
stɪmp x 2 staʊ x 2 staʊz x 2 stɑp x 2	deg x 2 dɜk x 2 dɑp x 2 dɔɪ x 2

Table 2 Stimuli used in each test for the /st/-/d/ contrast

Nonword Discrimination (NWD) - Audio-visual version (NWDAV) and audio- alone version (NWDAA)	
skɔt/gɔt x 3 gɔt/skɔt x 3 skɔt/skɔt x 3 gɔt/gɔt x 3	skil/gil x 3 gil/skil x 3 skil/skil x 3 gil/gil x 3
Real Word Discrimination (RWD) - Audio-visual version (RWDAV) and audio- alone version (RWDAA)	
skate/gate x 3 gate/skate x 3 skate/skate x 3 gate/gate x 3	school/ghoul x 3 ghoul/school x 3 school/school x 3 ghoul/ghoul x 3
Picture Yes/No Judgement (PYNJ) - Audio-visual version (YNJAV) and audio-alone version (YNJAA)	
Picture of *skate* skeɪt x 6 geɪt x 6 beɪt X 2 (not scored)	Picture of *school* skul x 6 gul x 6 bul x 2 (not scored)
Real Word Repetition (RWR) - Audio-visual version (RWRAV) and audio- alone version (RWRAA) and Naming	
skate x 2 school x 2 skirt x 2 scarf x 2	gate x 2 goat x 2 gun x 2 girl x 2
Nonword Repetition (NWR) - Audio-visual version (NWRAV) and audio-alone version (NWRAA)	
skɔt x 2 skil x 2 skɑt x 2 skɜf x 2	gaɪt x 2 gɑt x 2 gen x 2 gɔl x 2

Table 3 Stimuli used in each test for the /sk/-/g/ contrast

Description of Each Type of Test

Nonword Discrimination (NWD) and Real Word Discrimination (RWD)

For NWD and RWD the blue box appearing simultaneously with the first spoken stimulus (e.g. /stɑp/) appeared to the left of the screen and then the box corresponding to the second spoken stimulus (e.g. /dɑp/) appeared to the right. As described previously, in the audio-visual condition (AV) the box contained a video clip and in the audio alone condition (AA), the box contained only a white speech bubble. For both conditions the sound of the spoken stimulus was presented. When both stimuli had been played the child pressed either the “z” key or the “m” key, which were marked with stickers showing symbols for “same” and “different” respectively. If the child pressed the key before both stimuli had been presented, the stimuli were presented again. The order of the pairs of stimuli were randomised and the responses were automatically scored by the computer.

Picture Yes/No Judgement (PYNJ)

These tests were similar to "lexical decision tasks" where the child is making a judgement about whether a spoken stimulus is a real word or not. This label was not used in this battery because the alternative incorrect spoken items for some pictures were words themselves. For example, the alternative label for "skate" is "gate".

For the PYNJ tests the picture of the word remained on the left of the screen while the blue box corresponding to each spoken stimulus was presented on the right of the screen. For example, while a picture of *star* appeared on the left of the screen, six versions of /stɑ/, six versions of /dɑ/ and 2 versions of /bɑ/ were presented in a random order while blue boxes appeared simultaneously with each of these syllables on the right of the screen. As described previously, in the audio-visual condition (AV) the box contained a video clip and in the audio alone condition (AA), the box contained only a white speech bubble. After each spoken stimulus the child pressed either the “z” key or the “m” key, which were marked with stickers showing symbols for “yes” and “no”, respectively. Responses were automatically scored by the computer.

Naming, Real Word Repetition (RWR) and Nonword Repetition (NWR)

Pictures (for naming) or blue boxes appearing simultaneously with spoken stimuli (for repetition tasks) were presented one at a time in random order on the computer screen for the child to name or repeat. For the repetition tasks, the blue box contained a video clip for the audio-visual condition (AV) and only a white speech bubble for the audio alone condition (AA). The child's responses were video-recorded using a Panasonic RX9 Slim Palmcorder. The tester controlled the time between the presentation of each picture or blue box by pressing the enter key after each presentation. This allowed the tester to phonetically transcribe the child's response and indicate, by clicking on a small box on the screen, if the transcription should be checked at a later stage using the video-recorded material.

Administration of Tests

Each battery of tests examining a contrast was preceded by a familiarisation procedure where all the pictures used in the tests were presented on the computer screen one at a time. The child was asked to name them and, if necessary, was prompted to find the target word. This ensured that the child knew which label was expected – especially for those pictures that could be named in different ways. Items needing prompting were checked through a second time.

Before each test the participant was given clear information on what to expect and the speaker in the video clip was referred to by name (R). Nonwords were explained as not being real words. Before the audio-alone versions the child was told "in this test you won't be able to see R's face, so you will have to listen very carefully". The child was instructed to respond by "telling the computer what you think by pressing one of these buttons" (input tests), naming the pictures, or "saying it too" (repetition tests).

At the end of each subtest for each contrast (maximum 24 items), the child was provided with a reward for completion: a cartoon character appeared on the screen and offered a personalised message of congratulations.
The battery of tests for each contrast was expected to last 20-45 minutes and batteries for no more than two contrasts were completed per assessment session.

Piloting the First Version of the Rees-Coleman Procedure

Pilot with Hearing Participant

The full battery of tests for the contrast st/d was conducted with a typically-developing boy, ZH, who was 6;9 years old.

ZH completed all the tests in 25 minutes. He achieved full scores on all the input tests and made no errors on the output tests. He attended well throughout the testing procedure.
This indicated that the format of the tests was adequate for children of this age and that typically developing, hearing children with intelligible speech would have no difficulty with the tests.

Testing the Consistency of Performance

In order to test the robustness of the profiling procedure a deaf child, KC, was tested on the same two contrasts at two time points (T1 and T2) that were two weeks apart. (Further details of KC are in the next section.) The same battery of tests were completed for /sn/-/n/ and for /st/-/d/ at T1 and T2. This battery consisted of:

Picture Naming (PN)
Nonword Repetition Audio alone (NWRAA)
Nonword Repetition Audio-visual (NWRAV)
Picture Yes/No Judgement Audio-alone (PYNJAA)
Picture Yes/No Judgement Audio-visual (PYNJAV)
Nonword Discrimination Audio-alone (NWDAA)
Nonword Discrimination Audio-visual (NWDAV).

For each test at each time point the responses to each item were categorised as "correct" or "incorrect". For the input tests "correct" was applied to each successful judgement of an item. For the output tests "correct" was applied each time the target consonant/s were realised within the correct phonemic category for every repetition or attempt at naming. Thus the realisation would not cross a phoneme boundary into a possible alternative phoneme in English.

For each test, the responses to each item (correct or incorrect) at the two time points were compared using McNemar tests, to see if any of the differences were significant. The probabilities (*p*) of each difference being significant were calculated.

Contrast	PN		NWRAA		NWRAV		PYNJAA		PYNJAV		NWDAA		NWDAV	
	N	*p*	*N*	*p*	*N*	*p*	*N*	*p*	*N*	*p*	*N*	*p*	*N*	*p*
sn/n	8	#	8	1.000	8	1.000	24	.688	24	1.000	24	1.000	24	.727
st/d	8	1.000	8	#	8	1.000	24	.388	24	.180	24	1.000	24	1.000

all responses were incorrect for both time points and so statistical tests were not needed.

Table 4 Comparison of responses to each test for two time points for /sn/-/n/ and for /st/-/d/

None of the differences were significant. For the PYNJAV tests for /st/-/d/, the *p* value was 0.180. The score had improved by the second test. A possible explanation for the difference in the PYNJAV test is that KC had learnt to notice a visual difference between items in the first test and therefore performed better in the second test. However, it is important to remember that the scores at both time points are at chance level suggesting that KC had difficulty discriminating between /st/ and /d/ at both time points.

Piloting with Deaf Participants

Deaf participants were chosen by asking speech and language therapists to select participants who fulfilled the following criteria:

- Age between six and eleven years;
- No significant learning and/or attention difficulties;
- Speech used as main means of communication;
- At least three or four consonants or consonant clusters are incorrectly realised in naming tasks;
- Sensori-neural hearing loss but with some evidence of basic speech discrimination (e.g. for minimal pairs with contrasting vowels), when aided.

Participant 1

Data on this participant was collected by a final year speech and language therapy student, who was supervised by the author of this project.

Case Description

AE was born with a bilateral severe sensori-neural deafness that was diagnosed at 13 months, when she was first issued with hearing aids. Since then she had worn two Phonak PPCLP2 hearing aids and at school used a Phonak Microvox direct input radio aid. There was no known cause to her deafness including no relevant family history. Table 5 shows the summary of an audiogram plotted from results of a hearing test at 5;11 years and results of aided freefield testing at 4;11 years and at 5;11 years. The changes in the results at these two time points indicate that she had developed better use of her hearing during this time interval.

Frequency (kHz)	Threshold (dB SPL)			
	Unaided Hearing Tests Results at 5;11 years		Aided Hearing Test Results at 4;11 years	Aided Hearing Test Results at 5;11 years
	Right Ear	Left Ear		
0.25		100		55
0.5	115	95	55	50
1	100	90	70	40
2	95	75	70	35
4	80	70	65	35

Table 5 AE: Results of hearing tests

AE had attended a hearing-impaired unit in a mainstream primary school since the age of 3 years 3 months. This unit does not use any formal manual communication system. To establish AE's understanding of spoken English, the Test of Reception of Grammar (TROG) (Bishop, 1989) and the British Picture Vocabulary Test (BPVS) (Dunn and Dunn, 1997) were administered. The results are summarised in Table 6:

Test	Chronological Age	Age Equivalent Score	Centile
TROG	7;4 years	5;3 years	10
BPVS	7;1 years	3;1 years	2

Table 6 AE: Results of standardised language assessments

To establish the level of AE's non-verbal reasoning skills, two subtests of the Wechsler Intelligence Scale for Children (Wechsler, 1992) were administered: Picture Completion and Block Design. AE's scaled score for both subtests was 9, putting her within the average range for her chronological age.
Although these three tests are standardised on hearing children, AE's performance on the tests indicated non-verbal reasoning skills that were age-appropriate and comprehension skills that were adequate to follow the instructions and test items of the Rees Coleman procedure.

AE was selected for this study as she was making good use of her residual hearing and was making some speech errors, including the reduction of many word-initial consonant clusters beginning with /s/. The naming test of the PETAL (Parker, 1999), administered when she was 7;0 years , provided the following description of her use of segmental features:

Vowel contrasts were mostly established. Most consonants were realised correctly and consistently. The contrasts m/b and p/b were inconsistent but emerging. /ʃ/, /tʃ/ and /dʒ/ were not contrasted with each other as they were all usually realised as [ʃ]. /z/ was usually realised as /s/ and alveolar consonants were sometimes deleted in syllable-final position. Final /ŋ/ was realised as [k] or [kx]. Many consonant clusters were realised correctly (e.g. black → [blæk], fly → [flaɪ], sweet [swi] , swing → [swɪk]). Some /s/ clusters were realised incorrectly, either by [ə] being inserted after /s/ (e.g. spoon → [səbu]) or by the cluster being reduced, as in the case of /st/ and /sk/. AE's realisations of words beginning with /st/ and /sk/ in the PETAL naming test are illustrated in Table 7.

TARGET WORD	AE's REALISATION
star	dɑ
stick	dɪk
stairs	teə
stamp	dæm
stitch	dɪʃ
school	gul
skirt	dɜt
skate	skeɪ

Table 7 AE: Realisations of words beginning with /st/ and /sk/ in the PETAL naming test

The Rees Coleman procedure was used to profile the two contrasts /st/-/d/ and /sk/-/g/ for AE. These contrasts were selected as /st/-/d/ was not marked whereas the /sk/-/g/ contrast seemed to be emerging. It was hypothesised that the assessment procedure would assist in identifying the loci of breakdown in the speech processing profile for both contrasts and that the profiles may be different.

<u>Method</u>

AE was tested with the Rees Coleman procedure during two sessions, each one week apart, when she was 7;3 years. For each session AE wore both her Phonak PPCLPT hearing aids set at the recommended volume.

Both loudspeakers and the laptop screen were placed approximately 70 cms away from the child's head. The tester ensured that AE was looking at her before she gave instructions and spoke clearly, but naturally.

The complete battery of tests, previously described, were administered for the /st/-/d/ and /sk/-/g/ contrasts. All tests for one contrast were completed in one session but within that session the order of test type (input vs output and audio-alone vs audio-visual) was alternated and AE was given a five minute break after three or four tests. AE was given verbal encouragement during tests and rewarded at the end of each test by the computerised cartoon character offering a personalised message of congratulations. Responses to the output tests were all transcribed phonetically and videoed.

Results

/st/-/d/

Table 8 shows the scores of all the input tests for st/d. Using a binomial test (Siegel and Castellan, 1988) the probability of the score occuring chance was calculated.

Test	Score	Probability of score occurring by chance
PYNJAV	10/24	0.846
PYNJAA	15/24	0.154
RWDAV	23/24	<0.001 **
RWDAA	22/24	<0.001 **
NWDAV	17/24	0.032 *
NWDAA	13/24	0.149

** significant at the .001 level

* significant at the .05 level

Table 8 AE: Input tests for /st/-/d/

Responses to the output tests were transcribed at the time of recording and checked by watching the recorded videotape.

Table 9 shows the responses to all the items.

Word	Naming	RWRAV	RWRAA	NON-WORD	NWRAV	NWRAA
stamp	dæmp sæp	sæmp sʌʔ	skɑm dɑp	stɪmp	stimp stɪp	sɪp sɪʔ
star	sːɑ dɑ	dɑ dɑ	sːtɑ sːkɑ	stɑʊ	stɑʊ skɑʊ	gəʊ dæʔ
stairs	ʃeətʃ ʃeətʃ	sːteː seː	sːke sːke	stɑʊz	stɑʊ stɜ	gəʊ dæʔ
steep	sːtip dip	sːtip sːtip	sːtip sːtip	stɑp	dɑp stɑp	dɑk dɑ
Score for /st/ realised correctly	1/8	3/8	3/8		6/8	0/8
dog	dɒg dɒg	dɔː dɔː	dɒg dɒg	deg	seg seg	seg dek
duck	dʌk dʌk	dʌʔ dʌk	dijʌk jʌk	dɜk	dɜk sɜk	dag dak
deep	sip sip	dip dip	di dip	dap	dap dap	dap dak
door	dɔ dɔ	dɔ dɔ	dɔ dɔ	dɔɪ	dɔɪ dɒk	dɔ dɔ
Score for /d/ realise d correctly	6/8	8/8	7/8		5/8	7/8

Table 9 AE: Output tests for /st/-/d/

Table 10 shows the scores of all the input tests for /sk/-/g/. Using a binomial test (Siegel and Castellan, 1988) the probability of the score occurring by chance was calculated.

Test	Score	Probability of score occurring by chance
PYNJAV	17/24	0.032 *
PYNJAA	17/24	0.032 *
RWDAV	19/24	0.003 *
RWDAA	19/24	0.003 *
NWDAV	20/24	0.001 *
NWDAA	9/24	0.924

* significant at the .05 level

Table 10 AE: Input tests for /sk/-/g/

Responses to the output tests were transcribed at the time of recording and checked by watching the recorded video tape.

Table 11 shows the responses to all the items.

WORD	Naming	RWRAV	RWRAA	NON-WORD	NWRAV	NWRAA
Skate	geɪʔ səgɜ	geɪʔ sːkeɪ	sːkeit sːkeɪʔ	skɑt	sːkɑ sːta	sːkɜ sːkɜʔ
School	səgu gu	sːku sːku	sːku sːku	skil	sːki sːki	sːti sːki
Skirt	sədʒ səgɜ	səgɜ səgɜ	sːkɜ sːkɜ	skɔt	sːkɔ sːkɔ	sːkɔ sːkɔ
Scarf	səgɑv səgɑv	səgɑ səgɑ	sːku sːku	skɜf	gɜf sːkɜ	sːkɜk sːkɜ
Score for /sk/ realised correctly	0/8	2/8	8/8		6/8	7/8
Gate	geɪʔ geɪʔ	geɪʔ geɪ	geɪt geɪʔ	gɑt	gəʊt gɜ	ga skɜ
Goat	gəʊt gəʊ	gəʊt gəʊ	gəʊt gəʊ	gaɪt	geɪʔ gəʊt	gəʊt gəʊt
Gun	gʌʔ gʌn	gʌn gʌn	gəʊʔ gəʊʔ	gen	deɪʔ gəʊʔ	gəʊʔ gəʊʔ
girl	geʊ geʊ	gɜ gɜl	gɜ geʊ	gɔl	gɔ gɔ	gɔ gəʊ
Score for /g/ realise d correctly	8/8	8/8	8/8	8/8	7/8	7/8

Table 11 AE: Output tests for /sk/-/g/

Discussion

AE had a severe hearing loss and had not been exposed to Cued speech (Cornett, 1967) or any other kind of manual communication. Therefore she was relying on incomplete auditory information and limited visual information to develop phonological representations, as is the case for many deaf children (Leybaert, 2000). Therefore AE's performance on the PYNJ tasks for /st/-/d/ is unsurprising. She did not perform above the level of chance on the PYNJ tests, either in the audio-visual or audio-alone conditions. This indicates that she had inaccurate phonological representations of the words tested (*star* and *steep*) and most likely may have had inaccurate phonological representations of other words beginning with /st/.

Because AE had a severe hearing impairment we might assume that most of her inaccurate phonological representations were due to current difficulties with speech discrimination. However, she had little difficulty with same-different real word discrimination tests including the pairs *store/door* and *steep/deep*. She scored 23/24 for the audio-visual version and 22/24 for the audio-alone version. The probability of obtaining these scores by chance is minimal. These tests can be done by bypassing lexical representations and utilising lower level discrimination skills. It is highly likely that AE used this non-lexical route, as her performance on the PYNJ tests, requiring access to representations, was poor. This suggests that her lower level auditory discrimination skills for /st/-/d/ at the beginning of words is relatively good. It is therefore surprising that she performed less well when discriminating nonwords. Her performance on the same different tasks for /stɜk/-/dɜk/ and /stɑp/-/dɑp/ was above chance level in the audio-visual condition but not in the audio-alone condition.

Interference from inaccurate lexical representations is a likely explanation for the results of the repetition tests. Her ability to repeat words and nonwords beginning with /st/ was better than her use of this cluster in the naming task. She correctly realised /st/ 38% of the time in both the real word repetition and nonword repetition tasks but only 13% of the time in the naming task. Repetition tasks rely less on lexical knowledge and could be completed without accessing lexical representations (Stackhouse and Wells, 1997). Repetition tasks, unlike naming tasks, rely on auditory discrimination skills and so AE's improved performance on these tasks is further evidence for relatively good lower level auditory discrimination skills for /st/-/d/, especially when she is able to integrate auditory and visual information.

Despite good lower level input discrimination skills for /st/-/d/ at the beginning of words, /st/ seems to be underspecified in phonological representations of words beginning with /st/. This finding is similar to patterns discovered in the Ebbels study (Ebbels, 2000), where, for example, the ten-year-old deaf participant (TG) had an inaccurate phonological representation of *smoke* (indicated by failing to reject /məʊk/ consistently in the yes/no task with the picture of *smoke*) but was able to hear and discriminate /sm/-/m/ in initial position in a pair of words. There are two possible explanations for this kind of pattern.

One possible explanation is that the children have not yet learnt to use the discrimination skills they had acquired to update their phonological representations of particular words and may do so in time. This updating process is constantly occurring in early language development in typically developing children. However, the children concerned were both congenitally deaf and tested when they were over 7 years old (TG 10;4 years and AE 7;3 years) and both had language comprehension age equivalents of over 5 years according to the Test of Reception of Grammar (TROG) (Bishop, 1989). They had both been wearing hearing aids since 18 months and in neither case was there a report of a recent change in hearing aid. However recent improvements in use of hearing could have occurred. The results of freefield testing with AE at 4;11 years and then at 5;11 years support this possibility, showing a marked improvement in use of hearing.

A second explanation is that some phonological representations have become “frozen” and remained inaccurate and resistant to change, despite the later development of prerequisite auditory discrimination skills. Bryan and Howard (1992) describe the case of a 5-year-old hearing boy (DF), who was able to repeat a variety of nonwords with reasonable accuracy, despite a very limited phonological system used for naming, indicating relatively good auditory discrimination skills (and motor execution skills) compared to inaccuracies in lexical representations. DF’s lexical representations were described as “frozen” as he had failed to update them despite adequate hearing and discrimination skills. Previous therapy with DF had focused on spoken output and had been unsuccessful. In Bryan and Howard’s study DF was given therapy that helped him to reflect on phonological structure and the relationship between input and output phonology. This therapy was successful in helping DF to update his lexical representations.

AE’s profile for /sk/-/g/ was markedly different to her profile for /st/-/d/. With the exception of the nonword discrimination test in the audio-alone condition (NWDAA), she performed well on all input tasks (with the probability of scores occurring by chance being small. Her chance level score on the NWDAA could have been due to a general problem with nonwords and/or difficulty in attending to the audio-alone tests (previously discussed). Although there was an effect of the audio-visual condition for the nonword discrimination tests, which led to an effect for the sk/g tests in general, this was due to the poor performance on the NWDAA. As there are several other possible explanations for this poor performance, there is no strong evidence that AE was making use of lipreading cues to discriminate /sk/-/g/ at the beginning of words or nonwords.

Overall, the input results indicate that AE had good lower level input discrimination skills for /sk/-/g/ at the beginning of words and has well specified phonological representations of /sk/ in *skate* and *school* and possibly other words beginning with /sk/. This result is less surprising as, in typical development, good lower level discrimination skills lead to the laying down of more precise phonological representations (Stackhouse and Wells, 1997).

The developing motor program depends on the phonological representation for its specification (Stackhouse and Wells, 1997) and so, at a particular stage of development, a child can have a well specified phonological representation of a particular word but, as yet, an inaccurate motor program. The development of the motor program depends on the child's motor programming and motor execution abilities as well as being influenced by the phonological representation.

There is evidence of these principles in AE's responses to the output tests. In the naming test for words beginning with /st/ she only used /s/ on one occasion (steep -> [stip]). This is fairly predictable as the results of the PYNJ tasks indicate poor phonological representations of words beginning with /st/. As /st/ was realised correctly 38% of the time in repetition we could assume that AE was developing adequate motor execution skills and motor programming skills to produce /st/ before a vowel or vowel + consonant. It is therefore most likely that the locus of her speech processing difficulties with /st/ was the phonological representations of words beginning with this cluster. It is interesting that her most accurate naming response was for the word *steep* which may be less familiar and possibly only learnt during the familiarisation process and the remainder of the tests. Therefore, she may have been using her lower level input discrimination skills to learn this relatively "new" word and frozen inaccurate phonological representations for better known words would be less likely to interfere.

In general AE's responses to the naming test for words beginning with /sk/ were more accurate. /sk/ was realised as [səg] 50% of the time (e.g. school → [səgu]) . This could be an indication that fairly well specified phonological representations for words beginning with /sk/ were influencing the development of the motor programs so they were becoming closer to the adult form. Nevertheless responses to repetition tests for words and nonwords beginning with /sk/ were better than responses to the naming test in terms of the realisation of /sk/. /sk/ was realised as [sːk] 66% of the time in the repetition tasks. This is evidence of relatively good input processing skills for /sk/ and the development of adequate motor execution skills and motor programming skills to produce /sk/ before a vowel or vowel + consonant. It is therefore more likely that the locus of her speech processing difficulties with /sk/ was the motor program of words beginning with this cluster.

Conclusion

In this single case study, the Rees Coleman Speech procedure did offer some explanation for AE's difficulty with marking the /st/-/d/ and the /sk/-/g/ contrasts at the beginning of single words. It provided evidence for loci of difficulty in the speech processing profile of the two contrasts and the locus for each contrast was different. For /st/-/d/ there was evidence of inaccurate specification in phonological representations of words beginning with this contrast, despite relatively good lower level input discrimination skills for st/d at the beginning of words. For /sk/-/g/ there was evidence of good lower level input discrimination skills *and* accurate specification of /sk/ in phonological representations of words beginning with this contrast. In the case of both contrasts there was evidence for adequate motor execution skills and motor programming skills to produce the clusters in simple CCV or CCVC sequences.

This information may have important clinical implications. Because AE had adequate lower level auditory discrimination skills to distinguish /s/-/d/ and /sk/-/g/, she may have been more likely to respond to speech and language therapy targeting these contrasts than therapy targeting contrasts she has difficulty discriminating. Therapy for /st/-/d/ could focus on updating phonological representations on words beginning with /st/ whereas therapy for /sk/-/g/ could focus on updating motor programs of words beginning with /sk/. Psycholinguistic intervention should involve working on the whole speech processing system, activating relatively stronger levels of processing in order to help weaker levels (Rees, 2001b). However, it is important to have a principled starting point (Rees, 2001b) and therefore it is important to know which part of the speech processing system is targeted, even though several levels may be activated and utilised in the therapy. Selecting appropriate contrasts and speech processing levels at the initial assessment stage is less time-consuming than reaching similar decisions through experimentation and possible back-tracking in therapy.

The validity of the information gained from profiling two contrasts for AE was strengthened by careful matching of items across the tests in each battery. As Stackhouse and Wells (1997) state, careful matching across subtests "increases the strength of the conclusions that can be drawn from dissociations of performance." (p. 317). Although untested variables such as intonation and facial movements were not eliminated entirely, the use of carefully recorded speech, rather than live speech, improved the reliability of the results. The computerised nature of the tests helped to keep AE's attention during the tests and allowed for easier recording of results.

Although the patterns revealed in profiling two contrasts for AE were similar to patterns found in one other single case study conducted by Ebbels (2000), it was not clear how typical these patterns were for other deaf children and what other patterns may exist.

Other Deaf Participants

In order to investigate whether the patterns revealed were typical for deaf children and what other patterns may emerge, the Rees-Coleman procedure was used to profile five other deaf participants. The data for each of these five participants was collected by different speech and language therapy students, supervised by the author of this thesis. These case studies will not be described in detail. Descriptions of the participants and their test results will be kept to a minimum but their profiles for particular consonant contrasts will be presented and compared to AE's profiles for /st/-/d/ and /sk/-/g/.

Table 12 shows the age and average hearing loss in the better ear (AHLBE) for AE and each of the other five participants. The AHLBE was calculated across the frequencies of 250, 500, 1000, 2000 and 4000 Hertz for the ear with the smaller average loss. The table also shows the consonant contrasts that were profiled for each child and the results of each test. The majority of contrasts were selected because the participants had difficulty in marking them in single word naming. The only contrast not selected for this reason was /p/-/b/ . For participants HA, FI and KC it was decided to profile the contrast /p/-/b/ that these children were using successfully in naming. This was done in order to examine the profile of a "successful" contrast marked by a deaf child as a means of comparison for other contrasts. For AE and three of the remaining participants the following all the tests from the Rees-Coleman battery were used for each of the contrasts tested.

Originally real word tests were included as a gradual improvement or deterioration from tasks that required access to lexical representations to tasks where access to representations was decreasingly likely would strengthen any hypotheses regarding loci of breakdown. However, completing the full range of tests was time-consuming for the children and so the list was reviewed.

It was felt that the Real Word Discrimination and Repetition tests gave the least amount of information. The nonword tests gave more useful information about lower level input discrimination and motor execution skills (as the child was more likely to bypass the lexicon for these tests). Therefore, for the final two participants (FI and KC), the real word tests were omitted.

Results of the input tests show either a √ or x, where

√ = possibility of score occurring by chance is <0.05 and

X = possibility of score occurring by chance is >0.05

Results of the output tests show correct realisations of target consonants as a percentage of the number elicited. Except for /ʃ/-/tʃ/, the target consonants are the first in the pair (e.g /s/, /sm/). For /ʃ/-/tʃ/ both consonants are “targets” as the children tended to have difficulty with both and distinguishing between both in output.

Part.	AE		HW		AK				HA			FI				KC					
Age	7y 3m		11y 2m		10y 9m				8y 6m			10y 11m				7y 11m					
AHLBE	86 db		95dB		75dB				83dB			70dB				80dB					
Contrast	st/d	sk/g	st/d	sk/g	st/d	sn/n	sk/g	ʃ/tʃ	p/b	sm/m	st/d	p/b	st/d	sn/n	ʃ/tʃ	p/b	s/d	sm/m	st/d	sn/n	ʃ/tʃ
NWDAV	√	√	X	X	X	X	X	X	√	√	X	√	√	√	X	√	√	√	X	X	√
NWDAA	X	X	X	X	X	X	X	X	√	X	X	√	√	√	X	√	√	√	X	X	√
RWDAV	√	√	X	X	X	X	X	X	√	X	X										
RWDAA	√	√	X	X	X	X	X	X	√	X	X										
PYNJAV	X	√	X	X	X	X	X	X	√	X	X	√	√	X	X	√	X	X	X	X	X
PYNJAA	X	√	X	X	X	X	X	X	√	X	X	√	X	√	X	√	X	X	X	X	X
RWRAV	38	38	70	38	0	50	0	56	100	0	10										
RWRAV	38	75	40	0	0	63	0	38	88	0	0										
NWRAV	63	75	50	38	13	25	13	75	75	0	0	75	50	63	38	88	33	38	20	0	50
NWRAA	0	88	20	0	0	38	0	50	75	0	0	100	75	56	25	88	17	38	0	13	56
Naming	13	0	29	0	13	63	13	50	100	0	13	100	63	81	50	100	8	17	7	0	55
Profile Type	**3**	**4**	**2**	**2**	**2**	**2**	**2**	**2**	**5**	**1**	**2**	**5**	**4**	**4**	**2**	**5**	**3**	**3**	**2**	**2**	**3**

AHLBE = Average hearing loss in Better Ear calculated across the frequencies of 250, 500, 1000, 2000 and 4000 Hertz

NWDAV Nonword Discrimination Audio-visual
RWDAV Real Word Discrimination Audio-visual
PYNJAV Picture Yes/No Judgement Audio-visual
RWRAV Real Word Repetition Audio-visual
NWRAV Nonword Repetition Audio-visual

NWDAA Nonword Discrimination Audio-alone
RWDAA Real Word Discrimination Audio-alone
PYNJAA Picture Yes/No Judgement Audio-alone
RWRAA Real Word Repetition Audio-alone
NWRAA Nonword Repetition Audio-alpne

√ = possibility of score occurring by chance is <0.05 and
X = possibility of score occurring by chance is >0.05
Figures for output tests refer to correct realisations of target consonants as a percentage of the number elicited

Table 12 Profiles of consonant contrasts for 6 deaf participants

General Observations

The participant with the most severe loss (HW) performed at chance level for all the input tests. This could mean that the input tests in this procedure are too difficult for children with profound hearing losses. However, other profoundly deaf children could be making more use of acoustic cues and, as discussed in chapter one, may well be likely to be making better use of lipreading cues. Evidently it is possible to make use of the additional visual cues in the audio-visual condition as, for some of the participants (AE, HA, FI), performance on the same contrast improved in the audio-visual condition for at least one of the tests.

Where there is some success at nonword discrimination, there is generally success at repetition. This may indicate that the child is taking the non lexical route for both tasks. The child may be using lower-level (non lexical) skills to discriminate the difference between two sounds and then applying these skills to the repetition task. An advantage for repetition over naming tasks provides evidence for relatively intact motor execution skills. The only exception to this pattern was HA's inability to produce the /sm/ contrast accurately in repetition, despite being able to discriminate /sm/m/ in the nonword discrimination task in the audio-visual condition. However, HA was realising /sm/ as [m̥] and so may be picking up on audio-visual cues in the input tasks that enable her to produce the contrast in her own way, which should make her speech more intelligible than if the contrast was lost altogether. This sort of pattern, also noted by others (e.g. Parker, 1999), is discussed in Chapter 1.

Profile Types

Some patterns of results for individual contrasts in this group of children were very similar and so were grouped as a profile type. The following profile types (labelled in Table 12) seem to have emerged:

1. No evidence of input discrimination skills and no success at producing the target consonant/s in output tasks.
2. No evidence of input discrimination skills but some success at producing the target consonant/s in naming and/or repetition tasks.
3. Evidence of lower level discrimination skills but no evidence of ability to reject inaccurate productions of target words (in the AV or AA conditions) indicating that target consonants are not well specified in phonological representations.

Some success at producing the target consonant/s in naming and/or repetition tasks.

4. Evidence of lower level discrimination skills and an ability to reject inaccurate productions of target words (in the audio-visual and/or audio-alone conditions) indicating that target consonants are well specified in phonological representations. Some success at producing the target consonant/s in naming and/or repetition tasks.
5. Evidence of good input discrimination skills and consistent production of target consonants in naming tasks indicating accurate motor programs (although there may be some inconsistency in repetition tasks).

Evaluation of Profiles

The Rees Coleman procedure was initially devised to track the loci of breakdown for contrasts that were not marked successfully in naming. It was envisaged that patterns of strengths and weaknesses would vary across contrasts, even for individual children. The emergence of five different profile types indicates that this is the case. The exact nature of patterns that would emerge was not predicted, but some are more expected than others. It was envisaged that stronger input skills would be related to more success with output and, to some extent, this was the case. The only profile where motor programs seemed to be accurate was one where all input skills seemed to be unimpaired. The pattern that emerged for the contrast /st/-/d/ for AE, where phonological representations seemed inaccurate despite lower level discrimination skills, was also seen for three of the contrasts tested for KC and so this pattern was a profile worth noting. It is not clear how important intact input skills are for the development of output skills. In profiles 2, 3 and 4 there was evidence of motor ability to produce the target consonants despite evidence of impaired input skills. For example, in the profiles of contrast /sn/-/n/ for AK, the child produced /sn/ accurately 63% of the time despite showing no evidence of being able to discriminate the /sn/-/n/ contrast.

Development of Version 2 of the Rees Coleman Profiling Procedure

Review of Version 1

Each of the six deaf participants studied was assessed by a different final year speech and language therapy student who had been trained to conduct tests of spoken language with children and to transcribe speech phonetically.

Feedback was collected from each of these students and their supervisor, the author of this thesis, in order to make necessary amendments to the Rees-Coleman procedure.

Feedback included the following comments:

- The number of items in each input test (24) did not need to be so large to calculate probabilities of the scores being due to chance. It would be useful to reduce this number to save testing time and balance it with the number of items in each output test (16).
- Some of the real words used in the Picture Yes/No Judgement task (e.g. *store, steep)* were not in the children's lexicon. These words were chosen because they could be used to form minimal pairs (e.g. *store/door)* allowing for matching of items across tests. However, it would be better, wherever possible, to use real words that the child would have in their vocabulary (e.g. *star, stamp)*, so that they are more likely to be accessing lexical representations in this test and in the naming test. The less frequent words should only be kept for the Real Word Discrimination test that necessitates minimal pairs.
- As the spoken stimuli were recorded from a single microphone in mono, to reflect the nature of the speaking voice, it would be better to use one rather than two loudspeakers.
- Some efforts had been made to ensure that the presentation of the auditory stimuli were at an appropriate loudness level and consistent across tests. Testing aimed to create optimum listening conditions in realistic circumstances. However it was considered that the control of this factor could be improved by using a loudspeaker of better quality and measuring the loudness level more objectively to ensure that the level was 70-75dB, to maximise the chance of the participants receiving the signal above their threshold of hearing when using their personal hearing aids. This would help to ensure that the listening

conditions for the input tests are comparable to the best conditions encountered by the child day to day. Although the child would be in poorer listening conditions much of the time, the best conditions are those in which s/he would have the optimum opportunity to discriminate and store auditory information. Therefore the child's performance on the input tests should be a better reflection on how they have perceived and stored auditory information in the past.

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Version 2

Accordingly, the following amendments were made in order to make Version 2 of the procedure a more practical, reliable and useful clinical tool:

- The number of scored items for each of the input tests was kept to 16. For the same/different tests each combination of stimuli was presented twice rather than three times. For the PYNJ tests each stimulus was presented four (rather than six) times. See table X in the appendix for a list of all the stimuli in the revised procedure (Version 2).
- If any of the words in the PYNJ test was judged not likely to be in the vocabulary of a 6 year old deaf child (e.g. "steep"), it was changed to one more likely to be (e.g. "stamp"). See for a list of all the stimuli in the revised procedure (Version 2).
- The two small stereophonic speakers were replaced by a Yamaha monophonic speaker (model number: MS1011II) which was consistently set next to the laptop screen approximately 70 cms from the child and the volume was set to the midpoint of the dial. The volume control on the laptop computer was also set to the midpoint. Measures using a Bruel & Kjaer 2231 SLM showed that the average sound level at the child's head position was 75 dBA.

Version 2 of the Rees Coleman Procedure was used for the intervention study.

Summary and Implications

The Rees Coleman psycholinguistic profiling procedure was designed to be used with deaf children from the age of six years in order to explore the nature of their speech processing difficulties. Its development was guided by the Stackhouse and Wells single word processing model (Stackhouse and Wells, 1997). It aims to track the loci of difficulty for consonant contrasts not marked during naming by conducting a range of tests (e.g. nonword discrimination, picture yes/no judgement tasks, repetition tasks and naming) with matched items for ten consonant contrasts. These contrasts are those commonly not marked accurately by deaf children with speech difficulties. The tests are conducted on a computer and all relevant tasks have an audio alone and audio-visual condition. It was envisaged that the speech processing patterns revealed by the procedure would vary across contrasts and across children. Although the exact nature of the patterns was not predicted it was envisaged that stronger input skills would be related to more success with output.

The procedure was piloted with six deaf children. For each of these participants, at least two consonant contrasts (e.g. /st/-/d/, /sn/-/n/) not marked accurately during naming were profiled. When profiles are compared across contrasts and across children five main profile types seem to emerge. Each of these profile types points to different loci of breakdown. For example, profiles 1 and 2 show no evidence of input skills whereas profile 3 shows evidence of lower level (possibly non lexical) input skills but no evidence of being able to reject inaccurate productions of target words (in the audio-visual or audio-alone conditions) indicating that target consonants are not well specified in phonological representations. The remaining profiles show evidence of intact input skills for all tasks.

What are the implications of these different kinds of profiles for speech development? In typical development it is argued that children need perceptual skills to develop phonological representations and that motor programs depend on phonological representations for their own specification (Stackhouse and Wells, 1997). Therefore we could expect that, if a child is showing evidence of perceiving a consonant contrast in lexical and/or non-lexical input tasks, it will be easier for them to develop motor programs where the target consonants are well specified. The only profile where motor programs seemed to be accurate was one where all input skills seemed to be unimpaired. However, in profile types 3 and 4 there was evidence of motor ability to produce the target consonants despite evidence of impaired input skills, and so it could be the case that there was sufficient audio-visual discrimination skill to know how to produce the consonants. It is not yet clear how important intact input skills are for the development of output skills. Interestingly, in profile type 2 there was no evidence of input skills and yet evidence of motor ability to produce the target consonants . For example, in the profiles of contrast /sn/-/n/ for AK, the child produced /sn/ accurately 63% of the time despite showing no evidence of being able to discriminate the /sn/-/n/ contrast in the audio-alone or audio-visual condition. When older deaf children are unable to imitate a particular consonant, it is more likely that this is due to perceptual difficulties rather than problems with motor execution (unless they have some motor disorder in addition to their deafness). If this difficulty can be overcome, for example by providing the deaf child with instruction on how to produce a sound and providing kinaesthetic knowledge, could the child use this knowledge to update lexical representations?

Further Investigation through Intervention

One way of exploring the implications of input skills for the development of deaf children's speech is to assess a range of speech input and output skills in a group of deaf children at regular intervals in a longitudinal study. Another way could be to "fast-track" speech development by using intervention in order to see how input skills contribute to progress. Observing which intervention strategies are particularly effective and how new skills are generalised could inform theories on how deaf children can update their speech skills. Other intervention studies have been used in similar ways.

The main aim of most intervention studies is to investigate the effects of a particular type of intervention or to compare the efficacy of different intervention methods. However, many of these studies provide useful information about theories of aspects of language and their typical or atypical development. In comparing two methods of teaching vocabulary to twenty four children (aged 7-8 years) with poor existing vocabulary knowledge, Nash and Snowling (2006) found that teaching a strategy for deriving meaning from a written context was more effective than teaching vocabulary items using definitions. This finding led weight to the semantic network theory (Collins & Loftus, 1975) that a word obtains its meaning by its place in a network of other meanings (Nash & Snowling, 2006).

Evaluating the efficacy of different methods of intervention matched to suspected different underlying deficits can support the concept of the underlying deficits. Crosbie, Holm and Dodd (2005) found that core vocabulary therapy resulted in greater change in children with inconsistent speech disorder and phonological contrast therapy resulted in greater change in children with consistent speech disorder. As the first approach aims to improve the consistency of whole word production and the second aims to improve the way the child makes meaningful phonemic contrasts, the results of this study reinforced the concept of the two different underlying deficits: a phonological planning deficit leading to an inconsistent disorder and a cognitive-linguistic deficit leading to a consistent speech disorder.

Intervention could also be used to simulate a "fast-track" version of typical development of an aspect of language development in order to evaluate the contribution of specified skills to this development. Effects of specified skills on vocabulary acquisition can be investigated by using a novel word learning procedure where the child is exposed to novel objects and novel words amongst known words in an intensive procedure that allows the child to learn the novel words. Hansson, Forserg, Lofqvist, Maki-Torkko and Sahlen (2004) used such a procedure to explore the role of working memory in learning new words. By comparing measures of phonological short term memory and complex working memory with children's performance on a novel word learning procedure, they found that the best predictor of novel word learning in children with specific language impairment and in children with hearing impairment was complex working memory. This use of an intensive procedure to "teach" words is an alternative to a longitudinal study where vocabulary acquisition and memory would have to be measured before and after a much longer time period.

Intervention studies that are set up to investigate whether the "fast-track" development of one language form generalises to similar language forms can inform theory on how children may be processing / extracting information about these forms. Leonard, Camarata, Brown and Camarata (2004) found that children with specific language impairment receiving treatment for third person singular –s (3s) *or* auxiliary is/are/was made gains in the use of *both* these target forms but not for past –ed. The use of treated 3s generalised to untreated auxiliary is/are/were and vice-versa and these gains were significantly greater than improvement in the use of untreated past –ed.. This indicated that the children had extracted information about the grammatical features of the targeted form, had identified another form requiring these features and transferred the marking of tense and agreement from one form to another. This increase in sensitivity did not appear to apply to forms in the language that express tense only.

For this study it was decided to use intervention to "fast-track" speech development in order to investigate the role of input skills. For three single case studies, target consonants for therapy were classified according to the child's input skills in order to see whether the contrast/s that a child is able to distinguish auditorily and/or visually respond more effectively to therapy than contrasts where there is no evidence of input skills. Investigating whether any improvements in the use of consonants generalised to lexical items not used in therapy could indicate whether the children were updating their lexical items on a word-by-word basis or by some other means. Observing which therapy techniques seemed particularly effective in helping the children to update speech skills and generalise their use to spontaneous speech could also provide information on any strategies they were using.

Subsequent chapters describe these three single case studies that attempt to explore these issues. For lexical representations to be truly updated one could argue that the newly acquired speech skills need to be used in spontaneous speech as well as naming tasks. Two of the three case studies include a follow-up generalisation stage that examines what may influence a more permanent updating of the lexicon.

Chapter 3: Phase 1: Therapy Techniques

This third chapter outlines the therapy techniques used in Phase 1 of the intervention study. Chapter 2 explained the development and use of a new psycholinguistic assessment procedure that suggested five different profiles of speech processing that varied across consonant contrasts. These profiles indicated the complex relationship between input and output skills. Phase 1 was set up to explore the implications of input skills for updating lexical representations and to explore the strategies that deaf children may use to update representations. The aims, design and method of Phase 1 of the intervention study are covered in Chapter 4. This chapter focuses on which therapy techniques were chosen, providing a rationale for their choice. The chapter concludes with the description of a small study that piloted the techniques.

As all the participants in this project's intervention study were boys, the masculine pronoun is used when referring specifically to them.

Outline of Intervention Programme Phase 1

This programme, devised especially for this part of the study, focused on improving the participants' ability to perceive the difference between target consonants (e.g. /sm/) from their incorrect realisation of the targets (e.g. /m/) in words and to produce the target consonants in single words. For young children with phonological disorders, the American Speech and Hearing Association (ASHA) National Outcomes Measurement System survey conducted in 2002 reported three factors that predicted successful outcomes for therapy: the provision of individual treatment, more than 10 hours of treatment time and the implementation of a home programme (ASHA website, 2002, cited in Weiss, 2004). Each participant received 10-11 hours of individual therapy. The intervention took place in a quiet room in the child's school and was conducted by the author of this project, Rees, who is a qualified speech and language therapist with 15 years of experience in working with deaf children. Throughout the session the participants used the hearing aids they usually wore in class. Radio microphones were not used by the therapist as she was in close proximity to the child. As the participants (aged 8;1 – 9;0 years) were older than the children in the ASHA survey (ASHA website, 2002, cited in Weiss, 2004), a home programme was not implemented but the parents and teachers were kept informed on therapy targets and progess.

Therapy Techniques

The choice of therapy techniques drew on psycholinguistic theories and research evidence concerning factors that maximise the success of phonological therapy with hearing and deaf children. Benhardt (2004) describes phonological therapy as special instruction provided to children whose speech production lags behind expected developmental levels for their community in order to accelerate the developmental process. As discussed in Chapter 1, deaf children's speech difficulties are generally attributed to difficulties with auditory processing rather than difficulties with oro-motor skills or cognitive-linguistic processing. However, the original deficit in auditory processing can lead to an absence of English consonants in a deaf child's phonetic repertoire and difficulty in marking phonological contrasts in speech output. Therefore therapy techniques designed to address oro-motor problems and the meaningful use of sound contrasts could also be effective with deaf children. Each technique chosen is described in turn.

Encouraging Motivation and Responsibility for Change

It is often difficult to talk to a pre-school child about motivation and responsibility but, as a child matures, they frequently gain awareness of their communication competencies and recognise the academic and social benefits of improving them. Once this happens they become more motivated and work harder to change their speech production (Weiss, 2004). In this project this transition was initially encouraged by asking the participants to complete a questionnaire describing their speech intelligibility and its consequences and their desire to make changes (see Appendix 7). Weiss (2004) makes suggestions for enhancing a child's responsibility in therapy for phonological disorders. These include involving the child in goal setting and session planning. The questionnaire asked the participants which sounds and words they had difficulty saying and, in all cases, there was some correspondence with target consonants chosen by the therapist. Although the participants did not plan the sessions they were often asked to choose the order of the activities planned. After each session they were asked to reflect on what they had learnt, how hard they had worked and what was still difficult for them. Some of the activities were designed to demonstrate an improvement in communicative competence. For example, using pictures to illustrate a minimal pair such as *smile* and *mile*, the child was asked to name a picture for the therapist to identify. If their production of *smile* was good enough for the therapist to identify the correct picture rather than the picture of *mile*, the child knew that he had been successful. Motivation was also encouraged by using praise for correct responses and feedback on improved intelligibility.

Integrating Input and Output tasks

Although psycholinguistic assessment can identify weaknesses at specific levels of a speech processing model, it makes little sense to target these levels in intervention as if they occurred in isolation. Instead intervention should take advantage of the whole system allowing strengths or increasing strengths at one level to stimulate the others (Rees, 2001).   There is evidence that training that focuses on speech production can have an impact on deaf children's auditory discrimination. Kosky and Boothroyd (2003) conducted an intervention study with six deaf children between 8;1 and 12;4 that aimed to improve their auditory discrimination and production of the /s/-/ʃ/ contrast. The study compared the effects of perception training with those of production training. The production training did involve the students perceiving the target consonants as they wore their hearing aids and were provided with some models from the trainer and could hear their own imitations. However, the trainer did not draw the students' attention to the acoustic properties of the sibilants and much of the training involved description and feedback. This production-focused training had an impact on the students' ability to produce and discriminate the contrast. The students' performance on ABX auditory discrimination tasks for /s/-/ʃ/ in utterances improved significantly over both the production training periods and the perception training periods, but not during the "no treatment" periods. The perception training mainly involved giving the students right/wrong feedback on the same ABX tasks that were used in the testing. Interestingly the improvements in perception did not depend on the type of training so that the production-focused training had as great an impact on perception as the perception training. These findings indicate the value of using output tasks to improve auditory discrimination as well as production.

If output tasks have an impact on input as well as output skills, one could argue that intervention need not involve input tasks. Another noteworthy finding from the Kosky and Boothroyd (2003) study was that improvements in production of the /s/-/ʃ/ were only associated with the production training and not the perception training. This potentially devalues the impact of auditory discrimination training. However, for some hearing children, it seems that speech perception training can have an impact on speech production. Jamieson and Rvachew (1992) conducted an intervention study with 5 hearing children with expressive phonological delay. The training involved identifying words that contrasted fricative phonemes such as /s/ and /ʃ/ (e.g. *seat* and *sheet*) and /s/ and /θ/ (e.g. *sick* and *thick*) and excluded any explicit sound production training. Three of the children who misarticulated the target phoneme demonstrated an improved ability to produce it by learning the word identification task.

It seems that the combination of perception training and production training for problematic consonant contrasts could be more effective than one type of training alone. Rvachew (1994) conducted an intervention study where 27 hearing preschoolers, who were unstimulable for /ʃ/, were trained to identify naturally produced words. The children were randomly assigned to one of three training groups: Group 1 children listened to a variety of correctly and incorrectly produced versions of the word *shoe*; Group 2 listened to the words *shoe* and *moo* and Group 3 (the control group) listened to the words *cat* and *Pete*. All children received the same traditional sound production programme for correction of their /ʃ/ error, alongside the perception training. On post testing the mean number of correctly produced words beginning with /ʃ/ out of 5 was 2.0 (range 0-5) for Group 1,1.0 (range 0-5) for Group 2 and 0.1 (range 0 to 1) for Group 3. The differences in performance between groups 1 and 3 and between groups 2 and 3 were significant. Therefore, the addition of speech perception tasks geared to the target consonant, can improve the impact of speech production training for some children. Although the difference in performance between groups 1 and 2 were not significant, there was an improved performance for Group 1, where finer auditory discrimination skills were required as the children were expected to distinguish between /ʃu/ and stimuli that were phonetically similar and more likely to reflect their errors (e.g. [tu], [tʃu], [su], [sju]). Intervention studies with deaf people that have combined perception and production training have resulted in an improvement in the production of selected speech targets (Massaro et al., 2004; Busby, Roberts, Tong, & Clark, 1991). This evidence fits in with the theory that children need perceptual skills to develop phonological representations and that motor programs depend on phonological representations for their own specification (Stackhouse and Wells, 1997).

In intervention studies with deaf people the improvement in perception of consonant contrasts sometimes varies from participant to participant and, within participants, the improvement sometimes varies from contrast to contrast. For example, in the Busby et al study (1991), the auditory-alone discrimination of nasals versus voiced stops improved after training for the pre-lingually deaf adolescent (PRE3) but not for the two pre-lingually deaf adults (PRE1 and PRE2). However, for the auditory-alone detection of syllable-final consonants, there was an improvement for PRE2 but not for PRE1. For the discrimination of the six alveolar consonants the audio-alone condition was compared to a visual alone condition and an audio-visual condition. Interestingly all three pre-lingually deaf participants improved in the audio-visual condition and, for PRE1 and PRE2, the pre-training scores were not above chance for any of the conditions and the only post-training score that was significantly above chance was in the audio-visual condition. PRE3 achieved above chance scores for all conditions post-training but achieved a higher score in the audio-visual condition. All three of these participants were implanted with a multiple-electrode cochlear implant. As Busby et al (1991) discuss, there are a range of factors which could account for the variability in improvement of speech perception abilities across participants such as degree of deafness, age, linguistic capabilities and previous auditory experience. Therefore it is difficult to predict whether a deaf person will learn to perceive the difference between a consonant contrast during perception and/or production training. It is probably useful to monitor the deaf person's ability to perceive a contrast during training to inform decisions about how long to persist with input training.

In the intervention programme for this project it was decided to focus on speech production but to integrate input tasks with output tasks because of the potentially improved impact of the combined approach. When input tasks were used, the target consonants were contrasted with the child's incorrect realisations in words. For example, if the child realised *smile* as [maɪl] , the child would trained to see and hear the difference between /smɑɪl/ and /mɑɪl/ as well as being taught how to produce /s/ and blend it with the rest of the word *smile*. At first the contrast was often introduced in connected speech (e.g. *a smile* versus *a mile*) so that the child could take advantage of the additional acoustic cues, such as the break in voicing between *a* and *smile*. The visual and acoustic differences in the contrast were pointed out to the child in order to aid perception and knowledge for production. For example, a break in voicing and the visual gesture for /s/ would be described. In these ways the input training could easily be integrated with output training where the production of consonants such as /s/ would be explained and modelled. If the child quickly learnt to discriminate a contrast in the audio-visual condition, audio-alone exercises would be done to encourage the child to notice acoustic differences. However, if the child indicated that they could hear no differences after repeated exposures and explanation, training in the auditory-alone condition would be abandoned. The child's ability to learn to perceive a contrast was carefully monitored by recording the number of correct and incorrect responses during input exercises in both conditions. In this way decisions could be made as to whether to persist with the perception training in one or both conditions or focus more on output training, as too much failure could discourage the child from learning.

Familiarising and giving Information in Input Training

Perception training used in intervention studies often involves using testing techniques with the addition of right/wrong feedback. For example, in the Rvachew (2004) study, preschool hearing children were placed in front of a monitor which displayed a picture (for example, a duck pond) and two response alternatives (a picture of the target word and an X). Each child had to listen to a spoken stimulus through headphones, that was either the target word or an alternative, and choose to point to the picture or the X. Correct responses were rewarded with a change in the picture and incorrect responses led to the spoken word "wrong" being played through the child's headphones. In the Kosky and Boothroyd (2003) study, deaf children had to complete tasks where they listened to a pair of utterances (e.g. *sow/show*) and then had to decide whether the third spoken stimulus (e.g. *sow* OR *show*) was the same as the first or second in the pair. This is known as an ABX task. Each ABX task was followed by right/wrong feedback. In the Busby et al (1991) study, the deaf adults and adolescent had to carry out discrimination and identification tasks for spoken stimuli and were given feedback, by the trainer, when they made their choices. These studies did result in an improvement in speech perception for some of the contrasts targeted. However, this procedure does run the risk of demotivating a child who continues to fail and the child has very little opportunity to learn to notice a difference in the contrast as they are continually being asked to make judgements. If a child is unable to distinguish between a sound contrast s/he will probably need a period of familiarization to this contrast in order to learn to make the distinction (Rees, 2001). Using a testing technique with right/wrong feedback provides the child with no additional information about the nature of a phonological distinction above that provided by watching and/or listening to the contrast.

This project's intervention programme incorporated familiarization into auditory training and, where possible, tried to provide the child with useful information about the contrast being targeted. For example, if the *say/day* contrast was targeted, both words would be written side by side and the therapist would begin by pointing to one of the words and saying it aloud and then pointing to the other and saying that. This would be repeated several times and the child would be asked if s/he could hear and or see a difference. Any differences spotted by the child would be discussed. Information may also be provided about the production of /s/, thus integrating input and output work as described above. When the child felt confident that they could hear some difference, they would be asked to judge the difference and then be given right/wrong feedback. If they were still unable to make the distinction, they were provided with more familiarization to the difference, where the trainer would continue to point to the word being said and give any other information about the difference that may be useful.

Exploiting Phonological Awareness, making Links with Written Letters and using "Quasi-phonemic" Script

Many of the techniques used in this project's intervention study rely on the children having an awareness of how phonological representations can be segmented into phonemes. For example, explanations of the differences between stimuli in a contrast such as *smile/mile* require the child be aware that /s/ is a segment of the word *smile*. Many output tasks involve blending a newly learnt sound with the rest of the word. As the children in the study were over 7 years of age it was presumed that they would have the skills of phoneme segmentation and blending and that relevant activities would help to develop these skills further. The written form of target sounds was used for several reasons. Written letters served as a reference that could be used to remind the child that the sound was present in spoken input tasks and to remind the child to produce the sound in spoken output tasks. Using written letters also had the added benefit of promoting the development of literacy skills. Activities to improve phonological awareness tend not to promote literacy unless specific links are made between sounds and letters (Stackhouse, 2001; Hatcher, Hulme, & Ellis, 1994). It was explained to the children that the letters "sh" represented one sound that was different to /s/ and differences in production of /s/ and /ʃ/ were explained and demonstrated. It was explained that the letters "ch" represented a combination of the sounds /t/ and the sound for "sh" and the three letters "tsh" were sometimes used to explain how this affricate was produced. When such "quasi-phonemic" script (e.g. "tsh") was used, it was written in a different colour and above the correct spelling so that the children would not confuse the two.

Helping the child to make close links between sounds and written letters could also allow the child to develop a strategy to generalise to words not used in the therapy sessions. For example, if a child learnt to produce /tʃ/ accurately and had a strong association between the new motor pattern for that sound and the written letters "ch", the child should be able to generalise her/his use of /tʃ/ to words that s/he has not encountered in therapy by visualising the written form of the word and slotting the new motor pattern in the appropriate place.

Using Meaningful Minimal Contrasts

Minimal contrast therapy (Cooper, 1968) involves selecting pairs of words for which the child's pronunciation of one member of the pair (the target word) renders it identical to the second member of the pair. The child is then confronted with the word pair (e.g. *sea/tea*) and asked to eliminate the ambiguity by changing the pronunciation of the target word (Weiner, 1981). In this way the child is encouraged to update their inaccurate motor program. Weiner (1981) carried out a successful intervention study with two hearing children with phonological disability by using this technique in output tasks. He confronted the children with the fact that their productions of the target words were the same as their production of the second member of the pair. For example, if the child was telling the trainer which picture to choose and realising "sea" as /ti/, the trainer would choose a picture of a "tea" from a selection of pictures of "tea" and "sea". The effect was to show participants that their misarticulations were resulting in miscommunication. This intervention programme was successful in eliminating a number of simplification processes for these two four-year-old children.

However, in describing the treatment programme, Weiner (1991) mentions that if children miscommunicated a word more than twice they were offered instructions to complete the task that included modelling of individual sounds and words. Therefore it was impossible to gauge the contributions of the conceptual components emphasised by the use of minimal pairs with the motoric aspects of treatment (Powell, Elbert, Miccio, Strike-Roussos, & Brasseur, 1998). Powell et al (1998) compared conceptual and motoric treatment with groups of hearing children between 3;6 and 6;10 who had been referred for treatment of speech sound production disorders. All the children had difficulty with realising /s/ accurately and consistently but some of the children did have [s] in their phonetic inventory. Children were randomly assigned to a conceptual treatment group or a motoric treatment group and the aim of both treatments was to improve the production of correct [s] production in single words. The conceptual tasks emphasised how /s/ was used contrastively to convey meaning by using minimal pairs and encouraged the child to identify the presence of /s/ in words but none of the tasks involved imitation or articulatory instruction. The motoric tasks focused on [s] production practice and did not involve meaningful contrasts. In the motoric treatment group, all participants showed a change in the use of /s/ in single words from baseline score to final treatment score and this included seven children who scored zero for /s/ production at baseline. In the conceptual group, the four children who scored zero at baseline also scored zero for final treatment. The remaining children made some improvements in correct production of [s] in single words. This study, that cleverly separated out treatments representing opposite end of the motoric to conceptual continuum, indicated the potential impact of the two techniques. The motoric treatment resulted in an improved production in the use of /s/ in single words for all participants, even those who did not have [s] in their phonetic inventory. The conceptual treatment, mainly involving minimal pairs, did result in some improvements in the production of /s/ for all the participants who already had the motoric ability to produce [s], even if the sound was used very infrequently in spontaneous speech. Therefore it seems that it is advantageous to include motor practice as part of the treatment process, especially if the target sound is absent from a phonetic inventory, but that use of minimal pairs and other conceptual tasks could enhance the process.   The use of minimal pairs could help the child to realise that they need to update motor programs but, unless their motor execution skills are adequate, they will not necessarily be able to do so.

Intervention programmes with hearing children with speech difficulties often combine motoric practice with the use of minimal pairs and other conceptual metalinguistic tasks. Example of studies that report success with this kind combination are those conducted by Bowen and Cupples (1998), Bowen and Cupples (1999) and Howell and Dean (1994). In these studies, as in many intervention approaches, minimal pairs are not only used for output tasks but also for input tasks and phonological awareness tasks. Bowen and Cupples (1999) used minimal pair pictures for a range of activities that included “Point to the one I say!”, “Tell me the one to give you!” and “Give me the word that rhymes with the one I say!”. In theory, these kind of activities should help the child to strengthen links between different kinds of representations in the lexicon: the phonological representation, the semantic representation and the motor programme (Rees, 2001).

Several successful intervention studies with deaf people have also used minimal pairs in input and output tasks and combined this with phonetic level instruction (Massaro and Light, 2004; Busby et al, 1991). Therefore this project’s intervention study included the same combination of conceptual and motoric treatments.

Phonetic Level Instruction

The value of phonetic level instruction for hearing children has been discussed in the previous section. It seems that, particularly for phonemes with a high error rate, phonetic level instruction can also help deaf children to improve their ability to produce target consonants in spontaneous speech (Paatsch et al., 2001). In the Paatsch et al study (2001) 12 deaf children each received phonetic level training for three consonants that had a particularly high error rate. Four children showed a significant gain in their use of the target consonants in single word naming or conversation, even though the training only consisted of practising production of the sounds in isolation or in non-meaningful strings of consonants and vowels.

The training used in the Paattsch et al study (2001) is based on the Ling system (Ling, 2002; Ling, 1976). This system has been the most influential approach to the speech training of deaf children (Murphy et al., 2005) and aims to develop deaf children's phonetic level skills to a high level of automaticity so that the transition of patterns to the child's phonology should take place easily (Ling 2002). The Ling system includes detailed suggestions on how to elicit accurate production of consonants using instructions and any auditory, visual and tactile strategies that may assist the production. For example, to elicit /ʃ/, Ling (2002) suggests instructing the child to produce /θ/ and then telling them to retract their tongue sharply. He explains that the sharp retraction will encourage the child to keep the tongue blade relatively flat and widely spread. He also suggests phonetic contexts that will facilitate the transfer of each sound from production in isolation to single syllables. For /ʃ/, for example, he recommends using the consonant in final position after front vowels.

Some studies with deaf people combine phonetic instruction with the use of instruments that provide additional information, such as a real-time spectrographic display (Ertmer & Maki, 2000) and a computer-animated talking head (Massaro et al., 2004). The Ertmer and Maki study (2000) compared the use of the display with the use of noninstrumental instruction that was provided in both conditions. Each of the four participants in this study demonstrated improvements in the use of target consonants in single word naming for both forms of instruction. The noninstrumental instructions involved:

- signed instructions and gestures to explain the production characteristics of the target consonants (/m/ and /t/);

- visual cues through clinician models for appropriate lip compression and opening for /m/ and tongue placement for /t/;
- tactile cues such as feeling vibrations at the side of the nose for /m/ and feeling a brief burst of air released at the mouth for the production of /t/;
- providing verbal feedback on the accuracy of production of target consonants.

Once an accurate production of a sound had been established, it was practised in isolation, nonwords and then words to reinforce and establish the updated motor patterns.

Production training in the Kosky and Boothroyd (2003) study with deaf children also involved the use of modelling, description and feedback on accuracy.

This project's intervention study also used instructions to explain characteristics, modification of other sounds, visual cues, tactile cues and feedback on accuracy of production. When feedback was provided on the accuracy of the child's production, sliding scales were sometimes used with different points on the scale representing different degrees of accuracy.

The difficulty that older deaf children may have with producing particular sounds does not usually stem from motor execution difficulties in the physical sense. They have the physical and motor potential to produce the sound but the absence of clear auditory feedback prevents them from knowing how to execute the sound. This is why visual and tactile feedback are important as they can help to replace or supplement auditory feedback. The other way of supporting sound production is to strengthen the auditory feedback by integrating phonetic instruction with input tasks. Wherever relevant this was done in this study. For example, when a child produced [x] when trying to imitate /s/, the difference in production of both sounds was explained and modelled and the therapist explained that [x] was written as "ch" in other languages. The child was asked to complete input tasks where he had to notice a visual and auditory difference in the production of pairs such as /si/ vs. /xi/. The child then tried again to produce /s/ and was given feedback by the therapist placing a cross on a line that was drawn between "s" and "ch" and was given further instruction on how to produce a sound closer to /s/.

Use of Nonword Stimuli

Although nonwords are not part of functional communication they can assist the intervention process. If a child has inaccurate representations, this may interfere with tasks involving real words. However the use of nonwords allows the child to bypass the lexicon and build up lower level auditory discrimination skills or skills in motor programming and execution. For example, when a child has just learnt to produce a consonant such as /ʃ/ in isolation, if the child is then asked to use this "new sound" to repeat real words including /ʃ/, s/he is likely to revert to using established inaccurate motor programs. However, if s/he is asked to imitate nonwords including the sound (e.g. /iʃ/, /ʃɑ/), s/he is less likely to access representations and therefore is more likely to repeat them successfully. Once the lower level skills gain strength the child can then attempt to apply them to real words and update motor programs. Also, in some senses, the use of nonwords does mirror typical language acquisition as children first hear sounds in "new" words and often imitate "new" words that are not yet in their lexicon (Rees, 2001).

The Ling system (Ling 2002) suggests the following progression from imitation of consonants in isolation:

- imitation of the target consonant in different combinations with vowels
- imitation of repeated syllables with the target consonant
- imitation of syllables with the target consonant and different vowels
- alternation of syllables containing other consonants
- production of syllable strings containing the target consonant which vary in pitch.

Thus the child can practice newly acquired speech skills without taking a lexical route.

Ordering and Combining Therapy Techniques

Therapy used in clinical practice involves reacting appropriately to the child's responses. Therefore a strict programme of work was not devised. Instead a general ordering was adhered to and the chosen techniques were integrated as appropriate. Several examples of this kind of integration were given in the previous section.
Each consonant contrast targeted was introduced in turn and, in general, all had been introduced by the fourth therapy session and a roughly equal amount of time was spent on each contrast.
For each contrast the general order was as follows:

- The contrast was introduced in a minimal pair (e.g. switch/witch) using pictures and the written form;
- Information was provided about the difference between the pair such as underlining the difference in the written form, demonstrating any visual difference, using kinaesthetic cues;
- The audio-visual difference was modelled with the therapist pointing to the written word as she said it. At this stage the words were often used in connected speech (e.g. a witch / switch) so that more acoustic cues were available and these would be pointed out. If the child felt confident that they could hear and/or see a difference after a period of familiarisation, then he would try to point to the correct picture in an identification task and be given right/wrong feedback. The identification tasks were often incorporated into a game. For example, the child would be given ten toy bees and two toy hives, each labelled with a picture and written word corresponding to one of the minimal pair. The child would watch and/or listen to the therapist saying one word in the pair and be expected to place a bee in the appropriate hive. When the child had placed a bee in a hive, the therapist would then tell the child if his response was correct and repeat the whole procedure until all the bees were in hives. The child would add up the number of correct responses and check this against subsequent performances;
- The child was helped to produce any sound in the contrast that they did not have in their repertoire. They were provided with explanations of how to make the sound and provided with visual and tactile cues. “Quasi phonemic” script was used where appropriate. These techniques were used until the child had learnt to produce an accurate or acceptable version of the target sound. An “acceptable” version was a sound that was in the phonemic category of the target sound and so did not cross a phoneme boundary in English and therefore could not be confused with another phoneme by the listener.
- If and when the child had learnt to produce an accurate or acceptable version of the target sound in isolation, they were then asked to blend the sound in nonwords. In the case of a target cluster, this would imply blending with the other consonant and a vowel or rime (e.g. /swɑ/, /swem/) and, in the case of a target single consonant, this would imply blending with a vowel or rime (e.g. /ʃɑ/, /ʃɪm/). The child was given feedback on the accuracy of his response.
- If and when the child had learnt to imitate the target consonant/s in nonwords they were given practice at using the sounds in real words. This practice involved a range of games and activities involving single word naming of pictures such as lotto and bingo and board games with superhero characters.

The child was given feedback on the accuracy of his response and self correction was encouraged and rewarded.

- At intervals minimal pairs were re-introduced both for identification tasks, if the child had not learnt to see and/or hear the distinction, and for output tasks, where the child had to make the contrast accurately enough for the therapist to identify the right picture. Where it was not possible to find a minimal pair relevant to a particular word (e.g. *smoke*), a right/wrong pair would be used. For example, under a picture of smoke two squares would be drawn, one with a tick and the written word "smoke" and the other with a cross and "moke" written with a coloured pen.

Pilot Study

A small pilot study was conducted in order to see whether the techniques described above could be effective in improving a child's ability to mark consonant contrasts in naming tasks. The PIDS procedure, outlined in Chapter 2, had indicated a range of possible speech processing profiles for consonant contrasts and the first phase of the intervention study aimed to investigate whether some profiles were more amenable to change than others. Therefore it was not expected that the therapy would result in improvements for *all* contrasts a child found difficult. The aims of the pilot study were:

1. To assess whether the planned therapy programme was effective in improving the child's ability to mark consonant contrasts in naming tasks;
2. To investigate whether contrasts that responded more effectively to therapy had particular kinds of speech processing profiles.

The Participant

The intervention programme described above was piloted with SR, a congenitally deaf child of 7;6 years. He was reported by his speech and language therapist to be generally intelligible to those who know him but have difficulty in marking some consonant contrasts at the single word level.

SR was tested with a selection of tests from the PIDS procedure outlined in Chapter 2. He had difficulty in marking the following seven consonant contrasts in naming tasks: /p/-/b/, /sp/-/b/, /sk/-/g/, /sw/-/w/, /sm/-/m/, /st/-/d/, /ʃ/-/tʃ/.

In each case this was because he had difficulty in producing the first consonant or cluster in the pair accurately and consistently. The exception was /ʃ/-/tʃ/ where neither sound was produced accurately and consistently. SR's ability to produce these target consonants in naming tasks and in word repetition tasks in the audio-visual condition is shown in Table 13.

Target Consonant/s	PIDS Tests	
	Naming	Word Repetition (Audio-visual condition)
p	0/8	0/8
sp	5/8	7/8
st	2/8	2/8
sk	0/8	0/8
sw	1/8	1/8
sm	5/8	8/8
ʃ	5/8	7/8
tʃ	5/8	7/8

Table 13 SR's scores for correctly realising target consonant/s in naming tests and word repetition tests from PIDS

SR had been fitted with a cochlear implant two years before testing and speech and language therapists from the cochlear implant team reported that his speech discrimination was good. Higher scores in word repetition tasks could also indicate relatively good input skills. However, input testing from the PIDS battery was discontinued after completing the following 5 tests as the scores for each test reflected chance performance:

/sm/-/m/: Picture Yes/No Judgement Audiovisual condition

Picture Yes/No Judgement Audio-Alone condition

/sp/-/b/: Picture Yes/No Judgement Audiovisual condition

It was hypothesised that SR had difficulty with these kind of input tests. To check this out, Picture Yes/No Judgement tasks in both conditions were conducted for the /m/-/b/ contrast that SR marked accurately and consistently in naming as it was likely that he could discriminate this contrast. Performance on these tests was also at chance indicating that SR may have a general difficulty with these kind of input tasks and so performance does not necessarily indicate auditory discrimination difficulties.

Study Design

The following contrasts were chosen for the therapy study:
/p/-/b/, /sp/-/b/, /sk/-/g/, /sw/-/w/, /sm/-/m/,
/st/-/d/, /ʃ/-/tʃ /.

With the exception of /ʃ/-/tʃ/, the "target" consonants were those that were first in the pair, as SR realised these as the second in the pair (e.g. *pear* → [beə]). SR had difficulty with the realisation of /ʃ/ and /tʃ/ and so both these consonants were target consonants.

This single case study had a time series design where progress over periods without intervention (the A phases) were compared with an intervention period (the B phase) in an ABA time series order. Target consonants were assessed at four time points (Ts) with six week intervals between each one. At each assessment the same set of pictures was used to elicit at least four realisations of four different words for each target consonant. Ten 40 minute therapy sessions were provided between T2 and T3. The intervention programme included all the therapy techniques listed in this chapter.

During the assessments at each time point SR's realisations of all the target consonants were categorised as "incorrect" or "correct". A "correct" realisation was one within the phonemic category of the target phoneme, not crossing a phoneme boundary into a possible alternative phoneme in English. All other kinds of realisations were categorised as "incorrect".

Results

The McNemar test was used to measure any significant changes in realisations of all the target consonants (as a group) during the following intervals:

- Time 1 to Time 2 (T1-T2) (no intervention period prior to intervention)
- Time 2 to Time 3 (T2-T3) (intervention period)
- Time 3 to Time 4(T3-T4) (no intervention period following intervention).

There was no significant change for T1-T2 (N=62, p=0.523) or T3-T4 (N=62, p=065). . There was a significant change during the therapy period, T2-T3 (N=62, p<0.01).

Many of the therapy sessions included input tasks with minimal pair pictures and SR's progress in discriminating contrasts in these tasks was closely monitored by recording scores. For some contrasts he learnt to point to the correct picture out of a choice of two minimal pair pictures (e.g. pictures of *witch* and *switch*) with 100% accuracy (scores of 10/10) in the auditory alone condition whereas his performance for the other contrasts remained at chance level. The data was then split into two categories of contrasts based on whether SR had learnt to discriminate auditorily between the target consonant and his incorrect realisation during the therapy. These categories were:

- No evidence of Input skills (NEI) (/p/-/b/, /ʃ/-tʃ/)
- Evidence of Input skills (EI) (/sp/-/p/, /sm/-/m/, /sk/-/g/, /sw/-/w/, /st/-/d/)

A McNemar test was used to measure any significant changes in realisations during the different time intervals (T1-T2, T2-T3 and T3-T4) of both NEI and EI consonants. The results were as follows:

	T1-T2		T2-T3		T3-T4	
	n	*p* value	*n*	*p* value	*n*	*p* value
NEI	29	1.000	29	1.000	29	0.625
EI	33	0.607	33	**<0.001**	33	0.125

Table 14 SR: McNemar test comparing changes in classification of consonant realisations for three time intervals

Using this method of classification there was no significant change for the NEI consonants in any time period. For the EI consonants there was no significant change from T1 to T2 or T3 to T4 but a significant change during the therapy period (T2-T3).

Discussion

The intervention programme described in this chapter was successful in improving SR's ability to produce some targeted consonants accurately when naming. When all the target consonants were considered as a group there was a significant difference in the number of accurate realisations between pre and post intervention tests. During the initial assessments SR was unable to complete any of the input tests successfully. Therefore it was difficult to divide the contrasts into groups according to their speech processing profiles. However, the intervention was successful in improving SR's auditory discrimination of some consonant contrasts. For these contrasts he learnt to point to the correct picture out of a choice of two minimal pair pictures (e.g. pictures of *witch* and *switch*) with 100% accuracy indicating that he had updated his phonological representations of words with the target consonants (e.g. *switch*). These consonant contrasts were those that responded significantly to therapy, in terms of accurate production of targeted consonants in naming. There were some contrasts that he did not learn to discriminate either in the audio-alone or audiovisual condition. This variation in response to input training with deaf people was also found by Busby et al (1991). Where there was no evidence of input skills, contrasts did not respond significantly to therapy. This indicates that it may be more difficult for children to update motor programs for words if they do not have the ability to discriminate between the correct and incorrect production of these words in terms of input. This supports the argument that children need perceptual skills to develop phonological representations and that motor programs depend on phonological representations for their own specification (Stackhouse and Wells, 1997).

Summary and Implications

This chapter outlined the therapy techniques that were thought to be suitable for Phase 1 of the intervention study. The therapy techniques were used in a small pilot study with SR, a congenitally deaf boy aged 7;6 years. It was not possible to evaluate each technique as it was decided to provide therapy that involves selecting and integrating techniques in reaction to how the child is responding at each stage of the intervention. This kind of therapy more closely mirrors clinical practice. However, the consonant contrasts that made significant improvements were those SR had learnt to discriminate auditorily during the intervention. Therefore it does seem that the use of both of input and output tasks was effective as it has been in other intervention studies with deaf people (Massaro et al., 2004; Busby et al., 1991). The therapy programme designed was effective in improving the SR's ability to mark some consonant contrasts in naming tasks. The pilot study indicated that it was easier for SR to update motor programs for words if he had developed auditory discrimination skills that allowed him to update phonological representations for those words.

How reliant is the updating of motor programs on the updating of phonological representations? Is the updating of phonological representations dependent on developing auditory discrimination skills? Although the study with SR indicated that developing auditory discrimination skills was important in the updating of lexical representations, this may not be true for other deaf children. If other deaf children can update lexical representations despite no improvement in auditory discrimination, what strategies may they be using to do this? Subsequent chapters describe how the intervention programme described in this chapter was used with three other deaf children in a detailed intervention study in order to explore these research questions.

Chapter 4: Phase 1: Aims, Design and Method

This chapter outlines Phase 1 of an intervention study that was set up to explore questions about the nature and development of deaf children's speech processing skills. Chapter 2 explained the development and use of a new psycholinguistic assessment procedure that suggested five different profiles of speech processing that varied across consonant contrasts. These profiles varied in terms of input skills. Phase 1 of the intervention study was set up to explore the implications of input skills for updating lexical representations and to explore the strategies that deaf children may use to update representations. Chapter 3 described the therapy techniques used in Phase 1 and the way in which they were piloted with a deaf child. This chapter focuses on the aims, a description of the three participants, the design of the experiment and the methods used.

Aims

It is argued that typically developing hearing children need perceptual skills to develop phonological representations and that motor programs depend on phonological representations for their own specification (Stackhouse and Wells, 1997). Therefore we could expect that, if a child is showing evidence of discriminating a contrast including target consonants, in lexical and/or non-lexical input tasks, it will be easier for her/him to develop more accurate motor programs where the target consonants are specified more precisely. This may also be the case for deaf children, even if the child is using mainly visual skills to perceive the contrasts.

If deaf children can learn to update motor programs of a small set of words by the improved specification of target consonants, it may be possible for them to generalise this to other words by using phonological awareness, knowledge of orthography and other strategies.
If intervention consists mainly of single word naming tasks it is useful to know whether any improvement in speech skills is spontaneously generalised to connected speech.

Therefore the aims guiding the design of the intervention study are to investigate whether:

1) input skills for target consonants facilitate the development of their specification in motor programs and

2) any improved specification of consonants in motor programs of words used in therapy generalises to non-therapy words
3) any improved articulation of single words spontaneously generalises to connected speech.

Selection Criteria for Participants

As the Rees-Coleman PIDS procedure was designed to be used with children from 6 years, this was the lower age limit. As the intervention would involve withdrawing the child from lessons it was decided that this would be less disruptive for children attending primary school and so 11 years was the upper age limit. In order to explore the difference between processing profiles (some involving evidence of input skills and others not) it was necessary to find deaf children who had difficultly with marking at least five consonant contrasts in naming tasks, including at least one for which they had input skills and at least one where there was no evidence of input skills.

Therefore, selection criteria for phase one of the intervention study were:

1. sensori-neural hearing loss,
2. age 6-11years,
3. speech difficulties evident in single word naming test from the Phonological Evaluation and Transcription of Audio-visual Language (PETAL) (Parker, 1999) – involving difficulties in marking at least five consonant contrasts that are included in the Rees-Coleman PIDS battery of tests,
4. evidence of input skills for some (but not all) of these consonant contrasts not marked in naming.

Speech and language therapists specialising in deafness working in two counties in England were asked to find any participants who were likely to fit these criteria. If potential participants had not completed a PETAL naming test within the last three months, this was conducted by the author of this study. To ensure that the potential participant was able to complete a speech discrimination task successfully, they were asked to complete one brief informal input task using live speech to test a consonant contrast that they were able to produce. Each participant was asked to make same/different judgements about the following pairs: *my/by, by/my, by/by, my/my*. Each pair was presented three times and the twelve pairs were spoken in a random order by the tester. The participant's eyes were covered during presentation of the stimuli. If all twelve judgements were correct, this was taken as evidence of input skills for the /m/ - /b/ contrast. The fourth criterion was checked by completing the relevant tests from the Rees-Coleman procedure. The results of these tests are described in the main results section.

Participants Selected

DA

DA was 8;7 years when he was first tested on this study. He was diagnosed with a profound bilateral sensori-neural hearing loss at 18 months. The cause of his deafness is unknown. His parents and younger sister are hearing. There is no evidence of any learning or physical difficulties, other than deafness. Audiometric testing conducted at age 8;1 years revealed the following pure tone unaided thresholds:

Frequency (Hz)	Threshold (dB SBL)	
	Right Ear	Left Ear
250	80	105
500	80	No response
1000	100	No response
2000	105	No response

Table 15 DA: Audiometric testing results

No aided thresholds were obtained. DA consistently wears bilateral Phonak Supero 413 Digital Signal Processing (DSP) post aural hearing aids set at a mid volume level.

DA's family speak English and often support their speech with sign when communicating with him. DA attends a Hearing Impaired Unit (HIU) in a mainstream school. He participates in mainstream and HIU lessons. Sign Supported English is used by the teachers in the HIU and the teaching assistants who support DA in mainstream lessons. When taught in groups, DA's teacher uses a Solaris radio microphone.

DA's teachers report that he is a highly motivated child with age-appropriate literacy skills. His spoken language is in the lower half of the average range for his chronological age. The results of the Renfrew Action Picture Test (Renfrew, 1997) conducted when DA was 8;5 years indicated a z score of -0.18 for Information and -1.1 for Grammar. These scores were calculated using the means and standard deviation measurements provided. Although this test is not standardised on deaf children it allows for a comparison to hearing peers.

The teachers and children who work with DA understand most of his speech, even if he not signing. The naming test of the Phonological Evaluation and Transcription of Audio-visual Language (Parker, 1999) conducted at age 8;8 years indicated difficulties in realising the following consonants: /f/, /v/, /θ/, /s/, /z/, /ʃ/, /tʃ/ and /dʒ/ and the following clusters: /fr/, /θr/, /sm/, /sp/, /sw/ , /sn/, /st/, /sk/.

All the remaining consonants in English were elicited and all were realised accurately. A selection of other clusters was also elicited and realised accurately. Table 16 shows a list of the syllable initial realisations of all the problematic consonants and clusters. The figures refer to the number of times a target was realised in a particular way:

Target single consonant	Realisations	Target consonant clusters	Realisations
/f/	[p̪] x 8	/fr/	[p̪r]
/v/	[b̪] x1	/θr/	[t̪r]
/θ/	[t̪] x 2	/sm/	[m] x 4
/s/	[d] x 4	/sp/	[b] x 4
/z/	[d] x 2	/sw/	[ɸw] x 2, [kw] x 1
/ʃ/	[ʃ̟] x 2, [çj] x 2	/sn/	[n] x 3
/tʃ/	[kx] x 2, [gɣj] x 1, [çj] x1	/st/	[d] x 4
/dʒ/	[ʃ] x 1, [j] x 1, [dʒ] x1, [ʃj] x 1	/sk/	[d] x 3

Table 16 DA: Summary of SIWI consonants not marked during PETAL naming test

JB

JB was 8;1 years when he was first tested on this study. He was diagnosed with a bilateral sensori-neural hearing loss at 10 months. The cause of his deafness is unknown. His parents and younger brother and sister are hearing. The most recent audiometric testing was conducted at age 6;0 years and revealed the following pure tone unaided and aided thresholds:

Frequency (Hz)	Unaided Threshold (dB SBL)		Aided Threshold (dB SBL) with 2 X Primofocus Pro2 hearing aids
	Right	Left	
250	80	65	55
500	85	75	45
1000	80	75	25
2000	80	60	20
4000	90	80	55

Table 17 JB: Audiometric testing results

JB consistently wears his bilateral Primofocus Pro2 Digital Signal Processing (DSP) post aural hearing aids set at a mid volume level.

JB's family speak English and occasionally support their speech with sign when communicating with him. JB attends a Hearing Impaired Unit (HIU) in a mainstream school. He participates in mainstream and HIU lessons. Sign Supported English is sometimes used by the teachers in the HIU and the teaching assistants who support JB in mainstream lessons. JB usually speaks without signing and the teachers and children who know him understand most of his speech in context. When taught in groups JB's teacher uses a Solaris radio microphone. His teachers report that he is enthusiastic and eager to please and generally has good attention.

An educational psychologist's report, written when JB was 7;6 years, referred to him as having moderate learning difficulties and "struggling to learn, remember and use facts". His teachers report that, although he is very willing and co-operative, he has difficulty in remembering and generalising what he is being taught. Despite these difficulties, he attained a Reading Level of 1 at his Key Stage 1 assessment. Key Stage 1 assessments are completed at the end of Year 2 when children are 7 years old and although the majority are expected to have attained Level 2 by this stage, a Level 1 indicates that the child has learnt to recognise familiar words in simple texts and use phonic strategies and context cues when reading aloud. In JB's education authority 89% of children at Key Stage 1 achieved Level 2 or above, 9% achieved Level 1 only and 2% did not achieve level 1.

His comprehension of the spoken and written form seems to be just outside the average range.   On The British Picture Vocabulary Scales (Dunn, Dunn, Whetton, & Pintillie, 1982) conducted when JB was 8;1 years he scored at the14th centile. His expressive language seems significantly delayed. The results of the Renfrew Action Picture Test (Renfrew, 1997) conducted when JB was 8;1 years indicated a z score of -4.29 for Information and -4.14 for Grammar. These scores were calculated using the means and standard deviation measurements provided. Although these tests of receptive and expressive English are not standardised on deaf children, they allow for a comparison to hearing peers.

At age 8;3 years JB received an occupational therapy assessment and was reported to have difficulties with large and fine motor movements. According to this report, JB may have retained the Asymmetrical Tonic Neck Reflex indicating immaturity in the central nervous system, which impacts on postural stability and balance. JB had difficulty with bilateral movement which impacted on his ability to synchronise upper and lower limbs in tasks such as jumping and clapping at the same time. He had low muscle tone in his hands and completed fine motor movements at a slow speed and sometimes with difficulty. He had difficulty in sequencing movements in a task such as cutting out a circle. He had difficulties with kinaesthetic feedback and so, although he could touch each fingertip to the tip of his thumb in turn, he was not able to do this above his head when he could not see his hands.

The report from this assessment also indicated some visual perception difficulties. He has a marked left convergent squint and wears glasses to correct this.

The naming test of the Phonological Evaluation and Transcription of Audio-visual Language (Parker, 1999) conducted at age 8;1 years indicated difficulties in realising the following consonants: /t/, /d/. /k/, /f/, /v/, /θ/, /s/, /z/, /ʃ/, /tʃ/ and /dʒ/
and the following clusters:
/tr/, /dr/, /kr/, /gr/, /tw/, /θr/, /fr/, /θr/, /sm/, /sp/, /sw/, /sn/, /st/, /sk/.
All the remaining consonants in English were elicited and all were realised accurately. A selection of other clusters was also elicited and realised accurately. Table 18 shows a list of the syllable initial realisations of all the problematic consonants and clusters. The figures refer to the number of times a target was realised in a particular way:

Target single consonant	Realisations	Target consonant clusters	Realisations
/t/	[t] x 2, [k] x 2	/tr/	[pʊ] x 3
/k/	[k] x 5, [t] x 3	/dr/	[ʙ] x 1
/d/	[d] x 4, [g] x 1	/kr/	[pʊ] x 3,
/f/	[p] x 5	/gr/	[bʊ] x 2, [ʊ] x 1
/v/	[b] x1	/tw/	[ɸ]
/θ/	[d] x 2	/fr/	[ɸ]
/s/	[d] x 4	/θr/	[ɸ]
/z/	[d] x 2	/sm/	[m] x 3
/ʃ/	[kx] x 2, [xj] x 1, [kxj] x 1	/sp/	[b] x 2
/tʃ/	[kx] x 2, [gɣj] x 1, [çj] x1	/sw/	[w] x 1, [kw] x 1
/dʒ/	[dʒ], [gɣj] x 1	/sn/	[n] x 3
		/st/	[d] x 4
		/sk/	[g] x 1, [kx] x 1

Table 18 JB: Summary of SIWI consonants not marked during PETAL naming test:

MC

MC was 9;0 years when he was first tested on this study. He was diagnosed with a moderate bilateral sensori-neural hearing loss at 5 months, four weeks after his older sister was diagnosed with a similar loss at 2;11 years. Therefore, although his parents are both hearing, MC's deafness is likely to be inherited. Audiometric testing conducted at age 8;6 years revealed the following pure tone unaided thresholds:

Frequency (Hz)	Threshold (dB SBL)	
	Right Ear	Left Ear
250	30	25
500	45	40
1000	75	75
2000	70	65
4000	70	60

Table 19 MC: Audiometric testing results

No aided thresholds were obtained. MC consistently wears bilateral Phonak Supero 412 Digital Signal Processing (DSP) post aural hearing aids, issued at age 8;6 years, set at a mid volume level.

MC's family speak English and do not use sign language. He attends a Hearing Impaired Unit (HIU) in a mainstream school. He participates in mainstream and HIU lessons. Sign language is not used in the school. When taught in groups MC's teacher uses a Solaris radio microphone. People who know MC have no difficulty in following his speech. Strangers sometimes find his speech difficult to follow.

At age 7;5 years MC was assessed by an educational psychologist because of his difficulties with literacy and family history of dyslexia. The report on this assessment included the following information. On the Wechsler Objective Reading Dimensions Test (Wechsler, 1993) he performed below average scoring within the 5 to 6 year range. He was able to match sounds to letters in final and initial positions. He confused "o" and "a" in "hat" and "hot". As soon as he started to fail, his motivation reduced noticeably. On the reading comprehension test he attempted to answer questions without reference to the text and gave up as soon as the task became too difficult. His non-verbal cognitive skills were tested with 7 subtests of the Wechsler Intelligence Scale for Children (Wechsler, 1992). MC functioned within the average range, approximately between the 15th and 90th percentiles. He showed particular skill in Picture Arrangement (testing sequencing pictorial information to make picture stories) and had the most difficulty with Mazes (testing hand-eye-co-ordination and visual, spatial, perceptual skills) and Coding (testing simple visual learning and hand-eye-co-ordination). Because his performance on the literacy tests did not seem to be wholly explained by his moderate hearing loss, these findings led to a diagnosis of mild dyslexia and suggestions that support for literacy should include methods that assisted his motivation and improved his enthusiasm for learning.

MC's comprehension and expression of spoken English seem within the average range. On The British Picture Vocabulary Scale (Dunn et al., 1982) conducted when MC was 8;1 years he scored at the 34th percentile. On the Clinical Evaluation of Language Fundamentals (Semel, Wiig, & Secord, 1995) conducted when he was 8:11 years he obtained the following standard scores for six subtests (where mean=10 and standard deviation =3): Receptive Subtests – Concepts and Directions = 9, Word Classes = 6, Sentences Structure = 13, Expressive Subtests – Recalling Sentences = 10, Formative Sentences = 8, Word Structure = 7. Although these tests of receptive and expressive English are not standardised on deaf children, they allow for a comparison to hearing peers.

The naming test of the Phonological Evaluation and Transcription of Audio-visual Language (Parker, 1999) conducted at age 9;0 years indicated difficulties in realising the following consonants: /θ/, /s/, /z/, /ʃ/, /tʃ/ and /dʒ/

and the following clusters: /θr/, /sm/, /sp/, /sw/, /sn/, /st/, /sk/.

All the remaining consonants in English were elicited and all were realised accurately. A selection of other clusters was also elicited and realised accurately. Table 20 shows a list of the syllable initial realisations of all the problematic consonants and clusters. The figures refer to the number of times a target was realised in a particular way:

Target single consonant	Realisations	Target consonant clusters	Realisations
/θ/	[f] x 2	/θr/	[fʊ] x 3
/s/	[θ] x 4	/sm/	[m] x 2, [m̥m] x
/z/	[ð] x 2	/sp/	[b] x 2 1
/ʃ/	[θ] x 2, [ʃ] x 1, [ʃʊ] x 1	/sw/	[w] x 2
/tʃ/	[d] x 3, [t] x 1	/sn/	[n̥n] x 3
/dʒ/	[d] x 1, [dʒ] x 1,	/st/	[d] x 2, [s] x2, [st] x 2
		/sk/	[g] x 3

Table 20 MC: Summary of SIWI consonants not marked during PETAL naming test

Design

A single case study was conducted on each of these three participants. Each study had a time series design where progress over periods without intervention (the A phases) was compared with progress over an intervention period (the B phase) in an ABA time series order.

Each of the three participants was tested at four time points that were approximately 6 weeks apart from each other. Intervention was given between Time 2 and Time 3.

Assessments

The tests that were used at each time point were as follows:

Time 1:

Input Tasks

Consonant contrasts identified as being problematic for the individual children by the PETAL naming tasks (Parker, 1999) that were included in the Rees Coleman procedure were profiled with input tests from the procedure. Details of this procedure are given in Chapter 2. For each contrast the following input tests were conducted:

Nonword Discrimination Audio Alone (NWDAA)
Nonword Discrimination Audiovisual (NWDAV)
Picture Yes/No Judgement Audio Alone (PYNJAA)
Picture Yes/No Judgement Audiovisual (PYNJAV)

The only exception was the contrast /f/-/p/. One of the participants had difficulty with this contrast, consistently realising /f/ as [p]. The Rees Coleman PIDS procedure did not include tests for this contrast and so non-computerised live speech tests were designed specifically for this contrast following all the principles employed in the computerised procedure. Details of stimuli used in this series of tests are in Appendix --.

Naming Tasks

Ten naming tasks were designed to elicit the target consonants (i.e. those that were realised incorrectly). Words chosen for the naming tasks included only those judged to be in the vocabulary of children under 11 years. This meant that for some targets (e.g. /sn/) there were fewer words as there are not many words beginning with this cluster that would be in the lexicon of an 11-year-old child. The words elicited for each of the target consonants were:

1. /s/: sacks, sad, saddle, salad, salute, sand, sea, secret, seesaw, soldier, soup, sucking, sewing, Sumo, sun, supermarket, sword, six, seven, second, safe
2. /sm/: smack, small, smart, smash, smelling, smelly, smiling, smock, smoke, smooth, smuggle
3. /sp/: spaceman, spade, spaghetti, Spain, sparkler, spear, spell, spider, spilt, spinning, spinach, spitting, sponge, spoon, spot, spy, spaniel
4. /sw/: swallow, swan, swarm, swear, Sweden, sweeping, sweets, swimming, swollen, swerving, swing, switch, Switzerland

5. /sn/: snack, snail, snake, sneak, sneezing, sniffing, snooze, snow, snap
6. /st/: stable, stadium, stairs, stamp, standing, stapler, star, staring, starfish, station, steam, steep, stem, steering, stereo, stick, sting, stink, stirring, stitches, stomach, stones, stool, stop, storm, storytime
7. /sk/: scar, scared, scarecrow, scarf, school, scooter, score, Scotland, scout, skateboard, skeleton, sketching, skiing, skipping, skirt, skull, sculpture, sky
8. /ʃ/: shadow, shake, shallow, shampoo, shapes, sharing, sharp, shaving, shed, sheets, shelf, shield, shining, shirt, ship, shock, shoes, shooting, shop, shorts, shoulder, shower, shut, shutters, shuttlecock, shy
9. /tʃ/: chair, champion, change, cheap, cheese, chess, chicken, children, chimney, chimpanzee, Chinese, chips, chocolate, choking, choosing, chopping, church
10. /f/: face, fairy, falling, family, fast, fat, fighting, full, finger, film, fire, fish, fist, five, flag, float, flowers, flying, football, field, friends.

Each word was illustrated by a clear colour picture downloaded from www.clipart.com on to a blank A4 page and there were between 5 to 15 pictures spaced out on each page (see Appendix 2 for an example). The tester pointed to each picture in turn and asked the child to name it. If the child produced a different word or seemed confused the tester made one or two attempts to elicit the word (without producing it). These attempts usually involved a "gap fill" cue. For example, the picture illustrating *shut* showed a boy peering into a shop window that was dark. If the child said "shop" the tester would say "the boy is disappointed because the shop is -----" and, if the child replied "closed", the tester would say "what is another word for closed?" If, after two attempts at eliciting the word with cues or questions, the child still did not say the word, it was marked as unknown.

Each participant completed the relevant tasks for the target consonants that they had realised incorrectly in the PETAL naming test (Parker, 1999). Their responses were phonetically transcribed and video recorded with a Panasonic VHS-C movie camera (model number: RZ15).

Time 2:

Naming Tasks

The naming tasks conducted at Time 1 were repeated. All were video recorded and the responses were transcribed phonetically.

Letter Knowledge Task

In order to inform intervention and to explore what strategies the children may have been using to update motor programs, each participant was tested on letter name and letter sound knowledge. Each was shown all of the written consonants in turn and asked "What's the name of this letter/this one?" and then "How does it sound?". All the child's responses were transcribed phonetically.

Intelligibility / Motivation Questionnaire

Each participant was asked to complete a questionnaire concerning their speech intelligibility and its consequences and their desire to make changes in their speech production (see Appendix 7).

Time 3:

Input Tasks

Any input tasks from the Rees Coleman procedure that indicated chance performance at Time 1 were repeated.

Naming Tasks

The naming tasks conducted at Time 1 and Time 2 were repeated. All were video recorded and the responses were transcribed phonetically.

Sentence Repetition Tasks

In order to see if there had been any generalisation of any newly acquired speech skills to another task, sentence repetition was tested at Times 3 and 4. A selection of 5 words used in each of the naming tasks was used in a series of specifically designed sentence repetition tasks. For example in the naming task eliciting /ʃ/. the following words were used in the sentence repetition task: *sharp, ship, shoes, shop, shy*. The sentences for this group of words were: The knife is *sharp*. The *ship* has hit ice. The *shoes* are new. The *shop* is closed. The elephant is *shy*. All the sentences were between four and eight words. For a full list of the sentences see Appendix 3. Pictures to illustrate each of the sentences were downloaded from www.clipart.com and on to a blank A4 page and there were between1 to 5 pictures spaced out on each page (see Appendix 4 for an example). The tester explained to the child that they had to repeat some sentences. She pointed to each picture in turn, waited until the child looked up at her and then said the sentence. For the two participants who used signing in their schools, the content words of the sentence were signed simultaneously with speech. When the child had repeated the sentence the target word in the sentence was transcribed phonetically. All the tasks were video recorded.

Intelligibility / Motivation Questionnaire

Each participant was asked to complete the questionnaire concerning their speech intelligibility and its consequences and their desire to make changes in their speech production (see Appendix 7).

Time 4:

Naming Tasks

The naming tasks conducted at Times 2 and 3 were repeated.

Sentence Repetition Tasks

The sentence repetition tasks conducted at Time 3 were repeated.

Both sets of tasks were video recorded and the responses were transcribed phonetically.

Transcription and Coding

In order to check transcriptions done at the time of recordings the author of this study played back all the video tapes, checked all the transcriptions and made any necessary amendments. The Rees Rating Scale was developed in order to code the realisations of the target consonants. This was done due to the clinical observation that deaf children often progress from not producing a target correctly to producing closer though still inaccurate realisations. This observation was also reported by Ertmer and Maki (2000) who developed a 3 point rating scale for realisations of /t/ words and /m/ words for an intervention study.

The Rees Rating Scale, shown in Table 21, has four ratings and the criteria and examples relate to the consonants targeted in intervention. As with the Etmer and Maki (2000) rating codes, some have several alternative criteria based on typical inaccurate realisations and the progression from one rating to the next is influenced by how intelligible the realisation is likely to be. The scale was developed by Rees in discussion with phoneticians at UCL and other speech and language therapists specialising in deafness.

Rating	Description	Examples
1	target consonant is omitted or realised as plosive or frictionless continuant	/s/ → [d] [t] /tʃ/ → [d] /ʃ/ → [j]
2	realisation includes a fricative element (including audible nasal friction) but some other aspect of manner of target consonant is incorrect OR For /s/ clusters the /s/ is omitted but audible nasal friction accompanies the realisation of the second consonant OR realisation is within the phonemic category of the target consonant but is produced with an additional consonant OR For /s/ clusters the /s/ realisation is within the phonemic category but the second consonant is omitted OR (for /s/,/ʃ/,/tʃ/, /dʒ/): realisation has the manner of the target consonant but a different part of the tongue is used for the friction (i.e. dorsal as opposed to coronal) OR combinations	/s/ → [n̥] /s/ → [kx] /tʃ/ → [ʃ] [ʔʃ] /ʃ/ → [tʃ] /sw/ → [w̥] /s/ → [sᶴ t] /ʃ/ → [ʃd] [sʃ] [ʃj] /sn/ → [s̪] /s/ → [x] [ç] [ɕ] [h] /ʃ/ → [x] [ç] [ɕ] [h] /ʃ/ → [xj] /s/ → [cç]
3	(for /s/,/ʃ/,/tʃ/, /dʒ/): realisation has the manner of the target consonant and the correct part of the tongue is used for the friction but the place of articulation is not exact enough for the realisation to be perceived within the phonemic category of the target consonant (for /f/): realisation has the manner of the target consonant but the place is bilabial rather than labio-dental OR realisation has the same place and manner as the target consonant but incorrect voicing OR realisation is within the phonemic category of the target consonant but there is a pause between the realisation and the following phoneme OR combinations	/s/ → [ʃ] [ʃˢ] [ɬ] /ʃ/ → [s] [sᶴ] [s̪] [ʃ̪] /f/ → [ɸ] /tʃ/ → [dʒ] /tʃɪp/→[tʃ-ɪp] /tʃ/ → [dʒ-ɪp]
4	realisation is within the phonemic category of the target consonant (and so does not cross a phoneme boundary into a possible alternative phoneme in English)	/s/ → [s] [sᶴ] [s̪] [s̝] [ṣ] /ʃ/ → [ʃ], [ʃˢ] [ʃ̪] [ʃ̣]

Table 21 Rees Rating Scale for target consonants: f, s,ʃ,tʃ, dʒ:

A second transcriber and rater, AS, was employed to check inter-rater listener reliability. AS was a newly qualified speech and language therapist with some experience of transcribing the speech of deaf children. She received two one-hour training sessions in transcription of deaf children's speech from the author. These sessions included a description of the way in which some deaf children typically realise fricatives and affricates with transcription practice from live models produced by the author.

AS checked at least 10% of the transcribed words in each set of naming and sentence repetition tasks for each child at each time point. She was aware of the participant and of the target words, as both were evident on the video-recordings, but was unaware of the time point as all the videotapes were relabelled with codes.

For this check three words were selected from each naming task (i.e. 3 words eliciting /s/, 3 words eliciting /sm/ etc) and two words were selected from each sentence repetition task. The selection of words chosen from each task was guided by the following criteria:

- known by all three participants at all times,
- wherever possible, containing a vowel that was different to the vowels in the other words selected.

For example, for the naming task eliciting words beginning with /st/, the following words were selected: *stamp, star, station*.

The same set of selected words was checked for each participant at each time point. For each set, AS was asked to transcribe the whole word and then to code the target consonant/s using the Rees Rating Scale.

For each set of naming tasks and sentence repetition tasks completed at each time point with each participant, the rating codes assigned by AS were compared with the codes assigned by Rees using Cohen's Kappa (Cohen, 1960). Kappa is frequently used to measure agreement when observers are asked to use more than two categories (Pring, 2005). Kappa values obtained were as follows:

Participant	Time 1	Time 2		Time 3		Time 4	
	Naming	Naming	Sentence Repetition	Naming	Sentence Repetition	Naming	Sentence Repetition
DA	0.65	0.78	0.87	0.53	#(100%)	1	#(94%)
JB	0.69	0.79	0.84	0.51	0.83	0.78	0.87
MC	0.80	0.82	0.66	0.93	0.50	0.79	0.60

(#It was not possible to calculate Cohen's Kappa values for these tests as one or both assessors chose the same rating for every response. Therefore % agreements are given.)

Table 22 Phase 1: Cohen's Kappa values for each set of tasks at each time with each participant

Fleiss (1981) suggested that Kappa values between 0.4 and 0.6 are fair, those between 0.6 and 0.75 are good and those above 0.75 are excellent. No values were less than 0.5 and the majority were above 0.75. The original ratings were used for the analysis as Rees had the advantage of transcribing at the time of recordings (as well as checking from tape) and was the more experienced transcriber.

Intervention Programme

Aims of the intervention study are stated at the start of the chapter.

The therapy techniques and programme are described in detail in Chapter 3.

Intervention focused on improving the participants' ability to discriminate the target contrasts (e.g. /sm/-/m/) and their ability to produce the target consonant or cluster (e.g. /sm/) in single words.

Each of the three participants received 10 to 11 hours of individual therapy spaced out over six weeks in sessions of 45 minutes or an hour between Time 2 and 3. Because of cancellations, two participants (JB and MC) sometimes received two sessions in one day (with at least a 20 minute break separating them). JB received five double sessions and MC two. Between Time 1 and 2 they received speech and language therapy from the therapist based at their school on aspects of communication other than speech. The summer vacation fell between Time 3 and 4 and so the participants received no speech and language therapy during this time interval.

All intervention sessions with all three participants were conducted by the same therapist (Rees) in a quiet room in the child's school.
Each session began with checking that the child's hearing aids were functioning well and a few minutes of greeting and general conversation.

For each child, the target consonants were split into groups according to evidence of input skills. An equal amount of intervention time was spent on each group. The same therapy techniques were used with each group of consonants but the time spent on each technique varied as this depended on how the child was responding. Adapting methods according to a child's responses is a part of routine clinical intervention.

For each participant, the known words from each naming task were divided into two phonetically balanced groups and words from only one of the groups were used and practised in the intervention sessions. If the children were updating motor programs on a word by word basis it would be expected that words used in therapy would improve significantly and the other group would not. Conversely, if the child was using the strategy of updating the motor pattern for a consonant or consonant cluster and associating this with a sound and/or written letter/s it is more likely that there would be transfer to the words not used in therapy. For example, if the child learnt to produce /tʃ/ successfully and associated it with the written letters "ch" then you may expect the child to transfer the use of this sound to words not used in therapy that began with "ch".

If the state of the lexical representations of words before therapy was interfering with accurate production of the word, it may be easier for the child to incorporate a newly learnt motor pattern into a new word that would have no previously stored representation. To test out this possibility a selection of the unknown words identified at the naming task at T1 was taught to the child to investigate whether the child's production of these words improved more than the previously known words. This selection was guided by asking teachers which words would be most useful to teach and trying to ensure the words represented a range of different consonants / consonant clusters.

Research Questions concerning Outcomes of Intervention

1. For consonants not produced accurately in naming, will any significant improvements be determined by initial input skills?
2. Will any significant improvements in the production of target consonants occur for non-therapy as well as therapy words?

3. Will any significant improvements in the production of target consonants occur in sentence repetition tasks as well as naming tasks?

Summary

This chapter outlined the aims, design and methods of Phase 1 of the intervention study. Background information was provided on the three single cases in this study. The intervention programme within each case study aimed to investigate whether input skills for target consonants not produced accurately in naming would facilitate the specification of those consonants in motor programs, both for words used in therapy and words not used in therapy. The production of target consonants was to be tested in naming tasks for therapy and non-therapy words at four time points that were approximately six weeks apart. The participants would receive intervention for the therapy words between Time 2 and 3 and no intervention would be given in the other two intervals. Chapter 5 outlines the results for each participant.

Chapter 5: Results of Phase 1

This chapter outlines the results of Phase 1 of the intervention study. The previous chapter outlined the aims, design and methods of the study. The results for each of the three participants are presented in turn. A final summary highlights the important findings and makes some comparisons between the participants.

Participant DA

Input Tests at T1 (before intervention)

Consonant contrasts identified as being problematic for DA by the PETAL naming tasks (Parker, 1999) were profiled with selected tests from the Rees Coleman procedure. For each of these contrasts the following input tests were completed:
PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual
For most consonant contrasts the Picture Yes/No Judgement tasks (in both conditions) used pictures of two words beginning with the first consonant/s in the pair (e.g. pictures of *smile* and *smoke* to test the /sm/ - /m/ contrast) as the first consonant/s tended to be realised as the second in the pair (e.g. /sm/ → /m/). The /ʃ/-/tʃ/ contrast was tested differently as, in this case, participants had difficulty realising both phonemes in the pair, realising /ʃ/ as [tʃ] or another sound and realising /tʃ/ as [ʃ] or another sound. Therefore two Picture Yes/No Judgement tasks were completed in both conditions: one using pictures of words beginning with /ʃ/ (*shoe, ship*) and one with pictures of words beginning with /tʃ/ (*chair, chip*).

The nonword stimuli were matched to the words in the PYNJ tasks (e.g. for the /sm/ - /m/ contrasts /smɔl/ was matched to *smile* and /smɔɪk/ was matched to *smoke*). Details of all the stimuli are in Appendix 1.

Table 23 shows the raw scores for all the tests for each contrast (C). Scores for “right” or “same” items judged correctly (R/S) and scores for “wrong” or “different” items judged correctly (W/D) are included as well as total scores (T) for each test. The probability of each total score occurring by chance (*p* value) was calculated using a binomial table (Siegal & Castellan, 1998).

C	PYNJAA				PYNJAV				NWDAA				NWDAV			
	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value
s/d	6/8	1/8	7/16	.773	8/8	3/8	11/16	.105	7/8	3/8	10/16	.227	8/8	3/8	11/16	.105
sp/b	6/8	2/8	8/16	.598	8/8	8/8	16/16	**<.002**	8/8	3/8	11/16	.105	8/8	7/8	15/16	**<.002**
sm/m	6/8	3/8	9/16	.402	8/8	8/8	16/16	**<.002**	8/8	4/8	13/16	**.011**	8/8	7/8	15/16	**<.002**
sw/w	6/8	8/8	14/16	**<.002**	8/8	8/8	16/16	**<.002**	8/8	6/8	14/16	**<.002**	7/8	8/8	15/16	**<.002**
st/d	6/8	2/8	8/16	.598	8/8	2/8	10/16	.227	6/8	3/8	9/16	.402	8/8	1/8	9/16	.402
sn/n	8/8	6/8	14/16	**<.002**	6/8	7/8	13/16	**.011**	8/8	6/8	14/16	**<.002**	8/8	7/8	15/16	**<.002**
sk/g	8/8	2/8	10/16	.227	8/8	6/8	14/16	**<.002**	7/8	2/8	10/16	.227	8/8	5/8	13/16	**.011**
ʃ/tʃ:ʃ	6/8	1/8	7/16	.773	8/8	0/8	8/16	.598	8/8	3/8	11/16	.105	7/8	3/8	10/16	.227
ʃ/tʃ;tʃ	7/8	3/8	10/16	.227	8/8	0/8	8/16	.598								

C = Contrast
PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual
R/S = Scores for “right” or “same” judged correctly
W/D = Scores for “wrong” or “different” judged correctly
T = Total Score
p value= Probability of score occurring by chance (and emboldened numbers indicate those that are less than alpha of 0.05)

Table 23 DA: Raw scores and probabilities of chance for all input tests before intervention

Looking at the results overall, there is a bias for DA to judge that items match, choosing "yes" or "same" in the PYNJ tasks and the nonword discrimination tasks respectively. This pattern is likely for a child who has difficulty in judging that items do not match. Overcoming this bias in choosing "no" or "different" for the items that do not match indicates success in discriminating the contrast tested.

The columns headed R/S and W/D show a marked difference between the scores where "yes" or "same" was the correct response and the scores where "yes" or "same" was the incorrect response. When "yes" or "same" was the correct response (see columns headed R/S) scores ranged from 6/8 to 8/8 (23% were 6/8, 15% were 7/8 and 62% of these scores were 8/8). This is expected as, if a child had difficulty in discriminating a contrast, they are still likely to produce this response for the items that are identical. However when "yes" or "same" was the incorrect response (see columns headed W/D) scores ranged widely (from 0/8 to 8/8). These are the items where difficulty is expected as, if a child had difficulty in discriminating a contrast, they are likely to have problems in judging whether items are different. Where probabilities of the total scores occurring by chance were 0.05 or less, scores also ranged from 6/8 to 8/8 (and so all or the great majority of responses were "no" or "different"). However, for the remaining tests, scores ranged from 0/8 to 4/8. These lower scores indicate difficulties with discriminating the contrast being tested. Therefore the total scores related to above chance performance were taken as evidence of input skills.
Based on the results the contrasts were divided into the following input groups:

None: No evidence of input skills : /s/-/d/, /st/-/d/, /ʃ/-/tʃ/. For these contrasts the probability of the scores occurring by chance was greater than 0.05 for all input tests. This implies that DA cannot discriminate these contrasts in the audio-visual or auditory alone conditions whether taking a lexical or non-lexical route.

Audio-Visual Only: Evidence of audio-visual input skills (but not auditory-alone) for PYNJ and NWD: /sp/-/b, /sk/-/g/. For these contrasts the probability of the scores occurring by chance was less than 0.05 for the audio-visual versions of the PYNJ and NWD tests, but greater than 0.05 for the audio-alone versions of these tests. This implies that DA can only discriminate these contrasts in the audio-visual condition but can do so for both lexical and non-lexical routes.

Auditory – Nonwords Only: Evidence of audio-visual input skills for PYNJ and NWD and auditory input skills but for NWD only: /sm/-/m/. For this contrast the probability of the scores occurring by chance was less than 0.05 for both audio-visual versions of the PYNJ and NWD *and* the audio-alone version of the NWD, but greater than 0.05 for the audio-alone version of the PYNJ test. This implies that, as well as discriminating the contrast in the audio-visual condition, DA can also discriminate it in the audio-alone condition, but only if he is taking a non-lexical route.

Auditory – Full: Evidence of audio-visual input skills for PYNJ and NWD and auditory input skills for Picture Yes/No Judgement (PYNJ) and Nonword Discrimination (NWD): /sw/-/w/, /sn/-/n/. For these contrasts the probability of the scores occurring by chance was less than 0.05 for all input tests. This implies that, as well as discriminating the contrasts in the audio-visual condition, DA can also discriminate them in the audio-alone condition, for both lexical and non-lexical routes.

Input Tests at T3 (after intervention)

Each input test conducted at T1 where DA had performed at chance was repeated. The results of the repeated tests are shown in the following table that shows the raw scores for the tests for each contrast (C):

C	PYNJAA				PYNJAV				NWDAA				NWDAV			
	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	SR/S	W/D	T	*p* value	R/S	W/D	T	*p* value
s/d	6/8	1/8	7/16	.773	7/8	2/8	9/16	.402	7/8	3/8	10/16	.227	7/8	4/8	11/ 16	.105
sp/b	6/8	4/8	10/16	.227					7/8	3/8	10/16	.227				
sm/m	8/8	5/8	13/16	**.011**												
sw/w																
st/d	7/8	2/8	9/16	.402	8/8	4/8	12/16	**.038**	6/8	3/8	9/16	.402	Not completed			
sn/n																
sk/g	8/8	6/8	14/16	**.002**					8/8	7/8	15/16	**<.002**				
ʃ/tʃːʃ	8/8	0/8	8/16	.598	7/8	1/8	8/16	.598	8/8	2/8	10/16	.227	8/8	3/8	11/16	.105
ʃ/tʃ;tʃ	5/8	0/8	5/16	.962	8/8	0/8	8/16	.598								

C =Contrast
PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual
R/S = Scores for “right” or “same” judged correctly
W/D = Scores for “wrong” or “different” judged correctly
T = Total Score
p value= Probability of score occurring by chance (and emboldened numbers indicate those that are less than alpha of 0.05)

Table 24 DA: Raw scores and probabilities of chance for all input tests after intervention

Performance on the following tests had changed from being at chance level before intervention to being above chance level after intervention:

Picture Yes/No Judgment Auditory-Alone for /sm/ - /m/

Picture Yes/No Judgement Audio-Visual for /st/-/d/

Picture Yes/No Judgement for Audio-alone and Nonword Same/Different Discrimination for sk/g

Performance on other tests that were at chance level before intervention remained at chance.

Naming Data:

At lease nine pictures of different words were used to elicit each of the target consonants in word initial position. Transcriptions of the target consonants for all the naming responses in the four assessments conducted at four different time points were rated using the Rees Rating Scale, as described in Chapter 4. The ratings are summarised here as follows:

The lowest rating (1) was given when the target consonant was omitted or realised as a plosive ("omit/plosive"). The middle ratings (2 and 3) were given when the realisations of the target consonants were progressively closer to the target consonant ("some friction" and "close"). The highest rating (4) was given when the realisation was within the phonemic category of the target consonant ("on target").
Naming responses used for comparison across time points were those that occurred at each of the four time points.
The following figure illustrates the change in ratings over the four time points.

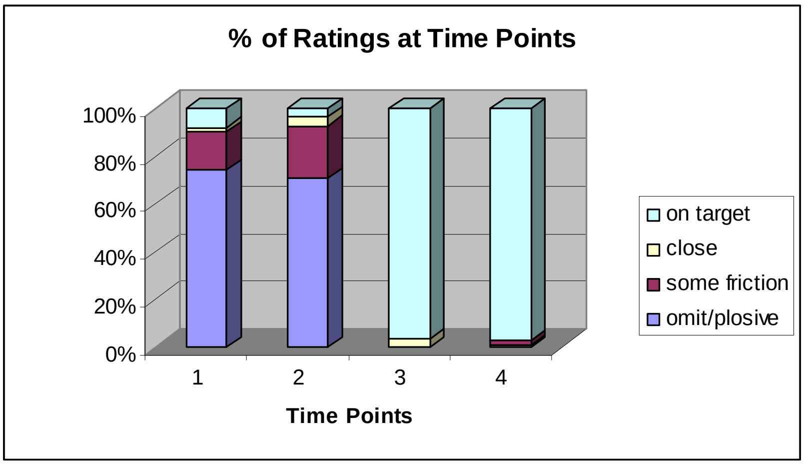


Figure 3 DA: Percentage of ratings at each time point

The ratings of target consonants in DA's responses were compared across the four time points using the Friedman test. Results showed a significant difference (X^2 (3, N = 136) = 359.894, p <.001)

Therefore the Wilcoxon test (see Table 25) was used to measure any significant improvements in ratings during the following intervals:

Time 1 to Time 2 (T1-T2) (no intervention period prior to intervention)

Time 2 to Time 3 (T2-T3) (intervention period)

Time 3 to Time 4 (T3-T4) (no intervention period following intervention)

As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	*N*	*z* value	*p* value
T1-T2	136	-0.607	0.544
T2-T3	136	-10.448	**<0.001**
T3-T4	136	-0.908	0.364

Table 25 DA: Wilcoxon test comparing changes in ratings of consonant realisations for the three time intervals

There were no significant improvements for T1-T2 or for T3-T4 . However there was a significant improvement in ratings during the intervention period, T2-T3.

In order to see whether evidence of input skills relating to target consonants prior to intervention had influenced changes in the ratings of their production, the data were split into the input groups (None, Audio-Visual Only, Auditory-Nonwords Only and Auditory Full). For example, for the contrast /st/-/d/ there was no evidence of input skills prior to intervention in either the audio or audio-visual conditions. Therefore all words eliciting the cluster /st/ were placed in Group 1 (None). For the contrast /sw/-/w/, DA showed evidence of auditory input skills for Picture Yes/No Judgement (PYNJ) and Nonword Discrimination (NWD). Therefore all words eliciting the cluster /sw/ were placed in Group 4 (Auditory Full). See Table 26 for details of how the data were divided.

Group Number	Input Group	Target Consonants in Group	Number of Words in Naming Test in Group
1	None	/s/, /st/, /ʃ/, /tʃ/	82
2	Audio-Visual Only	/sp/, /sk/	31
3	Auditory-Nonwords Only	/sm/	6
4	Auditory Full	/sw/, /sn/	17

Table 26 DA: Description of input groups

The number of items in each group reflects not only the number of consonants in the group but also the number of words used to elicit the consonants. As explained in Chapter 4, the numbers of words in a child's vocabulary that begin with particular consonants or clusters vary. For example, there are many words that begin with /s/ followed by a vowel and not many words that begin with /sm/ followed by a vowel.

The following figure illustrates the change in ratings over the four time points for each of the different input groups.

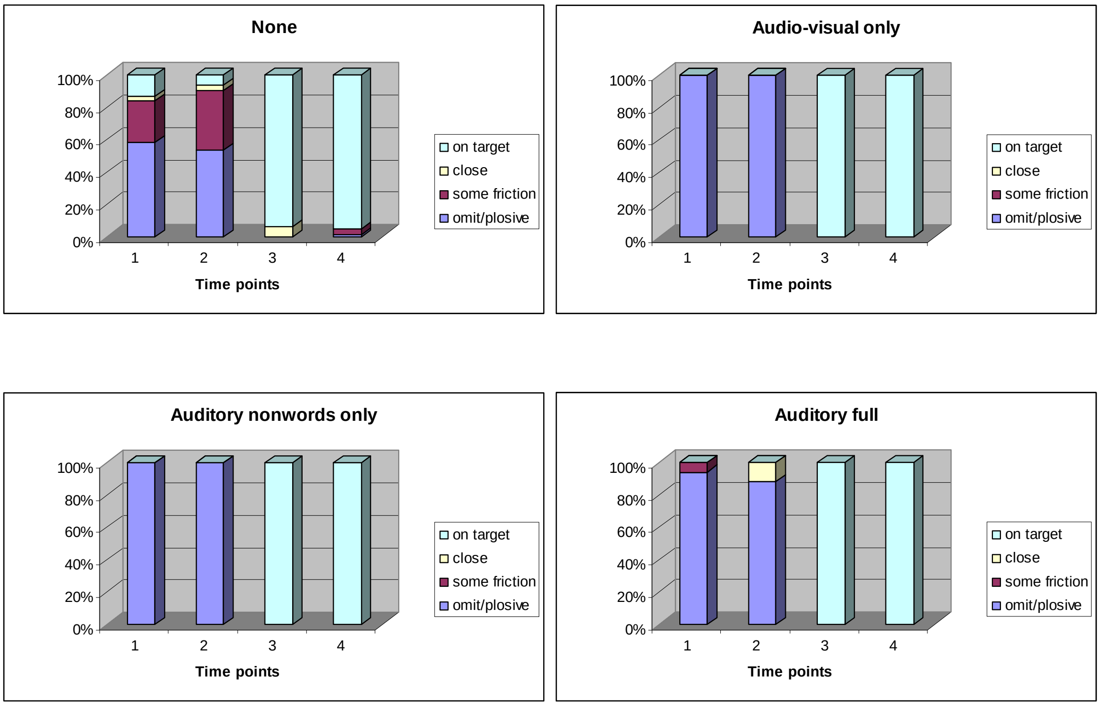


Figure 4 DA: Percentage of ratings at each time point for the four input groups

The Friedman test revealed that there were significant effects across time points for every input group (see Table 27).

Input Type	*n*	X^2	d.f.	*p* value
None	82	199.830	3	**<.001**
Audio-Visual Only	31	93	3	**<.001**
Auditory-Nonwords Only	6	18	3	**<.001**
Auditory Full	17	49.921	3	**<.001**

Table 27 DA: Friedman test comparing ratings of consonant realisations for each input group across the four time points:

Because all the results were significant a Wilcoxon test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for all the input skills groups (see Table 28). As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*z* value	*p* value
T1-T2	None	82	-1.033	.302
	Audio-Visual Only	31	0.000	1.000
	Auditory-Nonwords Only	6	0.000	1.000
	Auditory Full	17	-1.089	.276
T2-T3	None	82	-7.836	**<.001**
	Audio-Visual Only	31	-5.568	**<.001**
	Auditory-Nonwords Only	6	-2.449	**.014**
	Auditory Full	17	-3.945	**<.001**
T3-T4	None	82	-0.908	.364
	Audio-Visual Only	31	-5.568	1.000
	Auditory-Nonwords Only	6	-2.449	1.000
	Auditory Full	17	-3.945	1.000

Table 28 DA: Wilcoxon test comparing changes in ratings of consonant realisations for the three time intervals for each input group

All the significant improvements in ratings of target consonants occurred during the intervention period (T2-T3) for all the input groups. The input group did not influence whether significant improvements were made to the ratings.

In order to see whether any changes in the ratings of the target consonants were influenced by whether the particular words containing them had been used in intervention, the whole data set was split into the following word groups:

Therapy: words used in intervention

No Therapy: words not used in intervention.

Figure 5 shows the change in ratings over the 4 time points for the Therapy and No Therapy groups.

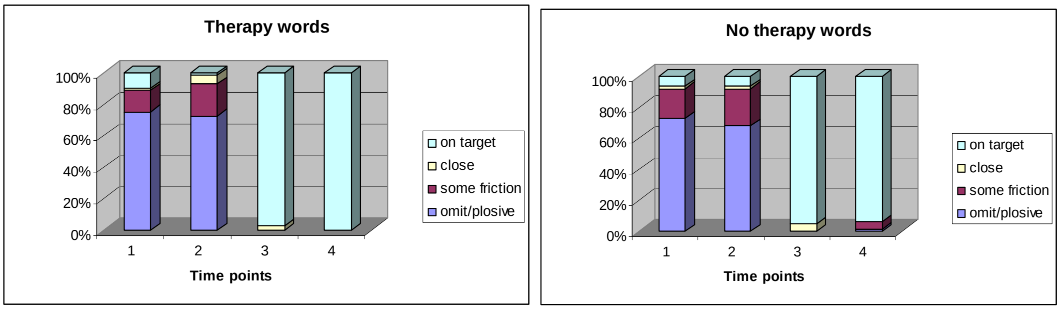


Figure 5 DA: Percentage of ratings over time points for the therapy and no therapy groups

The Friedman test revealed that there were significant effects across time points for both word groups (see table 29).

Word Group	*n*	*X*²	d.f.	*p* value
Therapy	73	196.666	3	**<.001**
No Therapy	63	163.548	3	**<.001**

Table 29 DA: Friedman test comparing ratings of consonant realisations for each word group across the four time points

Because the results for both groups were significant a Wilcoxon test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the words used in intervention and those not used in intervention (see Table 30). As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Therapy vs No Therapy	*n*	*z* value	*p* value
T1-T2	Therapy	73	-1.152	.249
	No Therapy	63	-4.84	.628
T2-T3	Therapy	73	-7.749	**<.001**
	No Therapy	63	-7.027	**<.001**
T3-T4	Therapy	73	-1.414	.157
	No Therapy	63	-1.372	.170

Table 30 DA: Wilcoxon test comparing changes in ratings of consonant realisations for the three time intervals for each word group

All the significant improvements in ratings of target consonants occurred during the intervention period (T2-T3) for both sets of words. Whether words containing the target consonants had been used in intervention did not influence whether significant improvements were made to the ratings of those consonants.

In order to see whether the same groups (input groups and therapy/no therapy groups) influenced DA achieving a “correct” target sound (as opposed to an improved realisation), all the realisations were then scored as “incorrect” or “correct” as opposed to being rated. A “correct” realisation was one within the phonemic category of the target phoneme that did not cross a phoneme boundary into a possible alternative phoneme of English. All other kinds of realisations were categorised as “incorrect”.

McNemar tests were used to measure any significant changes during the time intervals. (For details of the results see Appendix 14). All the significant changes took place during T2-T3 (the intervention period) for all but one of the input groups and both the “Therapy” and “No Therapy” groups. The group for which there was no significant change during the intervention period was for the “Auditory – Nonwords Only” group. However, this may have been due to lack of power. There were only 6 items in this group and all showed improvement from “omit/plosive” at T2 to “on target” at T3, but the p level of 0.031 fell short of the significance level of 0.0167 (adjusted with the Bonferroni correction).

Sentence Repetition Data

In order to see whether DA found it more difficult to use the target consonants when repeating sentences, ratings in the naming task at T2 were compared with ratings in the sentence repetition task at T2 using the Wilcoxon test. (As sentence repetition was not assessed at T1 this comparison had to be made at T2). There was no significant difference (N = 43, z = -1.633, p = 0.102).

In order to see whether there were changes in ratings for the sentence repetition tasks across time, the ratings of target consonants in DA’s responses to these tasks were compared across time points T2, T3 and T4 using the Friedman and Wilcoxon tests. In order to see whether the input groups influenced any changes in the ratings the Freidman and Wilcoxon tests were used. (For details of all these results, see Appendix 14).

All the significant improvements took place during T2-T3 (the intervention period) for all but one of the input groups. The group in which there was no significant change during the intervention period was for the “Auditory – Nonwords Only” group. However, this may have been due to lack of power. As a small selection of words was used for the sentence repetition test there were only four items in this input group and all four showed improvement from "omit/plosive" at T2 to "on target" at T3, but the *p* level of 0.046 fell short of the significance level of 0.0167 (adjusted with the Bonferroni correction).

Unknown and Taught Words

The naming test designed for this study had 158 items judged to be in the vocabulary of children under 11 years of age. During the assessment at T1, 137 of these items elicited a naming response. All but one of these items easily elicited a naming response at each time point. The exception was *snap* which was elicited successfully at all time points except T4. The remaining 136 items were used for statistical analysis previously reported. At T1 21 items were not named. Responses to these items are shown in Table 31.

Taught/Not Taught	Word	Ratings of Target Consonant/s in Word at Different Time Points (NR = no response)			
		T1	T2	T3	T4
Taught	secret	NR	NR	4	4
	smart	NR	NR	4	4
	smuggle	NR	NR	4	4
	spear	NR	NR	4	4
	spaniel	NR	NR	4	4
	swarm	NR	NR	4	4
	swerving	NR	NR	4	4
	snooze	NR	NR	4	4
	stable	NR	NR	4	4
	stadium	NR	NR	4	4
	steering	NR	NR	4	4
	stereo	NR	NR	4	4
	shutters	NR	NR	3	4
Not Taught	saddle	NR	1	4	2
	salute	NR	NR	NR	NR
	smack	NR	1	4	4
	smash	NR	1	4	4
	smock	NR	NR	NR	NR
	Switzerland	NR	1	4	4
	sketch	NR	NR	4	4
	scout	NR	NR	NR	NR

Table 31 DA: Responses to word items not named at T1 across time points.

As shown in this table, 13 of the 21 words not known at T1 were taught to DA during the intervention period. These unknown words represented a range of the consonant / consonant clusters and the selection was also based on teachers' comments on which would be the most useful words for DA to learn. All these items were also unknown at T2 but named correctly at T3 and T4. The target consonants in these responses were rated with the Rees Rating Scale. All the realisations were rated as 4 (on target), except for the realisation of /ʃ/ in the word *shutters* rated as 3 (close) for T3.

Five of the eight unknown untaught words also showed improvement over time. Four were named correctly at T2 (with target consonant ratings of 1 (omit/plosive)) and named correctly at T3 (with consonant ratings of 4 (on target)). Of these four, all the ratings of target consonants remained at 4 at T4 except for the realisation of /s/ in the word *saddle* which had changed to a rating of 2 (some friction). The remaining three unknown untaught words (*salute, smock* and *scout*) remained unknown at T4.

Letter Knowledge Task

The complete set of results of this task are in Appendix 5. DA provided names and sounds for all the written consonants shown to him. He named "s" as [eʔh] gave its sound as [dəʔ]. He gave the sound [çjə] for "sh" and the sound [çʒjə] for "ch".

Response to Intervention

Details of skills that were acquired during each of the ten intervention sessions are outlined in Appendix 6. A summary of these skills follow:

DA began by imitating /s/ as [x]. After successfully learning how to discriminate between these two sounds in the audio-visual condition and receiving explanations of how each sound was produced, DA could imitate /s/ as [s̪]. By the end of the third session he was realising /s/ as [s̪] when producing single words beginning with /s/ clusters in a naming task. At this time he had more difficulty in blending /s/ with a vowel at the beginning of nonwords and words as he would insert [t̄] between /s/ and the vowel. By the fourth session he had successfully learnt to distinguish between *sun* and /stʌn/ in the AV condition and eventually produced a few accurate productions of *sun*. By the fifth session he had learnt to distinguish between *smile* and *mile* in the AA condition and was realising /s/ as [s̪] in all the therapy words but the production of /s/ was sometimes inappropriately long. After we had discussed this he was able to modify his production to an appropriate length. At first DA had difficulty producing a clear difference between /s/ and /ʃ/ but after phonetic instruction and modelling he made a clear difference between the two phonemes and by the end of session 9 he was realising /s/, /ʃ/ and /tʃ/ as sounds that were within the phonemic category of the target consonant at the beginning of nonwords and words. By the end of the last session DA was using these consonants in word initial position consistently in naming tasks and for the majority of the time when retelling stories. However he did not seem to be using his newly acquired speech skills in conversation or outside intervention sessions.

Intelligibility / Motivation Questionnaire

Details of the questions and responses to the intelligibility / motivation questionnaire at T2 (before intervention) and T3 (after intervention) are outlined in Appendix 7. A summary of this follows:

To describe his overall intelligibility DA chose “Most people understand everything I say” at both time points and so his rating of intelligibility did not change. There were no marked changes in how he rated the degree of difficulty of seven speaking situations. Two situations were rated as a little easier at T3, 3 situations were rated as a little more difficult at T3 and the remaining two situations were given the same rating at T2 and T3. In response to “Do you want your speech to be clearer?” DA chose the response “I think so, I don’t mind” at T2. At T3, when asked what he had learnt to do in the speech and language therapy lessons this term, he replied “How to say /s/, /ʃ/ and /tʃ/.

Participant JB

Input Tests at T1 (before intervention)

Consonant contrasts identified as being problematic for JB by the PETAL naming tasks (Parker, 1999) were profiled with selected tests from the Rees Coleman procedure. The only contrast that JB found difficult that was not included in the Rees Coleman procedure was /f/-/p/. Therefore this contrast was tested with live speech following the format of the tests from the computer procedure.

For all the contrasts the following input tests were completed:

PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual

JB: Raw scores and probabilities of chance for all input tests before intervention

C	PYNJAA				PYNJAV				NWDAA				NWDAV			
	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value
f/p*	8/8	8/8	16/16	**<.002**	8/8	8/8	16/16	**<.002**	8/8	3/8	13/16	**.011**	8/8	4/8	12/16	**.038**
s/d	8/8	7/8	15/16	**0.002**	8/8	5/8	13/16	**.011**	8/8	1/8	9/16	.402	8/8	0/8	8/16	.598
sp/b	8/8	0/8	8/16	.598	8/8	1/8	9/16	.402	4/8	3/8	7/16	.773	8/8	1/8	9/16	.402
sm/m	8/8	1/8	9/16	.402	8/8	2/8	10/16	.227	8/8	0/8	8/16	.598	8/8	1/8	9/16	.402
sw/w	7/8	8/8	15/16	**<.002**	8/8	7/8	15/16	**<.002**	8/8	0/8	8/16	.598	7/8	1/8	8/16	.598
st/d	8/8	2/8	10/16	.227	8/8	0/8	8/16	.598	8/8	0/8	8/16	.598	8/8	0/8	8/16	.598
sn/n	7/8	5/8	12/16	.038	8/8	5/8	13/16	**.011**	7/8	3/8	10/16	.227	5/8	3/8	8/16	.598
sk/g	8/8	1/8	9/16	.402	8/8	1/8	9/16	.402	8/8	0/8	8/16	.598	8/8	0/8	8/16	.598
ʃ/tʃːʃ	8/8	0/8	8/16	.598	6/8	1/8	7/16	.773	8/8	0/8	8/16	.598	8/8	0/8	8/16	.598
ʃ/tʃ;tʃ	8/8	0/8	8/16	.598	7/8	0/8	8/16	.598								

* (this test was done live as no computer test available)

C = Contrast

PYNJAA = Picture Yes/No Judgement Audio-alone

PYNJAV = Picture Yes/No Judgement Audio-visual

NWDAA = Nonword Same/Different Discrimination Audio-alone

NWDAV = Nonword Same/Different Discrimination Audio-visual

R/S = Scores for “right” or “same” judged correctly

W/D = Scores for “wrong” or “different” judged correctly

T = Total Score

p value= Probability of score occurring by chance (and emboldened numbers indicate those that are less than alpha of 0.05)

Table 32 JB: Raw scores and probabilities of chance for all input tests before intervention

JB did not perform above a chance level on any of the nonword computer tests and it was observed that during these tests he was not attending well. Therefore the results of these tests were thought to be unreliable and his contrasts were divided into the following two groups based on the results of the PYNJ tests only:

None: No evidence of input skills: /sp/-/b/, /sm/-/m/, st/-/d/, /sk/-/g/, /ʃ/-/tʃ/. For these contrasts the probability of the scores occurring by chance was greater than 0.05 for all input tests. This implies that JB cannot discriminate these contrasts in the audio-visual or auditory alone conditions when taking a lexical route.

Auditory – Full: Evidence of audio-visual input skills and auditory skills for PYNJ: /p/-/f/, /s/-/d/, /sw/-/w/, /sn/-/n/. For these contrasts the probability of the scores occurring by chance was less than 0.05 for both PYNJ input tests. This implies that, as well as discriminating the contrasts in the audio-visual condition, DA can also discriminate them in the audio-alone condition, for the lexical route.

Input Tests at T3 (after intervention)

Each PYNJ input test conducted at T1 where JB had performed at chance was repeated. To check the reliability of the procedure (as JB had failed so many tests) the input tests for /s/-/d/ was repeated. Due to the unreliability of the nonword tests (see above) these were not repeated, except for two (/sm/-/m/, /sw/-/w/ in the auditory alone condition) to see if performances were still at chance. The results of the repeated tests are shown in the following table that shows the raw scores for the tests for each contrast (C):

C	PYNJAA				PYNJAV				NWDAA				NWDAV			
	R/S	W/D	T	p value	R/S	W/D	T	p value	R/S	W/D	T	p value	R/S	W/D	T	p value
s/d	7/8	8/8	15/16	**<.002**	8/8	8/8	16/16	**<.002**								
sp/b	8/8	3/8	11/16	.105	6/8	3/8	9/16	.402								
sm/m	7/8	2/8	9/16	.402	8/8	4/8	12/16	**.038**	7/8	0/8	7/16	.773				
sw/w									8/8	1/8	9/16	.402				
st/d	7/8	4/8	11/16	.105	7/8	4/8	11/16	.105								
sk/g	8/8	0/8	8/16	.598	7/8	1/8	8/16	.598								
ʃ/tʃ:ʃ	8/8	0/8	8/16	.598	8/8	0/8	8/16	.598								
ʃ/tʃ;tʃ	8/8	0/8	8/16	.598	8/8	1/8	9/16	.402								

C = Contrast
PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual
R/S = Scores for “right” or “same” judged correctly
W/D = Scores for “wrong” or “different” judged correctly
T = Total Score
p value= Probability of score occurring by chance (and emboldened numbers indicate those that are less than alpha of 0.05)

Table 33 JB: Raw scores and probabilities of chance for all input tests after intervention

The probability of the score for the Picture Yes/No Judgement task for /sm/-/m/ (audio-visual condition) occurring by chance was less than 0.05. Before intervention performance on this task was at chance level. The difference in the raw scores was not great (10/16 before intervention vs 12/16 after intervention). Performance on all other tests that were at chance level before intervention remained at chance. For the two tests for /s/-/d/ that were completed to check the reliability of the procedure, performances that were above a chance level before intervention remained above chance. Performances on the nonword tests remained at chance.

Naming Data:

As JB had learning difficulties it was decided to restrict the number of contrasts targeted in intervention. The selection of contrasts was based on the input test results and functional use. Therefore it was decided to omit /ʃ/-tʃ/. As this contrast was not targeted it was not elicited in the naming tests at each time point. At least nine pictures of different words were used to elicit each of the target consonants in word initial position. Transcriptions of the target consonants for all the naming responses in the four assessments conducted at four different time points were rated using the Rees Rating Scale, as described in Chapter 4.

Naming responses used for comparison across time points were those that occurred at each of the four time points.

The following figure illustrates the change in ratings over the four time points.

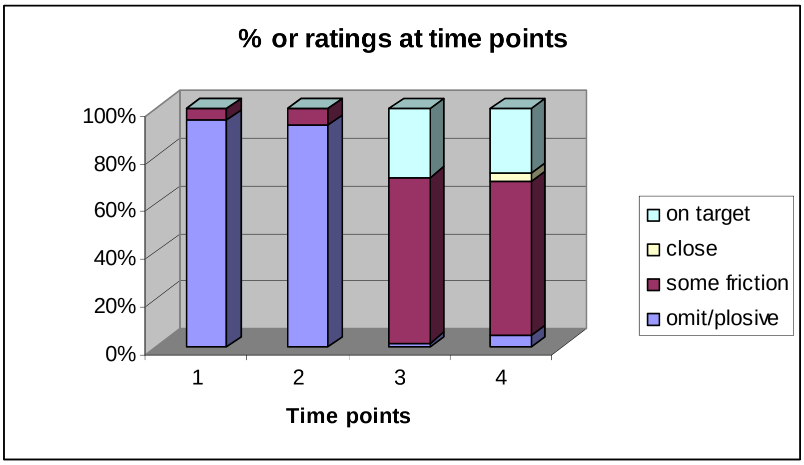


Figure 6 JB: Percentage of ratings at each timepoint

The ratings of target consonants in JB's responses were compared across the four time points using the Friedman test. Results showed a significant difference (X^2 (3, N = 59) = 160.686, p <.001) .

Therefore the Wilcoxon test (see Table 34) was used to measure any significant changes in ratings during the following intervals:

Time 1 to Time 2 (T1-T2) (no intervention period prior to intervention)
Time 2 to Time 3 (T2-T3) (intervention period)
Time 3 to Time 4 (T3-T4) (no therapy period following intervention)

As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	*N*	*z* value	*p* value
T1-T2	59	-1.000	.317
T2-T3	59	-6.812	**<.001**
T3-T4	59	-0.632	.527

Table 34 JB: Wilcoxon test comparing changes in ratings of consonant realisations for the three time intervals

There were no significant improvements for T1-T2 or for T3-T4. However there was a significant improvement in ratings during the intervention period, T2-T3.

In order to see whether evidence of input skills relating to target consonants prior to intervention had influenced changes in the ratings of their production the data were split into the input groups (None and Auditory Full). For example, for the contrast /sp/-/b/ there was no evidence of input skills prior to intervention in either the audio or audio-visual conditions. Therefore all words eliciting the cluster /sp/ were placed in group 1. For the contrast /f/-/p/, JB showed evidence of audio-visual and auditory input skills for Picture Yes/No Judgement (PYNJ). Therefore all words eliciting the cluster f/ were placed in Group 2 (Auditory Full). See Table 35 for details of how the data were divided.

Group Number	Input Group	Target Consonants in Group	Number of Words in Naming Test in Group
1	None	/sp/, /sm, /st/, /sk/	28
2	Auditory Full	/f/, /s/, /sw/, /sn/	31

Table 35 JB: Description of input groups

The number of items in each group reflects not only the number of consonants in the group but also the number of words used to elicit the consonants.

The following figure illustrates the change in ratings over the four time points for each of the input groups.

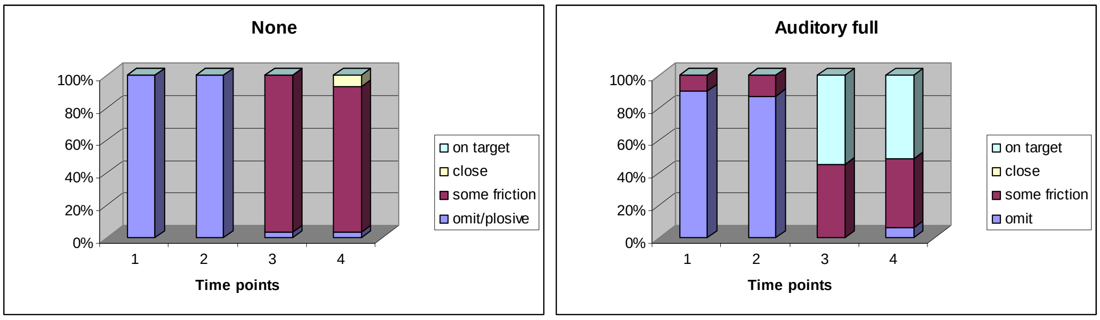


Figure 7 JB: Percentage of ratings at each time point for the two input groups

The Friedman test revealed that there were significant effects across time for both input groups (see Table 36).

Input Type	*n*	X^2	d.f.	*p* value
None	28	75.865	3	**<.001**
Auditory Full	31	82.148	3	**<.001**

Table 36 JB: Friedman test to compare ratings of consonant realisations for each input group across the four input groups

Because all the results were significant a Wilcoxon test was used to measure any significant improvements in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the input skills groups. As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*z* value	*p* value
T1-T2	None	28	0.000	1.000
	Auditory Full	31	-1.000	.317
T2-T3	None	28	-5.196	**<.001**
	Auditory Full	31	-4.824	**<.001**
T3-T4	None	28	-1.000	.317
	Auditory Full	31	-1.633	.102

Table 37 JB: Wilcoxon test to compare changes in ratings of consonant realisations for the three time intervals for each input group

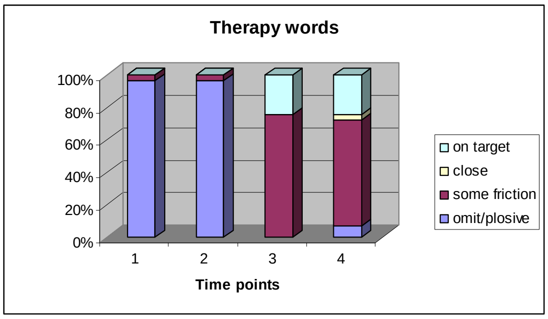
All the significant improvements in ratings of target consonants occurred during the intervention period (T2-T3) for all the input groups. The input group did not influence whether significant improvements were made to the ratings.

In order to see whether any changes in the ratings of the target consonants were influenced by whether the particular words containing them had been used in therapy, the whole data set was split into the following word groups:

Therapy: words used in intervention

No Therapy: words not used in intervention.

Figure 8 shows the change in ratings over the 4 time points for the Therapy and No Therapy groups.



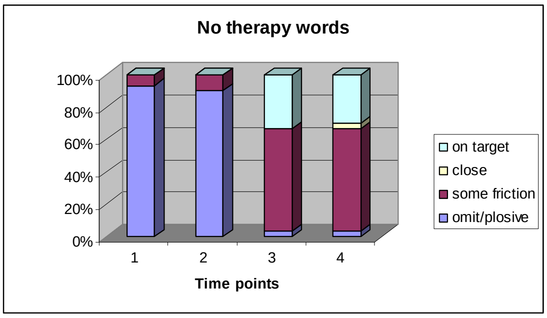


Figure 8 JB: Percentage of ratings over time points for the therapy and no therapy groups

The Friedman test revealed that there were significant effects across time points for both word groups (see Table 38).

Word Group	*n*	X^2	d.f.	*p* value
Therapy	29	76.290	3	**<.001**
No Therapy	30	81.468	3	**<.001**

Table 38 JB: Friedman test comparing ratings of consonant realisations for each word group

Because the results for both groups were significant a Wilcoxon test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the words used in intervention and those not used in intervention (see Table X). As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Therapy vs No Therapy	*n*	*z* value	*p* value
T1-T2	Therapy	29	0.000	1.000
	No Therapy	30	-1.000	.317
T2-T3	Therapy	29	-4.882	**<.001**
	No Therapy	30	-4.789	**<.001**
T3-T4	Therapy	29	-0.577	.564
	No Therapy	30	-0.378	.705

Table 39 JB: Wilcoxon test to comparing changes in ratings of consonant realisations for the three time intervals for each word group

All the significant improvements in ratings of target consonants occurred during the intervention period (T2-T3) for both sets of words. Whether words containing the target consonants had been used in intervention did not influence whether significant improvements were made to the ratings of those consonants.

For JB statistical tests were carried out to see whether patterns were similar if realisations were scored as “incorrect” or “correct”. However, in JB’s case, the “correct” score was only achieved at two of the time points (T3 and T4) for realisations of /f/. Therefore, with this classification, the only significant change that took place during the intervention period was for the “Auditory Full” consonants and this was solely due to the change in the /f/ consonant. (See Appendix 14 for details of these results).

Sentence Repetition Data

In order to see whether JB found it more difficult to use the target consonants when repeating sentences, ratings in the naming task at T2 were compared with ratings in the sentence repetition task at T2 using the Wilcoxon test. There was no significant difference (N = 34, z = -0.000, p= 1.000).

In order to see whether there were changes in ratings for the sentence repetition tasks across time, the ratings of target consonants in JB’s responses to these tasks were compared across time points T2, T3 and T4 using the Friedman test. Results showed no significant differences (X^2 (3, N = 33) = 3.5, p = 0.174). Therefore there were no significant improvements in ratings of target consonants in sentences across the time points T2, T3 or T4.

Unknown and Taught Words

The naming test designed for this study had 136 items (excluding items to elicit /ʃ/-/tʃ/ and including items to elicit /f/-/p/) judged to be in the vocabulary of children of 11 years of age. During the assessment at T1, 62 of these items elicited a naming response. All but three of these items were elicited easily at each time point. These 59 items were used for statistical analysis previously reported. At T1 74 items were not named. Ten of these items were taught and responses to this teaching are shown in Table 40.

Taught/Not Taught	Word	Ratings of Target Consonant/s in Word at Different Time Points (NR = no response)			
		T1	T2	T3	T4
Taught	salad	NR	NR	2	2
	sew	NR	NR	2	2
	sponge	NR	NR	3	2
	switch	NR	NR	2	2
	snack	NR	NR	2	2
	stomach	NR	NR	2	2
	skeleton	NR	NR	2	2
	skull	NR	NR	NR	NR
	fist	NR	NR	4	4
	float	NR	NR	4	4

Table 40 JB: Responses to taught items not named at T1 across time points

As shown in this table, 10 of the 74 words not known at T1 were taught to JB during the intervention period and nine of these were taught successfully. These unknown words represented a range of the consonants / consonant clusters and the selection was also based on teachers' comments on which would be the most useful words for JB to learn. All nine words were also unknown at T2 but named correctly at T3 and T4. The target consonants in these responses were rated with the Rees Rating Scale. Almost all the realisations were rated as 2 (some friction), except for the realisation of /f/ which, for each word, was rated as 4 (on target) at T3 and T4.

For the 64 that were not taught, JB was still unable to name 54 of the items at T2, T3 or T4. For the remaining 10 he had some success at naming at T3 and/or T4. Almost all these realisations were rated as 2 (some friction), except for the two realisations of /f/ which were rated as 4 (on target).

Letter Knowledge Task

The complete set of results of this task are in Appendix 5. JB provided names and sounds for all the written consonants shown to him. He named “f” as [ep˺] and gave its sound as [bə] and named “s” as [eʔ] gave its sound as [kx]. He gave the sound [ç] for “sh” and the sound [tç] for “ch”.

Response to Intervention

Details of skills that were acquired during each of the ten intervention sessions are outlined in Appendix 6. A summary of these skills follow:

During the second and third session JB learnt to discriminate *spell* vs *bell* and *smile* vs *mile* in the auditory alone condition, but only when they followed the word *a* (*a spell* vs *a bell* and *a smile* vs *a mile*) when there were more acoustic cues available to aid the detection of the devoiced /s/. He then learnt to discriminate *smile* and *mile* (as single words) in the auditory alone condition (achieving scores of 14/16, 15/16 and 16/16) but did not achieve above chance scores for discriminating *spell* and *bell* (in single words) in the auditory alone condition. JB had great difficulty in producing /s/ in isolation. Various techniques were tried to elicit this consonant: modelling, phonetic explanation, modification of other sounds and use of tactile cues. By the sixth session JB could imitate /s/ as [x] or [kx] but had difficulty in using this realisation in words beginning with /sn/, /sm/ or /sp/. By the tenth session he was generally successful at realising /s/ as [ç] or [x] when naming pictures of words beginning with /s/ clusters. JB also had difficulty in learning to imitate /f/ in isolation. He needed lots of practice at carefully graded skills: imitating the labiodental position in a mirror by using his hands to put the articulators in position, imitating this position without using his hands, keeping the position and producing an airflow. By the fourth session he was able to imitate /f/ in word final position and by the seventh session he managed to imitate some words beginning with /f/ successfully. Until the eleventh session /s/ clusters and /f/ were worked on separately but during session eleven pictures of words beginning with the different consonants were mixed. JB then had difficulty in switching from one consonant to another. Therefore he was asked to classify the words into those beginning with /s/ and those beginning with /f/. He did this successfully and then found it easier to switch from one consonant to the other. However he was still realising /s/ as [x], [kx] or [ç] and when realising words beginning with /s/ + vowel he used an intrusive [t] before the vowel. By the last session JB was able to switch from his realisations of /s/ to his correct realisations of /f/ after one reminder at the beginning of the session. After lots of reminding and practice he was able to use these skills to retell a short story containing four words beginning with /f/ and four words beginning with /s/. However he did not seem to be using his newly acquired speech skills in conversation or outside intervention sessions.

Intelligibility / Motivation Questionnaire

JB was not able to understand the questions in this questionnaire, despite explanations and rephrasing and so it was not used in his case study.

Participant MC

Input Tests at T1 (before intervention)

Consonant contrasts identified as being problematic for MC by the PETAL naming tasks (Parker, 1999) were profiled with selected tests from the Rees Coleman procedure. For each of these contrasts the following input tests were completed:

PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual

The following table shows the raw scores for all the tests for each contrast (C). Scores for “right” or “same” items judged correctly (R/S) and scores for “wrong” or “different” items judged correctly (W/D) are included as well as total scores (T) for each test. The probability of each total score occurring by chance (*p* value) was calculated using a binomial table (Siegal et al., 1998).

C	PYNJAA				PYNJAV				NWDAA				NWDAV			
	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value
s/d	8/8	7/8	15/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**	7/8	8/8	15/16	**<0.002**
sp/b	8/8	8/8	16/16	**<0.002**	8/8	7/8	15/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**
sm/m	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**
sw/w	8/8	8/8	16/16	**<0.002**	8/8	7/8	15/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	7/8	15/16	**<0.002**
st/d	7/8	8/8	15/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**	7/8	8/8	15/16	**<0.002**
sn/n	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	7/8	15/16	**<0.002**	8/8	8/8	16/16	**<0.002**
sk/g	8/8	8/8	16/16	**<0.002**	8/8	8/8	16/16	**<0.002**	7/8	8/8	15/16	**<0.002**	8/8	7/8	15/16	**<0.002**
ʃ/tʃ:ʃ	8/8	7/8	15/16	**<0.002**	8/8	8/8	16/16	**<0.002**	8/8	7/8	15/16	**<0.002**	8/8	7/8	15/16	**<0.002**
ʃ/tʃ;tʃ	8/8	3/8	11/16	0.105	8/8	3/8	11/16	0.105								

C = Contrast
PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
NWDAA = Nonword Same/Different Discrimination Audio-alone
NWDAV = Nonword Same/Different Discrimination Audio-visual
R/S = Scores for "right" or "same" judged correctly
W/D = Scores for "wrong" or "different" judged correctly
T = Total Score
p value= Probability of score occurring by chance (and emboldened numbers indicate those that are less than alpha of 0.0)

Table 41 MC: Raw scores and probabilities of chance for all input tests after intervention

Based on these results the contrasts were divided into the following input groups:

1. **Auditory – Nonwords Only**: Evidence of audio-visual input skills for PYNJ and NWD and auditory input skills but for NWD only: /ʃ/-/tʃ/. For this contrast the probability of the scores occurring by chance was less than 0.05 for both audio-visual versions of the PYNJ and NWD *and* the audio-alone version of the NWD, but greater than 0.05 for the audio-alone version of the PYNJ test. This implies that, as well as discriminating the contrast in the audio-visual condition, MC can also discriminate it in the audio-alone condition, but only if he is taking a non-lexical route.
2. **Auditory – Full:** Evidence of audio-visual input skills for PYNJ and NWD and auditory input skills for Picture Yes/No Judgement (PYNJ) and Nonword Discrimination (NWD):
/s/-/d/, /sp/-/b/, /sm/-/m/, /sw/-/w/, /st/-/d/, /sn/-/n/, /sk/-/g/. For these contrasts the probability of the scores occurring by chance was less than 0.05 for all input tests. This implies that, as well as discriminating the contrasts in the audio-visual condition, MC can also discriminate them in the audio-alone condition, for both lexical and non-lexical routes.

Input Tests at T3 (after intervention)

The only input test conducted at T1 where MC had performed at chance was the Picture Yes/No Judgement Audio-alone (PYNJAA) test for words beginning with /tʃ/. This was repeated after intervention and the results are shown in the following table.

C	PYNJAA				PYNJAV			
	R/S	W/D	T	*p* value	R/S	W/D	T	*p* value
ʃ/tʃ;tʃ	8/8	6/8	14/16	**<.002**	8/8	7/8	15/16	**<.002**

C = Contrast
PYNJAA = Picture Yes/No Judgement Audio-alone
PYNJAV = Picture Yes/No Judgement Audio-visual
R/S = Scores for "right" or "same" judged correctly
W/D = Scores for "wrong" or "different" judged correctly
T = Total Score
p value= Probability of score occurring by chance (and emboldened numbers indicate those that are less than alpha of 0.05)

Table 42 MC: Raw scores and probabilities of chance for all input tests after intervention

Performance on this test had changed from being at chance level before intervention to being above chance level after intervention.

Naming Data:

At least nine pictures of different words were used to elicit each of the target consonants in word initial position. Transcriptions of the target consonants for all the naming responses in the four assessments conducted at four different time points were rated using the Rees Rating Scale, as described in Chapter 4.

Naming responses used for comparison across time points were those that occurred at each of the four time points.

The following figure illustrates the change in ratings over the four time points.

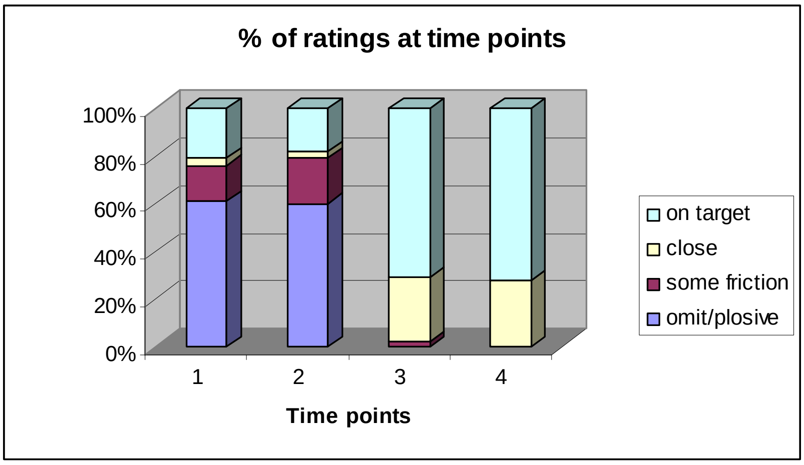


Figure 9 MC: Percentage of ratings at each time point

The ratings of target consonants in MC's responses were compared across the four time points using the Friedman test. Results showed a significant difference (X^2 (3, N = 100) = 198.416, p <.001) .

Therefore the Wilcoxon test was used to measure any significant changes in ratings during the following intervals:

- Time 1 to Time 2 (T1-T2) (no intervention period prior to intervention)
- Time 2 to Time 3 (T2-T3) (intervention period)
- Time 3 to Time 4 (T3-T4) (no intervention period following intervention)

As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	*N*	*z* value	*p* value
T1-T2	100	-0.600	0.548
T2-T3	100	-7.959	**<0.001**
T3-T4	10	-0.577	0.564

Table 43 MC: Wilcoxon test comparing changes in ratings of consonant realisations for the three time intervals

There were no significant changes for T1-T2 or for T3-T4. However there was a significant improvement in ratings during the intervention period, T2-T3.

In order to see whether evidence of input skills relating to target consonants prior to therapy had influenced changes in the ratings of their production the data were split into the two input groups (Auditory Nonwords Only and Auditory Full). See Table 44 for details of how the data were divided.

Group Number	Input Group	Target Consonants in Group	Number of Words in Naming Test in Group
1	Auditory Nonwords Only	/tʃ/	11
2	Auditory Full	/s/, /sp/, /sm/, /sw, /st/, /sn/, /sk/, /ʃ/	89

Table 44 MC: Description of input groups

The number of items in each group reflects not only the number of consonants in the group but also the number of words used to elicit the consonants.

The following figure illustrates the change in ratings over the four time points for each of the two input groups.

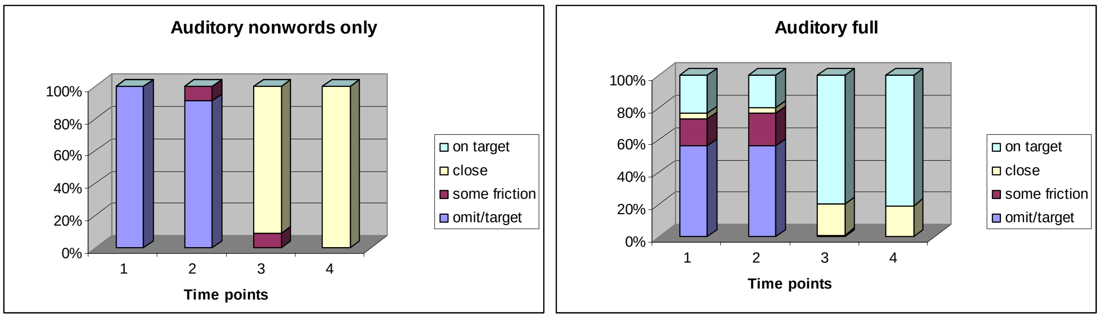


Figure 10 MC: Percentage of ratings at each time point for the two input groups

The Friedman test revealed that there were significant effects across time for both input groups (see Table 45).

Input Type	*n*	X^2	d.f.	*p* value
Auditory Nonwords Only	11	32.333	3	**<.001**
Auditory Full	89	166.764	3	**<.001**

Table 45 MC: Friedman test to compare ratings of consonant realisations for each input group across the four time points

Because all the results were significant a Wilcoxon test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for the two input groups See Table 46). As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*z* value	*p* value
T1-T2	Auditory Nonwords Only	11	-1.000	.317
	Auditory Full	89	-0.618	.496
T2-T3	Auditory Nonwords Only	11	-3.217	**.002**
	Auditory Full	89	-7.466	**<.001**
T3-T4	Auditory Nonwords Only	11	-1.000	.317
	Auditory Full	89	-0.392	.695

Table 46 MC: Wilcoxon test to compare changes in ratings of consonant realisations for the three time intervals for each input group

Significant improvements in ratings of target consonants occurred during the intervention period (T2-T3) for both input groups. There were no significant improvements for the other time intervals.

In order to see whether or not any changes in the ratings of the target consonants were influenced by whether the particular words containing them had been used in intervention, the whole data set was split into the following word groups:

- Therapy: words used in intervention
- No Therapy: words not used in intervention.

Figure 11 shows the change in ratings over the 4 time points for the Therapy and No Therapy groups.

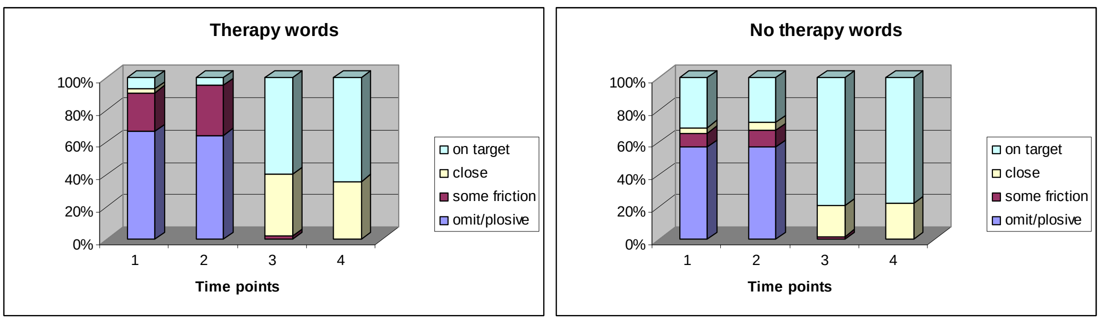


Figure 11 MC: Percentage of ratings over time points for the therapy and no therapy groups

The Friedman test revealed that there were significant effects across time points for both word groups (see Table 47).

	n	X^2	d.f.	*p* value
Therapy	42	98.881	3	**<0.001**
No Therapy	58	98.622	3	**<0.001**

Table 47 MC: Friedman test to compare ratings of consonant realisations for each word group across the four time points

Because the results for both groups were significant a Wilcoxon test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the words used in intervention and those not used in intervention (see Table X). As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Therapy vs No Therapy	*n*	*z* value	*p* value
T1-T2	Therapy	42	-0.213	.831
	No Therapy	58	-0.423	.672
T2-T3	Therapy	42	-5.614	**<.001**
	No Therapy	58	-5.730	**<.001**
T3-T4	Therapy	42	-0.775	.439
	No Therapy	58	0.000	1.000

Table 48 MC: Wilcoxon test to comparing changes in ratings of consonant realisations for the three time intervals for each word group

All the significant improvements in ratings of target consonants occurred during the intervention period (T2-T3) for both sets of words. Whether words containing the target consonants had been used in intervention did not influence whether significant improvements were made to the ratings of those consonants.

In order to see whether or not the same groups (input groups and therapy/no therapy groups) influenced MC achieving a “correct” target sound (as opposed to an improved realisation), all the realisations were then scored as “incorrect” or “correct” as opposed to being rated. A “correct” realisation was one within the phonemic category of the target phoneme. All other kinds of realisations were categorised as “incorrect”.

McNemar tests were used to measure any significant changes during the time intervals. (For details of results, see Appendix 14.) All the significant changes took place during T2-T3 (the intervention period). This was the case for the group of consonants as a whole, the "Auditory Only" group, the "Therapy" group and the "No Therapy" group. The group for which there was no significant change during the intervention period was for the "Auditory – Nonwords Only" group. There were 11 items in this group. None of these consonants reached a rating of 4 (on target) at any time point and so all were scored as "incorrect" at each time point and so there was no change to measure. However, all the ratings were at 1 (omit/plosive) or 2 (some friction) at T1 and T2 and all were at 3 (close) at T3 and T4.

Sentence Repetition Data

In order to see whether MC found it more difficult to use the target consonants when repeating sentences, ratings in the naming task at T2 were compared with ratings in the sentence repetition task at T2 using the Wilcoxon test. Unexpectedly, MC's ratings showed a significant improvement in the sentence repetition task ($N = 42$, $z = -4.377$, $p < .001$).

In order to see whether there were changes in ratings for the sentence repetition tasks across time, the ratings of target consonants in MC's responses to these tasks were compared across time points T2, T3 and T4 using the Friedman and Wilcoxon tests. In order to see whether the input groups influenced any improvements in the ratings the Friedman and Wilcoxon tests were used. (For details of all these results, see Appendix 14.)

Significant improvements took place during T2-T3 (the intervention period). This was the case for the group of consonants as a whole, the "Auditory Only" group, the "Therapy" group and the "No Therapy" group. There was no significant change for the "Auditory – Nonwords Only" group. There was also a significant improvement for the whole group of consonants between T3 and T4 ($N = 42$, $z = 2.054$, $p = .05$).

Unknown and Taught Words

The naming test designed for this study had 158 items judged to be in the vocabulary of children under 11 years of age. During the assessment at T1, 118 of these items elicited a naming response. One hundred of these items elicited a naming response easily at each time point and these were used for statistical analysis previously reported. Eighteen of the words, elicited easily at T1, were not elicited successfully at one or more of the other time points. Forty items were not named at T1. Responses to these items are shown in Table 49.

Taught/Not Taught	Word	Ratings of Target Consonant/s in Word at Different Time Points (NR = no response)			
		T1	T2	T3	T4
Taught	smart	NR	NR	NR	NR
	smuggle	NR	NR	4	4
	sparkler	NR	NR	4	4
	spear	NR	NR	4	NR
	spinach	NR	NR	4	4
	spaniel	NR	NR	4	4
	swarm	NR	NR	4	NR
	Sweden	NR	NR	4	4
	swollen	NR	NR	4	4
	snap	NR	NR	NR	NR
	scar	NR	NR	4	NR
	skull	NR	NR	4	4
	shampoo	NR	NR	4	4
	sheets	NR	NR	NR	NR
	shutters	NR	NR	NR	NR
	shuttlecock	NR	NR	NR	4
	cheap	NR	NR	3	3
	chimpanzee	NR	NR	3	NR
	choking	NR	NR	3	NR
	chopping	NR	NR	3	NR
Not Taught	salad	NR	NR	NR	4
	salute	NR	NR	NR	4
	Sumo	NR	NR	NR	NR
	safe	NR	NR	NR	NR
	smash	NR	NR	3	4
	smock	NR	NR	NR	NR
	Spain	NR	NR	NR	NR
	swerving	NR	NR	NR	NR
	Switzerland	NR	NR	NR	NR
	stadium	NR	NR	4	4
	stapler	NR	1	3	4
	starfish	NR	1	4	4
	steam	NR	1	4	4
	stem	NR	NR	NR	NR
	steering	NR	NR	NR	4
	stitches	NR	NR	NR	4
	stomach	NR	NR	NR	NR
	sketch	NR	NR	NR	NR
	sculpture	NR	NR	NR	NR
	change	NR	NR	3	NR

Table 49 MC: Responses to Word Items not Named at T1 across Time Points.

As shown in Table 49, 20 of the 40 words not known at T1 were taught to MC during the intervention period. These unknown words represented a range of the consonant /

consonant clusters and the selection was also based on teachers' comments on which would be the most useful words for MC to learn. All these items were also unknown at T2 but 15 of them were named correctly at T3 and 10 at T4. The target consonants in these responses were rated with the Rees Rating Scale. Most the realisations were rated as 4 (on target), except for the realisation of /tʃ/ rated as 3 (close).

Eight of the 20 unknown untaught words also showed improvement over time. Three were named correctly at T2 (with target consonant ratings of 1 (omit/plosive) and eight were named correctly at T3 and/or T4 (with consonant ratings of 3 (close) or 4 (on target)).

Letter Knowledge Task

The complete set of results of this task are in Appendix 5. MC provided names for most of the written consonants and sounds for all of them. He gave the sound [s̺] for "s" and the sound [də] for both "sh" and "ch".

Response to Intervention

Details of skills that were acquired during each of the ten intervention sessions are outlined in Appendix 6. A summary of these skills follows:

By the third session MC could imitate /s/ as [s̺] or [sʃ]. By the eleventh session MC was consistently realising /s/ as [sʃ] when naming pictures of all the therapy words beginning with /s/ or /s/ clusters. By the last session he had transferred this skill to sentence level and was also able to recognise when the therapist omitted /s/ from the therapy words when they were said in a sentence.

By the end of the third session MC could auditorily discriminate the difference between *a ship* and *a chip*. By the end of the fifth session he could discriminate between *mash* and *match* when the difference was exaggerated. Towards the end of the programme had learnt to discriminate between between *ship* and *chip*, where there were fewer acoustic cues. In terms of output he initially found it easier to produce a clear and accurate difference between /ʃ/ and /tʃ/ in final position in words. By the end of session 7 he was producing a few successful attempts at imitating /ɑtʃɑ/ and by the ninth session he was producing accurate spontaneous productions of *a chimney* and *a chair*. By the eleventh session he had 80% success in classifying pictures into those that start with /ʃ/ and those that start with /tʃ/ and could then contrast these phonemes when naming, usually leaving a slight pause between the consonant and the following vowel. By the end of the programme he successfully blended the two phonemes with vowels in naming tasks with some reminding. He also made a few attempts to use this new skill in general conversation. However he did not seem to be using his newly acquired speech skills outside intervention sessions.

Intelligibility / Motivation Questionnaire

Details of the questions and responses to the intelligibility / motivation questionnaires at T2 and T3 are outlined in Appendix 7. A summary of this follows:
To describe his overall intelligibility MC chose "Most people understand everything I say" at T2 and T3. At T2 he rated 4/6 speaking situations as being "very easy" (the highest rating). At T3 he only gave this rating to two situations and he rated the following three situations as "very difficult" or "impossible": calling out to friends in games, explaining a game to a friend and talking to a stranger when it is noisy. In response to "Do you want your speech to be clearer?" MC chose "Definitely" at T2. At T3, when asked what he had learnt to do in the speech and language therapy lessons this term, he replied "Nothing" whilst grinning.

Summary

Results of the input tests that were re-administered showed small improvements in speech input skills for all three participants. Tests were re-administered if the initial performance was at chance. For DA, of the 18 input tests that were re-administered, he performed at chance again for 14 and his performance was above chance for four. These four tests involved detecting /s/; two in the AV condition and two in the AA condition. During the intervention it was noted that DA learnt to produce a more accurate realisation of /s/ in clusters before he learnt to detect it in clusters beginning with /st/ (AV condition only) and /sm/ (AA condition). For JB, of the 14 input tests that were re-administered he performed at chance again for 13 and his performance was above chance for only one, scoring 12/16 for /sm/ - /m/ in the AV condition. During the intervention he was observed to distinguish between *smile* and *mile* in the AA condition but was not able to do this during the formal tests at T3. For MC, only two tests needed to be re-administered: the PYNJ tests for /ʃ/-/tʃ/: /tʃ/ in the AA and AV conditions. After intervention he scored 14/16 and 15/16 for these tests respectively. During the intervention it was noted that this improvement in discrimination occurred after learning to distinguish between /ʃ/ and /tʃ/ in single word naming tasks.

Considerable improvements in speech output skills were noted after intervention for all three participants. When the ratings of target consonants in naming tasks were compared across the four time points there were significant improvements during the intervention period for all three participants. There were no significant improvements during periods of no intervention. For each participant, the target consonants were divided into input groups according to responses to the input tests completed at T1. Significant improvements in ratings of target consonants occurred during the intervention period for all input groups for all participants. For each participant, the words containing the target consonants were divided into "therapy" and "no therapy" words depending on whether the words were used during intervention. Significant improvements in ratings of target consonants occurred for both sets of words during the intervention period for all participants. When the same comparisons were made according to whether the participants had achieved "accurate" use of the target consonants, these patterns were identical for DA and a little different for JB and MC. This was because JB only learnt to produce one consonant accurately in words (/f/) and MC was still having difficulty in blending /tʃ/ with vowels at T3. JB had great difficulty in imitating the movements of the articulators.

For DA and MC, significant improvements in ratings of target consonants also occurred in the sentence repetition tasks. JB did not use his improved productions of the target consonants in the sentence repetition tasks and so there were no significant improvements in ratings over any of the time intervals. During intervention MC was observed to be making a few attempts to use his new speech skills in conversation, but, in general, there seemed to be little carry-over to spontaneous speech. At the end of the programme DA and JB could use their newly acquired speech skills when retelling a simple story during an intervention session, but no generalisation was noted in conversation or outside intervention sessions.

DA and JB successfully learnt the words that they had been taught during intervention. These were words that were unknown during naming tasks at T1 and T2. DA used all his 13 taught words during naming tasks at T3 and T4 and used accurate realisations of the target consonants in every case except one. JB used 9 out of his 10 taught words and used his improved realisations of the target consonants in every case. MC only used 9 of his 20 taught words during naming tasks at both T3 and T4, but he did use his improved realisations of the target consonants when he did use the words.

JB did not understand the questions in the intelligibility / motivation questionnaire. DA and MC chose "Most people understand everything I say" to describe their intelligibility at T2 and T3 and there were no marked changes in their ratings of the degree of difficulty they encountered in different speaking situations. To the question “Do you want your speech to be clearer?” at T2 DA chose “I think so, I don’t mind” and MC chose “Definitely”. At T3, when DA and MC were asked what they had learnt during intervention, DA replied “How to say /s/, /ʃ/ and /tʃ/” and MC replied “Nothing”, whilst grinning.

Chapter 6: Phase 2: Therapy Techniques

This chapter outlines the therapy techniques used in phase 2 of the intervention study. Chapter 5 discussed the results of phase one where three deaf children were taught to use target consonants in naming tasks. Two of these participants, DA and MC, learnt to produce all the target consonants with a high degree of accuracy and consistency in naming tasks. Although there was generalisation of these newly acquired speech skills to single words not used in therapy, informal observations indicated that there was very little generalisation to spontaneous speech. In general, it seemed that the children were accessing motor programs that had been established prior to Phase 1 of the intervention study. One could argue that the motor programs they were accessing during the naming tasks were not fully established. Phase 2 was set up to explore what processes need to take place in order to ensure that motor programs are more permanently updated. Therefore the aim of this intervention programme was to investigate whether DA and MC could form better established motor programs for words that included the target consonants, so that they could access them in a range of speaking situations, including conversation. Details of the aims, design and method of Phase 2 of the study are covered in Chapter 7. This chapter explains the timing and structure of the programme and describes the therapy techniques that were chosen, providing reasons for choices.

Outline of Intervention Programme in Phase Two

This programme, devised especially for this part of the study, focused on generalising the participants' ability to produce the target consonants in a range of speaking situations and was used with participants DA and MC. JB was not included in this phase of the study as there were only resources to provide further therapy to two children and, unlike DA and MC, JB had some difficulties in generalising his newly acquired speech skills to spontaneous naming.

Timing and Structure of Programme

There is evidence that deaf children are able to generalise taught speech skills to conversation if they are given enough training. Paatsch et al (2001) conducted an intervention study with twelve deaf children between 5 and 10 years old. The participants were assessed with three procedures:

- The Phonetic Level Evaluation (Ling, 1976) that includes the imitation of consonants in isolation, in syllables and syllable strings;
- A single word naming test;
- The collection of a spontaneous speech sample.

Each participant received training on six misarticulated phonemes. Three of these phonemes had a high error rate (the child scored less than 40% in one or more of the assessments) and so received “phonetic level training” involving a programme that progressed from eliciting the target sound in isolation through to producing the sound in multiple syllable strings with vowel variation. The remaining three phonemes were those that the participant was already producing with 40-70% accuracy in one or more of the speech assessments. These phonemes received a “phonological level training” involving meaningful practice using selected words, phrases, expressions, rhymes and stories. Each participant received therapy for all six phonemes in daily therapy sessions of 20-30 minutes for eight weeks. Although the phonemes receiving phonetic training showed some improvements overall, no individual assessment revealed a significant improvement for the group as a whole. However, the remaining phonemes improved significantly in all assessment types, including conversation. Paatsch et al (2001) concluded that children still developing phonemes at a phonetic level need further practice to generalise these skills into spontaneous speech and that, if this training specifically addresses carry over, it is possible to achieve generalisation to conversation.

DA and MC had already received phonetic level training for the target consonants to a level that involved using the target consonants in single words with a high degree of consistency. This second phase of the intervention could therefore focus on levels beyond the single word aiming for carry over to conversation. It was not possible to provide daily therapy to the participants and so longer sessions were provided less frequently. As DA and MC were at the upper end of the age group in the Paatsch et al study (2001) and were producing the target phonemes with a high degree of accuracy in single words it was felt that a shorter programme with less frequent sessions may be adequate to achieve some generalisation.

Each participant was allocated a final year speech and language therapy student who conducted the therapy and the two students were supervised by the author. Each participant received eight 45-minute individual therapy sessions spaced over five weeks. All sessions took place in a quiet room in the child’s school. Throughout the session the participants used the hearing aids they usually wore in class. Radio microphones were not used by the student therapist as they were in close proximity to the child.

Therapy Techniques

The choice of therapy techniques drew on psycholinguistic theories and research evidence concerning factors that maximise the success of generalisation programmes. Some of this evidence came from studies with hearing children as there is limited information on methods used to generalise speech skills taught to deaf children through to conversation (Shaw & Purcell, 1987). Most intervention studies with deaf children conducted after Shaw and Purcell's review in 1987 also provide limited relevant information on attempts to generalise speech skills. There are several studies concerned with deaf children's speech development conducted since 1987 that measure the effects of cochlear implantation on spontaneous speech (Lachs, Pisoni, & Kirk, 2001; Tobey, Geers, Brenner, Altuna, & Gabbert, 2003) but these do not involve specific intervention to improve speech skills. The generalisation process is expected to be similar for hearing and deaf children, even though there may be differences in the foundations on which generalisation is based. Therefore techniques that have been successful in helping hearing children to generalise newly acquired speech patterns are likely to be helpful for deaf children. Each technique chosen is described in turn.

Repeated Practice of Motor Patterns in a Range of Graded Tasks

Hewlett (1990) proposed that the output lexicon consists of information gained from highly learned combinations of muscle commands. He suggested that changes can be made to the output lexicon when the child has sufficient dexterity to implement speech sounds at speed in a variety of contexts. This seems to imply that the child has to practise and use newly acquired motor patterns repeatedly in order to produce them with ease and for the muscle commands to be stored. McReynolds (McReynolds, 1987) reviewed models of perceptual motor skill learning in the context of articulation disorders and explained that at the early stages of skill acquisition the learner needs to plan the movement and consciously attend to the incoming information but, with practice, movements are produced more rapidly and gradually conscious control is relinquished. Kamhi (2000) reported on his daughter's response to therapy and noted that she would not use new speech sounds outside therapy until she had mastered them to a high degree. This degree of automatization or mastery may be an indication of the newly acquired motor patterns being stored more permanently. McReynolds (1987) noted that when children are moving towards automatization, the ease with which they can generalise newly acquired speech skills is dependent on the task. In the intervention studies reviewed by McReynolds (1987) children generalised most easily to imitative tasks, less to reading tasks and least to spontaneous conversation (although there was a high degree of individual variation). More spontaneous speaking tasks require more planning for what is said and, in a limited capacity system, it is likely that the resources required to plan what to say leave fewer resources available to focus on speech production (Kamhi, 2000).

As discussed in Chapter 3, the Ling system (Ling, 2002; Ling, 1976), used widely with deaf children, includes repeated practice of target consonants in isolation, with different vowels and in syllable strings. Ling (2002) maintains that these kinds of patterns need to be practised until it takes conscious attention to produce them inaccurately. He believes this ensures the establishment of sensory-motor patterns that, once established, are resistant to distortion even when there is auditory deprivation. Ling (2002) states that if speech patterns are practised towards this level of automaticity at the phonetic level, then the transition of these patterns to the child's phonology should require relatively little effort. The advantage of training with nonword stimuli is that there is less interference from stored representations and therefore the child may find it easier to establish new motor patterns. However Abraham and Weiner (1985) found word training to be more effective than syllable training in facilitating generalisation to untrained words with two different groups of deaf children. In a successful generalisation study with 12 profoundly deaf children, Perigoe and Ling (1986) included specific training where the children practised producing target consonants in single words and then two and three-word combinations. The "phonological level training" provided in the Paatsch et al study (2001), as described earlier, was particularly effective and included meaningful practice using selected words, phrases, expressions, rhymes and stories. Participants DA and MC had already strengthened their sensory-motor patterns to an extent that they were achieving a high degree of accuracy in producing target consonants in a range of single words (including untrained words) but had not transferred their new speech skills to connected speech.

Therefore Phase 2 of the intervention study included repeated practice at producing a range of words with the target consonants. The programme progressed from tasks predicted to be less effortful in terms of generalising newly acquired speech skills through to tasks where generalisation was predicted to be more difficult. Therefore the programme began with repetition tasks, progressed to reading tasks and then moved on to tasks requiring the use of spontaneous speech. An attempt was made to grade the spontaneity and processing demand of the task so that retelling of stories was practised before making up stories from given words and then the programme moved on to quizzes and card games and ended with general conversation. This progression was not kept to rigidly but used as a guide. Each session included a small range of tasks but when the participant showed evidence of generalising successfully to the easier tasks these were then replaced by more demanding tasks in subsequent sessions.

Encouraging Planning and the Role of Self-Monitoring

Some evidence suggests that successful generalisation of speech skills in intervention programmes relies partly on whether the child is encouraged to monitor their own speech. Ruscello and Shelton (1979) investigated whether greater generalisation would be obtained by adding a self-monitoring component to a treatment programme. Two groups of hearing children participated in the study. One group of children were required to think about producing the target sound before producing it and then to evaluate the accuracy with which they had produced the sound. The other group received identical training without the planning and self evaluation components. Results showed that the participants who used planning and self-evaluation performed better on sound production tests and in conversation in the acquisition phase of treatment. However, Ruscello and Shelton (1979) noted that the children in Group 1 did not learn to self-evaluate accurately and so it was likely that the planning element had enhanced treatment rather than the self-monitoring.

Auditory feedback for self monitoring may be more important in earlier stages of therapy rather than at a generalisation stage. With hearing children, it seems that this may be the case. McReynolds (1987) reviewed a series of studies by Manning and others in 1976 and 1977 that aimed to investigate the role of auditory feedback at various levels of acquisition and automization of target speech sounds in hearing children. Some of these studies divided children into a "high acquisition" group that scored at least 80% correct production on an articulation test and a "low acquisition" group that scored less than 80%. The articulation tests were then repeated in a condition where noise was introduced to interfere with auditory feedback. Results indicated that the introduction of noise disrupted the performance of the low acquisition group more than the performance of the children in the high acquisition group. The authors concluded that the children who were closer to automizing their speech skills were less dependent on auditory feedback. In the initial stages of updating lexical representations it may be more important for the child to listen to and monitor their own productions whereas this may be less necessary as speech patterns become more automatic.

It is therefore possible that deaf children become less dependent on sensory feedback as acquired speech skills become less effortful and more automized. Also, as Ling (2002) points out, using sensory-motor skills to monitor connected speech may be an impossibility. In reviewing studies on sensory-motor reaction time Ling (2002) concludes that neurological and mechanical constraints prevent speakers from using feedback to exercise moment-by-moment control over speech production and suggests that speech training programmes should put more emphasis on pre-planning of speech sequences.

Therefore Phase 2 of the study did not include asking the participants to evaluate their own productions of the target consonants but feedback from the clinician was used to encourage the participants to plan their speech more carefully. As most of the activities encouraged the use of connected speech, it would have been disruptive to stop the child after every production of a target consonant to self monitor. Also, as noted by Ruscello and Shelton (1979), children often do this inaccurately and this may indicate, as Ling (2002) points out, that the task is too difficult. When the child has already realised a particular target consonant and has started producing the next word/s it may be very difficult for the child to reflect back on their production of the particular consonant and one could argue that, if they were aware of an incorrect production, that they would have self-corrected. Although the use of self monitoring was not specifically targeted, participants had every opportunity to do this as all therapy sessions were conducted in a quiet room and any spontaneous self-correction was rewarded.

Previous clinical observations had shown that, if the therapist gave subtle and immediate feedback on the child's production of target consonants, this would encourage the child to plan more carefully and self-correct. Therefore the method used was as follows. During each speaking task the therapist would complete a feedback chart that was clearly visible to the participants. This chart recorded the number of times the child had remembered to produce the target consonants correctly (using a column heading "Right"), the number of times the realisation was closer to the target than the original omission or realisation recorded before Phase I of the intervention study (using a column headed "Nearly Right") and the number of times the target consonants had been omitted or realised incorrectly as it was before Phase 1 (using the column heading "Wrong"). Each time the child realised a target consonant the therapist would mark a horizontal line in the relevant column in front of the child. Watching the compilation of the chart encouraged the participants to plan their speech more carefully. Often, if the child saw that the therapist's pen was moving towards the "Nearly Right" or "Wrong" column, they would self-correct before the therapist had made a mark. After a few sessions the participants began realising target consonants correctly "outside" the activities when, for example, they commented on the activity or initiated conversation on another topic. From this point onwards a box headed "Right Outside Activity" was added to the chart and the number of correct realisations was recorded there.

Encouraging Motivation and Responsibility for Change

As in Phase 1 of the intervention study, it was noted that if children can see the benefits of improving their speech they are more likely to change their speech production (Weiss 2004). Therefore each session in Phase 2 began with a discussion of the aim of the programme (improving intelligibility) and its potential advantages.

The participants were encouraged to take an active part in the programme and to monitor their progress towards the aim. At the end of each activity (e.g. reading a story, card game) the participants used an electronic calculator to convert the figures in the three columns into percentages of correct use of the target phonemes. For example, if they had 12 marks in the "Right" column, 4 in the "Nearly Right" column and 4 in the "Wrong" column, they would add all three figures together, totalling 20 and then convert 12/20 to 60%. (See Table 50 for a blank feedback chart) They then wrote these figures on a progress chart that summarised the percentages for each activity across the eight sessions. They also transferred the number of times they had realised target consonants correctly outside the activity. (SeeTable 51 for a blank summary progress chart).

Developing Input Skills

Although the use of input for self-monitoring was not targeted in therapy for reasons previously explained, the use of input to respond to the trainer's speech production was considered.

Ling (2002) believes that generalisation from the phonetic to the phonological level includes the child understanding how meaning is derived from changes in the speech patterns of others. Tasks involving responding to changes in the trainer's speech could assist this development. Several successful intervention studies with deaf people have included such input tasks with output work (Busby et al, 1991; Massaro & Light, 2004). Training in the Paatsch et al study (2001) with deaf children also placed emphasis on learning through audition in all activities, including those aiming to promote generalisation of speech skills to connected speech.

Although Phase 2 focused mainly on repeated practice in output tasks, each session included one input task at the sentence level. The participants were presented with two minimal pairs of written words containing one of the target consonants (e.g. *skate/gate, ship/chip*). As each pair was presented in turn they listened to sentences containing one of the words in the pair. The sentences took one of the following formats:
" I have never said X or Y in the bath before" or "My birthday was the last time I said X or Y"
(where X and Y are the words in the minimal pair).
At first the student therapist would produce a sentence and point to the relevant word in the pair. When the participant was confident that he could recognise the word, he was encouraged to point to the corresponding word and given feedback on the accuracy of his response. The participants' eyes were not covered and so they had the option of using visual as well as auditory cues.

Exploiting Phonological Awareness, Making links with Written Letters and using "Quasi-phonemic" Script

As in Phase 1, many of the techniques used in Phase 2 of the intervention study rely on the children having an awareness of how phonological representations can be segmented into phonemes. In successfully monitoring and correcting their speech the participants had to be aware of which phonemic segment of the word to change as they were expected to use the target phonemes in all syllable and word positions. In Phase 1 of the study both DA and MC had successfully generalised their use of the target consonants to words not used in therapy which implies that they had already made links between the consonant sounds and their equivalent written letters. As DA and MC had already learnt to produce /s/ successfully in clusters in single words it was likely that they were able to segment words into phonemes (rather than just into the onset and rime) and link the phoneme segments to written letters. Phase 2 assessments checked to see whether DA and MC had generalised their use of target consonants to the syllable-final, word-final position as further evidence that they were successfully using phoneme segmentation (as Phase 1 of the study had only focused on consonants in word-initial position). Phase 1 of the study had involved the use of "quasi-phonemic" script. This was mainly used to explain the pronunciation of /tʃ/. It was rarely used to explain unusual spellings as none of the target words contained target consonants that had unusual spellings. Therefore there was the possibility that DA and MC had not generalised their speech skills to non-therapy words with unusual spellings. This was checked out by assessing the production of words with unusual spellings at all stages of Phase 2.

In Phase 2 of the study the participants were encouraged further to make use of the links between phonemes and graphemes. Some of the activities involved reading and, at first, the participants were asked to underline all the written letters in a written passage that were pronounced as /s/, /ʃ/ or /tʃ/. This encouraged the participants to plan their speech more carefully and allowed the student therapist to see if the children were aware of where the consonant target occurred in the word. If the participants failed to underline any relevant written letters, because of unusual spellings or oversight, the student therapist would point out the extra letters and how they were pronounced, sometimes writing the sound in "quasi-phonemic" script in red above the written letter. Often the participants underlined the written letter "s" and the end of words such as "is", "was" and "as", assuming that they were pronounced as /s/ instead of /z/. Previous clinical observations had shown that deaf children, without instruction, often naturally add voicing to this phoneme in connected speech when it is surrounded by other voiced segments and, as it may have been difficult to learn a /s/ → /z/ rule just for these circumstances, the children were not discouraged from underlining these consonants or attempting to pronounce them as /s/.

Helping the participants to make these grapheme-phoneme links as well as encouraging them to plan their speech in general allowed them the possibility of using an "orthographic strategy" to generalise their speech skills. They could think about the orthography of a word before they said it and, if the word included target consonants, they could plan to produce the correct realisation.

Therapy Programme

Therapy used in clinical practice involves reacting appropriately to the child's responses. Therefore a strict programme of work was not devised. Instead a general ordering was adhered to and the chosen techniques were used and integrated as described above.

Each of the eight 45-minute sessions had the following structure:

- checking that the child's hearing aids were functioning well and a few minutes of greeting and general conversation;
- brief discussion of reasons for therapy (benefits of improved intelligibility) and progress already made (by reviewing progress chart);
- input task (as previously described);
- five to six output tasks from a range of seven tasks (range of tasks is listed in later in this section);
- calculation of percentage correct scores for each task and discussion of progress made during the session.

During all the output tasks the following chart was completed. As previously described, the student therapist filled in most of the boxes and the participant calculated the final percentage and entered the figure in the last box.

Task:		Date:
Right	Nearly Right	Wrong
TOTAL =	TOTAL =	TOTAL =
% for task =		

Table 50 Therapy feedback chart

This chart was completed separately for each of the five to six output tasks completed during the therapy session.
After several sessions the student therapist also made a note of how many times the target consonants were used outside the tasks for each session. At the end of each session the participant then transferred the % figure to the following summary chart and discussed progress made.

Date	% Target consonants correct during tasks							Number of consonants used correctly outside task
	Single Word Naming	Reading	Retelling Stories	Making up Stories or Dictation	Quiz	Card Game	Conver-sation Therapy Task	

Table 51 Summary Progress Chart

Range of Tasks

1. Single Word Naming: Participants had to name a selection of pictures with a spoken word including at least one of the target consonants.
2. Reading: Participants were asked to read stories containing at least 10 words that included the target consonants. For MC, who had some literacy difficulties, the student therapist read the text to MC before asking him to read it, to make the task easier. In earlier sessions the participants were asked to underline all the written letters pronounced as the target consonants before they read an unmarked passage. As their production of target consonants improved in later sessions, the participant no longer needed to underline the letters before reading.
3. Retelling Stories: Participants were asked to retell stories that they had just read without looking at the text.
4. Making Up Stories (MC only): Five written words containing the target consonants were given to the participant and he was asked to make up a story containing these sounds. These words were read out to MC.
5. Dictation (DA only): DA was asked to make up a short story for the therapist to transcribe.

6. Quiz: The participants were asked a set of ten questions that had single word answers that each included at least one target consonant. For example, they were asked “What comes out of chimneys” in order to elicit “smoke”. They scored one point for each correct answer.
7. Card Game: The commercially available game of “Starwars Top Trumps” was used. In this game each player has a set of cards, each depicting a “Starwars” character (e.g. “Anakin Skywalker”). “Starwars” is the name of a film popular with children at this time. On each character card five attributes are listed (Height, Brains, Dark Side, Jedi Powers, Battle Skills and Force Factor) with scores for each one. One player calls out an attribute and score for her/his character card that s/he thinks is high (e.g. “Anakin Skywalker’s score for Battle Skills is 55, which is high compared to most of the other characters) and the other player calls out their character’s score for the same attribute and the name of the character. It their character’s score for the selected attribute is higher they win their partner’s card and, if it is lower, they relinquish their card to their partner. The winner then chooses the attribute and score for their next card. This game was chosen because both participants were interested in “Starwars” and “Top Trump” games and four of the six attributes on the character cards were described with words including target consonants.
8. Conversation: The student therapist engaged the participant in spontaneous conversation for at least two minutes.

As the programme progressed, the student therapist spent less time on the less spontaneous tasks (especially if the participants were making no or very few errors during the task) and more time on the more spontaneous tasks that seemed more challenging for the participants in terms of generalising their speech skills.

Summary

Phase 2 of the intervention study was set up to investigate whether two of the participants, DA and MC, could generalise speech skills they had acquired during Phase 1. The timing and structure of the programme was guided by a previous study with deaf children conducted by Paatsch et al (2001). This chapter outlined the rationale that guided the selection of therapy techniques that were used. The structure of each session and the range of tasks used throughout the programme were described. Chapter 7 describes the aims, design and method in Phase 2 of the study.

Chapter 7: Phase 2: Aims, Design and Method

This chapter outlines Phase 2 of the intervention study. This was set up to explore what processes need to take place in order to ensure that motor programs are permanently updated so that two of the participants from Phase 1 could generalise their newly acquired speech skills to spontaneous speech. This chapter focuses on the aims, a summary of how the two participants progressed in Phase 1 and the design of the experiment.

Aims

In Phase 1 the participants DA and MC had learnt to use the following consonants and consonant clusters to a high degree of accuracy and consistency in word initial position in single word naming tasks: /s/, /sp/, /sm/, /sw/, /st/, /sn/, /sk/, /ʃ/ and /tʃ/. The use of these consonants had generalised to word initial position in untrained words and words within imitated sentences. For DA, this could not be fully explained by his ability or improved ability to auditorily discriminate the consonants from the previously incorrect realisations in words or nonwords. DA still had difficulty in detecting /s/, and discriminating /ʃ/ - /tʃ/ in input tasks in the AA condition after intervention. It is possible that one or both participants were using the strategy of linking a new realisation of a target phoneme with its corresponding written letter. Therefore we might expect that there would be generalisation to syllable-final word-final position where the target consonants and clusters were spelt in a predictable way. We could also predict that it would be more difficult to generalise this strategy to words with unusual spellings e.g. realising word initial /s/ when articulating the word *circus*, even in single word tasks. At the end of Phase 1 there were no assessments that investigated generalisation to other word positions, to words with unusual spellings or other speaking situations involving spontaneous connected speech. Informal observation of conversation at the end of Phase 1 indicated that there was very little or no generalisation of newly learnt speech skills to spontaneous connected speech. McReynolds (1987) noted that when hearing children are moving towards automatization, the ease with which they can generalise newly acquired speech skills is dependent on the task. In the intervention studies reviewed by McReynolds (1987) children generalised most easily to imitative tasks, less to reading tasks and least to spontaneous conversation (although there was a high degree of individual variation). It is likely that this is also the case for deaf children and so the extent to which they can generalise speech skills over a short fixed time period may be dependent on the task.

Authors experienced in working with deaf children, such as Perigoe and Ling (1986), think that the generalisation of learnt speech skills to connected discourse requires practice and effort on the part of the trainer and the student and stress the need to design and evaluate programmes for deaf children that facilitate generalisation.

Therefore the aims guiding the design of the Phase 2 of the intervention study are to investigate whether:

- speech skills acquired in Phase 1 had spontaneously generalised to syllable-final word-final position in naming tasks after an interval of 5 months (between Phase 1 and Phase 2);
- speech skills acquired in Phase 1 had spontaneously generalised to words with unusual spellings over the interval of 5 months (between Phase 1 and Phase 2);
- a specifically designed intervention programme provided during Phase 2 results in any generalisation of speech skills acquired in Phase 1;
- the degree of any generalisation during Phase 2 varies according to the demands of the speaking task.

Participants

There were three participants in Phase 1 of the intervention study: DA, JB and MC. DA and MC learnt to use their targeted consonants and clusters to a high degree of accuracy and generalised these skills to untrained words and sentence repetition. However, JB had more difficulty acquiring an accurate production of targeted consonants and did not generalise skills he acquired to sentence repetition. Resources for this study only allowed for intervention programmes with two participants and as DA and MC were ready for further progress they were chosen as they would be more likely to succeed.

Full details of DA and MC are given in Chapter 4. Below is a brief summary of skills acquired during Phase 1.

DA

Before Phase 1 DA had difficulty in realising most of the English fricatives and affricates and reduced /s/ clusters. He was able to discriminate the following contrasts in the audio-alone condition in initial position in words or nonwords:

/sw/-/w/, /sm/-/m/ and /sn/-/sn/. He was able to discriminate /sp/-/b/ and /sk/-/g/ in initial position in the audio-visual condition only and there was no evidence of input skills for the following contrasts: /s/-/d/, /st/-/d/ and /ʃ/-/tʃ/. During Phase 1 he had learnt to produce /s/, /s/ clusters, /ʃ/ and /tʃ/ with a high degree of accuracy in word-initial position in single word naming tasks. He also used these skills when repeating sentences and, at the end of the intervention programme he used them when retelling a short story. He also learnt to discriminate /sk/-/g/ in initial position in the audio-alone condition for words and nonwords and learnt to discriminate /st/-/d/ in initial position in the audio-visual condition for words.

MC

Before Phase 1 MC had difficulty in realising /s/ clusters and /ʃ/ and /tʃ/. He was able to discriminate all the consonant contrasts assessed with input tests in the audio-alone condition. The only test where he performed at chance was the Picture Yes/No Judgement task for words beginning with /tʃ/. His auditory discrimination of /ʃ/-/tʃ/ improved during therapy in Phase 1 and during the post-therapy testing he performed successfully on the same Picture Yes/No Judgement task in the audio-alone and audio-visual conditions. By the end of Phase 1 MC was producing /s/, /s/ clusters, /ʃ/ and /tʃ/ with a high degree of accuracy in word-initial position in single word naming tasks with some reminding. He also made a few attempts to use this new skill in general conversation.

Design

A single case study was conducted with each participant. Each study had a time series design where progress over periods without intervention (the A phases) was compared with progress over an intervention period (the B phase) in an ABA time series order.

Each participant was tested at four time points that were approximately 5 weeks apart from each other. Intervention was given between Time 2 and Time 3.

The Phase 2 testing began five months after the final assessment of Phase 1.

Assessments

The assessments were devised by the author of this project with some assistance from two final year students. Each student was allocated a participant. At T1 the assessments were conducted by the author and one of the students and the remainder of the assessments were conducted by the students. As the students video-recorded all the assessments, the author was able to check all the transcriptions.

The following assessments were used at each time point with each participant:

Intelligibility / Motivation Questionnaire

Each participant was asked to complete a questionnaire concerning their speech intelligibility and its consequences and their desire to make changes in their speech production (see Appendix 13).

Elicitation Tasks

Each of the five set tasks elicited the same set of 40 targeted words. These 40 words were selected to represent the following 4 groups of target consonants:

Group 1: 10 words with the target consonants in final position:

bus, cross, horse, mask, toast, wash, fish, brush, watch, switch.

Group 2: 10 words where the spelling of the target consonant was unusual:

I**ce**, poli**ce**, **c**ircus, pen**c**il, **c**inema, **s**ugar, sta**ti**on, ti**ss**ue, ques**ti**on, pic**t**ure.

Group 3: 10 words with /s/ or /s/ clusters in word initial position:

sad, seven, smelly, spider, sweets, snake, snow, stop, scared, scooter.

Group 4 : 10 words with /ʃ/ or /tʃ/ in word initial position:

shadow, shampoo, ship, shop, shut, chair, cheese, children, chocolate, choose.

The five elicitation tasks were chosen to represent different levels of spontaneity and effort in terms of processing. Selection of materials and language used in the assessments were also guided by the language skills and age group of the participants.

All the tasks were video recorded with a Panasonic VHS-C movie camera (model number: RZ15) so that transcriptions could be checked.

The tasks are described in an order which was judged to reflect the level of spontaneity and effort in terms of processing. The first task is judged to be the least spontaneous and effortful. (The order of presentation of tasks is described later in this section.)

Naming

Each of the 40 words was illustrated by a clear colour picture downloaded from www.clipart.com on to a blank A4 page and there were 10 pictures spaced out on each page (see Appendix 8 for an example). The tester pointed to each picture in turn and asked the child to name it. If the child produced a different word or seemed confused the tester made one or two attempts to elicit the word (without producing it). These attempts usually involved a “gap fill” cue. For example, the picture illustrating “stop” showed a policeman holding out the palm of his hand. If the child labelled this picture as “policeman” the tester would say “The policemen is telling the car to -----“. Responses were transcribed phonetically.

Sentence Repetition

Each of the 40 words was elicited in a separate sentence that the child was asked to repeat. For example “chair” was elicited by asking the child to repeat the sentence “The chair was too small for the man”. Pictures to illustrate each of the sentences were downloaded from www.clipart.com and on to a blank A4 page and there were between three to six pictures spaced out on each page (see Appendix 9 for the full list of sentences and an example of a page of pictures). The picture illustrating “The chair was too small for the man”, for example, showed a very large man looking at a small chair with a question mark between them. The tester explained to the child that they had to repeat some sentences. She pointed to each picture in turn, waited until the child looked up at her and then said the sentence. For DA, who used signing in his school, the content words of the sentence were signed simultaneously with speech. When the child had repeated the sentence the target word in the sentence was transcribed phonetically.

Reading Passages

Each of the 40 words was used at least once in one of four type-written passages. Each passage consisted of between seven and 11 sentences and told a simple story. For example, the third passage began with the sentences:
“Once there was a snake called Sid. His nasty owner would make him sharpen pencils all day. –“
All the passages are shown in Appendix 11.

At T1 only the assessor first read out a different story of the same length as a model. At all time points the participant was then asked to read out the four set passages. The assessor transcribed the realisation of the first occurrence of each of the 40 target words, as some of the words were used more than once in each passage. If the child spontaneously self corrected his speech, the self corrected version was taken as the response to analyse.

Retelling Read Passages

At T1 only, when the assessor had read the model passage for the “reading passages” task, she turned the passage over and retold the story without any visual cues. The participant was told that they would have to do the same after they had read each of their four passages. At each time point, when the participant had finished reading each one of the set passages, the assessor turned the passage over and encouraged the child to tell the story from memory. If the child did not produce all the words targeted by the story at least once, the tester waited until the child had finished and then asked a question to elicit the word. For example, if the child did not produce the word “pencil” in the third passage, the assessor would ask a question like “What did his owner make poor Sid do?” The assessor transcribed the realisation of the first occurrence of each of the 40 target words. If the child spontaneously self corrected his speech, the self corrected version was taken as the response to analyse.

Making Up Stories

Each of the 40 words was used once in one of four sets of 10 words that needed to be included in a made-up story. Each set of 10 words was presented in the written form with accompanying pictures that had already been used in the naming test. For example, one page headed “Story 1” contained the following written words written under their accompanying illustrations: wash, toast, cheese, sugar, tissue, scooter, stop, shop, choose, sweets (see Appendix 12).
The assessor began by demonstrating the procedure using a similar page with written words and pictures for a set of 10 different words. The assessor explained that she was going to make up a story using the 10 words and then told a simple story using the words. The participant was then asked to do the same for the first set of 10 words. They were told that they did not have to keep strictly to the order of the words on the page. If the participant finished their story without using one of the words the tester asked them to extend the story to include the missing word/s. The assessor transcribed the realisation of the first occurrence of each of the 40 target words. If the

child spontaneously self corrected his speech, the self corrected version was taken as the response to analyse.
Transcriptions of each targeted word were checked from video and realisations of all the target consonants in these words were rated with the Rees Rating Scale (see Chapter 4 for details).

Conversation

At least 5 minutes of conversation between the assessor and participant were video recorded with a Panasonic VHS-C movie camera (model number: RZ15). The assessor encouraged the child to talk as much as possible by choosing topics of interest and asking as many open questions as possible. The conversation was transcribed from video until the point that the **child** had talked for two minutes. This point was estimated by starting and restarting a stopwatch each time the child began or finished a speaking turn. An orthographic transcription was made of the whole conversation until this point. The child's realisations of all the target consonants and /z/ were rated with the Rees Rating Scale. /z/ was included as the therapy was now targeting consonants in word final position.

Order of Assessments

In order to re-establish a relationship with the participants and to help put them at their ease it was decided to conduct the conversation before the elicitation tasks. To avoid the child using the set written passages as models for the "making up stories" task, this task was completed before the reading and retelling tasks.
The assessments were ordered in the following way at each time point:

- intelligibility/motivation questionnaire,
- conversation,
- naming,
- sentence repetition,
- making up stories,
- reading passages,
- retelling read passages.

Inter-Rater Reliability

A second transcriber and rater, AS, was employed to check inter-rater listener reliability.

AS checked at least 10% of the words transcribed at each of the assessment time points. She was aware of the participant and of the target words, as both were evident on the video-recordings, but was unaware of the assessment time points as all the videotapes were relabelled with codes.

For this check two words were selected from each group of ten words (i.e. two words eliciting the target consonants in final position, two words where the spelling of the target consonant was unusual, two words eliciting /s/ or /s/ clusters in word initial position and two words eliciting /ʃ/ or /tʃ/ clusters in word initial position). This selection was done for each of the five elicitation tasks but, for each output task, different words were chosen so that, in total, all 40 target words were checked at each time point. The same set of selected words was checked for each participant at each time point. For each set, AS was asked to transcribe the whole word and then to code the target consonant/s using the Rees Rating Scale. For the conversation samples AS was asked to transcribe the first 10 words including the target consonants and /z/.

For each set of assessments (five elicitation tasks and conversation) completed at each time point with each participant, the rating codes assigned by AS were compared with the codes assigned by Rees using Cohen's Kappa (Cohen, 1960). Kappa is frequently used to measure agreement when observers are asked to use more than two categories (Pring, 2005). Kappa values obtained were as follows:

Participant	Time 1	Time 2	Time 3	Time 4
DA	0.87	0.88	0.60	0.96
MC	0.68	0.65	0.48	0.94

Table 52 Phase2: Cohen's Kappa values for each set of assessments at each time with each participant

Fleiss (1981) suggested that Kappa values between 0.4 and 0.6 are fair, those between 0.6 and 0.75 are good and those above 0.75 are excellent. No values were less than 0.4 and all but one were above 0.6. The original ratings were used for the analysis as Rees had the advantage of transcribing some assessments at the time of recordings (as well as checking all from tape) and was the more experienced transcriber.

Intervention Programme

Intervention focused on generalising the speech skills acquired by DA and MC in Phase 1.

Each participant was allocated a final year speech and language therapy student who conducted the therapy under the supervision of the author. The author explained all the tasks and techniques to the students and visited at least one session of intervention to observe and give any necessary feedback. Each participant received eight 45-minute individual therapy sessions spaced over five weeks between T2 and T3. Between Time 1 and 2 and between Time 3 and 4 they received speech and language therapy from the therapist based at their school on aspects of communication other than speech.

The intervention programme, therapy techniques and structure of each session were described in detail in Chapter 6.

Research Questions concerning Outcomes of Intervention:

1. Will the participants' production of target consonants improve significantly as a result of intervention in any of the assessment tasks involving spontaneous connected speech?
2. Will the degree of generalisation of target consonants vary according to the demands of the speaking task?
3. Will it be more difficult for participants to generalise the correct production of target consonants to words with unusual spellings in all of the speaking tasks?
4. What strategies do the participants appear to use to generalise speech skills?

Summary

This chapter outlined the aims and design of Phase 2 of the intervention study. Two case studies were to be carried out to investigate whether a specifically designed intervention programme would result in any generalisation of speech skills acquired in Phase 1 and whether the degree of any generalisation would vary according to the speaking task. The production of target consonants was to be tested in a range of speaking tasks at four time points that were approximately five weeks apart. The participants would receive therapy between Time 2 and 3 and no therapy would be given in the other two intervals. Chapter 8 outlines the results for each participant.

Chapter 8: Results of Phase 2

This chapter outlines the results of Phase 2 of the intervention study. The results for each of the two participants are presented in turn. A final summary highlights the important findings and makes some comparisons between the two participants.

Participant DA

Naming Task at T1

Results of the naming task at T1 were used specifically to investigate whether DA's improved realisations of target consonants in word initial position in naming had generalised to word final position and to words with unusual spellings over the 5 month interval between Phase 1 and Phase 2.

In order to do this the 40 words (listed in the last chapter) named at T1 were divided into three groups:

Initial:	20 words with the target consonants in initial position (comprised of 10 words beginning with /s/ or /s/ clusters and 10 words beginning with /ʃ/ or /tʃ/).
Final:	10 words with the target consonants in final position.
Unusual:	10 words where the spelling of the target consonant was unusual.

Table 53 Groups of words at T1

Consonants rated with 1,2 or 3 were classified as "incorrect" and those rated as 4 were classified as "correct". Realisations of consonants in the initial group were first compared to those in the final group and then to those in the unusual group. Classifications for the initial and final groups are shown in Table 54.

Consonant Group	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
Initial	17	3	20
Final	4	6	10
Total	21	9	30

Table 54 DA: Observed numbers of incorrect and correct realisations of target consonants for the initial group and final group

A Chi-squared analysis showed an association between consonant group and realisation of target consonant/s (X^2 (1, N = 30) = 6.429, p <.05). Inspection of the observed frequencies indicate that realisations of target consonants in initial position are more likely to be correct than those in final position. Classifications for the initial and unusual groups are shown in Table 55.

Consonant Group	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
Initial	17	3	20
Unusual	3	7	10
Total	20	10	30

Table 55 DA: Observed numbers of incorrect and correct realisations of target consonants for the initial group and the unusual group

A Chi-squared analysis showed an association between consonant group and realisation of target consonant/s (X^2 (1, N = 30) = 9.075, p <.05). Inspection of the observed frequencies indicate that realisations of target consonants in initial position are more likely to be correct than those in words where the spelling of the target consonants was unusual. However it should be noted that for two of the words in the unusual spelling group, target consonants were in final position and DA's realisation of these were incorrect.

Comparison of Assessments across Time Points

Elicitation Tasks

The elicitation tasks repeated at 4 time points were as follows:

- Naming
- Sentence Repetition
- Reading Passages
- Retelling Read Passages
- Making up Stories

Each task contained the same set of 40 words that elicited one target consonant or consonant cluster. Transcriptions of the target consonants for all the tasks in the assessments conducted at four different time points were rated using the Rees Rating Scale, as described in Chapter 4. The ratings are summarised here as follows:

The lowest rating (1) was given when the target consonant was omitted or realised as a plosive (“omit/plosive”). The middle ratings (2 and 3) were given when the realisations of the target consonants were progressively closer to the target consonant (“some friction” and “close”). The highest rating (4) was given when the realisation was within the phonemic category of the target consonant (“on target”).

The following figure illustrates the change in ratings over the four time points for each elicitation task.

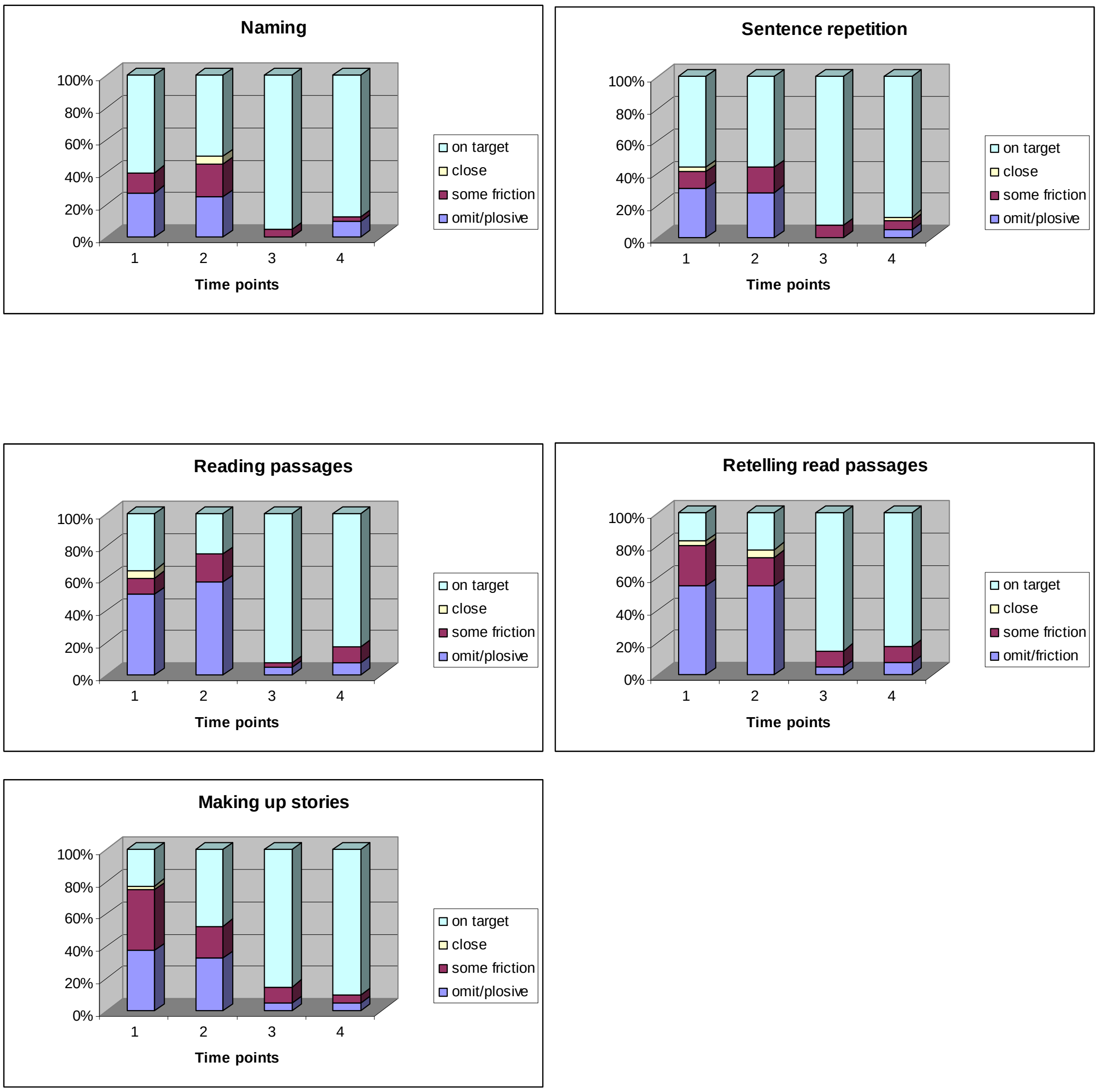


Figure 12 DA: Change in ratings for the five elicitation tasks

For each task the ratings of target consonants in DA’s responses were compared across the four time points using the Friedman test. The results are shown in Table 56.

Task	N	X^2	d.f.	p Value
Naming	40	36.019	3	**<.001**
Sentence Repetition	39	28.019	3	**<.001**
Reading Passages	40	57.810	3	**<.001**
Retelling Read Passages	40	65.734	3	**<.001**
Making Up Stories	40	48.870	3	**<.001**

Table 56 DA: Friedman tests comparing changes in ratings of target consonants for each elicitation task across the three time intervals

As the results for all tasks showed a significant difference the Wilcoxon test (See Table 57) was used to measure any significant changes in ratings for each task during the following intervals:

- Time 1 to Time 2 (T1-T2) (no intervention period prior to intervention)
- Time 2 to Time 3 (T2-T3) (intervention period)
- Time 3 to Time 4 (T3-T4) (no intervention period following intervention).

As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Task	N	T1-T2		T2-T3		T3-T4	
		z Value	p Value	z Value	p Value	z Value	p Value
Naming	40	-0.774	.439	-3.816	**<.001**	-1.734	.083
Sentence Repetition	39	-0.366	.715	-3.508	**<.001**	-1.089	.276
Reading Passages	40	-1.463	0.143	-4.823	**<.001**	-1.179	.238
Retelling Read Passages	40	-0.347	.729	-4.737	**<.001**	-0.744	.457
Making Up Stories	40	-0.288	.022	-3.586	**<.001**	-0.324	.746

Table 57 DA: Wilcoxon tests comparing changes in ratings of target consonants for each elicitation task across each time interval

For all tasks there were no significant improvements for T1-T2 or for T3-T4. However there were significant improvements in ratings for all tasks during the intervention period, T2-T3.

Conversation

The conversation data at each time point consisted of the first two minutes talking time from DA during a conversation with the tester. The child's realisations of all the target consonants and /z/ were rated with the Rees Rating Scale. /z/ was included as the therapy had involved encouraging the participants to realise this consonant accurately. Then consonants rated with 1,2 or 3 were classified as "incorrect" and those rated as 4 were classified as "correct".

The changes in percentages of correct ratings were compared over the four time points (see Figure 13).

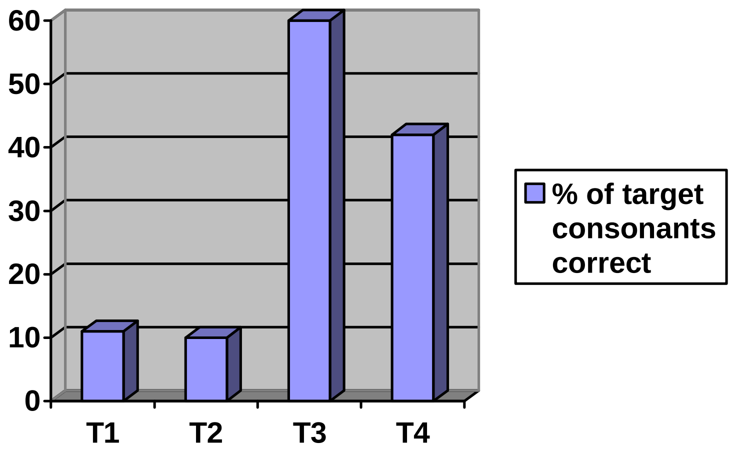


Figure 13 DA: Changes in percentages of target consonants correct during conversation at the four time points

All the classifications of the data from each of the four conversations conducted at each time point were compared using Chi-squared tests.

Classifications for T1 and T2 are shown in Table 58.

Time point	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
T1	6	49	54
T2	6	56	62
Total	12	105	117

Table 58 DA: Observed numbers of correct and incorrect realisations of target consonants at T1 and T2

A Chi-squared analysis showed no association between time point and realisation of target consonant/s (X^2 (1, N=117) = 0.048, p=.827). Inspection of the observed frequencies indicates that realisations of target consonants are not more likely to be correct at T2 than at T1.

Classifications for T2 and T3 are shown in Table 59.

Time point	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
T2	6	56	62
T3	24	16	40
Total	30	72	102

Table 59 DA: Observed numbers of correct and incorrect realisations of target consonants at T2 and T3

A Chi-squared analysis showed an association between time point and realisation of target consonant/s (X^2 (1, N = 102) = 29.657, p <.001). Inspection of the observed frequencies indicates that realisations of target consonants are more likely to be correct at T3 than at T2.

Classifications for T3 and T4 are shown in Table 60.

Time point	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
T3	24	16	40
T4	21	29	50
Total	45	45	90

Table 60 DA: Observed numbers of correct and incorrect realisations of target consonants at T3 and T4

A Chi-squared analysis showed no association between time point and realisation of target consonant/s (X^2 (1, N = 90) = 2.88, p = .09). Inspection of the observed frequencies indicates that realisations of target consonants are not more likely to be correct at T4 than at T3.

Response to Intervention

The structure of the eight therapy sessions and the range of tasks used are detailed in Chapter 6.

From the beginning of the programme DA was producing all the target consonants with a high degree of accuracy in naming tasks. DA found the compilation of summary progress chart (see Table 61) motivating and was always pleased when his percentage of target consonants produced accurately had risen from the week before. During the last two sessions the percentages for all the tasks completed were above 90%. Table 61 shows which tasks were completed at each session and how his ability to produce the target consonants accurately changed over time. It shows that by the end of the intervention period DA was also producing a large number of accurate realisations of the target consonants when speaking between tasks and making speaking asides during the tasks.

SN	% Target consonants correct during tasks							Number of target consonants used correctly outside task
	Single Word Naming	Reading	Retelling Stories	Dictation	Quiz	Card Game	Conver-sation Therapy Task	
1	100	76	-	-	81	-	85	
2	99	79	-	57	-	72	63	
3	100	95	-	33	-	71	77	4
4	-	-	88	83	100	86	90	66
5	-	-	84	-	94	100	100	132
6	-	-	92	100	92	88	73	235
7	-	-	96	-	100	100	91	57
8	-	-	96	-	-	100	94	104

SN = session number - = task not done during session

Table 61 DA: Summary progress chart

Intelligibility / Motivation Questionnaire

Details of the questions and responses to the intelligibility / motivation questionnaire at all time points are outlined in Appendix 13. A summary of this follows:

To describe his overall intelligibility DA chose “Most people understand everything I say” at all 4 time points and so his rating of intelligibility did not change. There were no marked changes in how he rated the degree of difficulty of seven speaking situations over the four time points. In response to “How much would you like to improve your speech?” DA chose the response “I’d like to improve my speech if it’s not too much work.” at all four time points. Therefore his rating of motivation did not change.

Participant MC

Naming Task at T1

Results of the naming task at T1 were used specifically to investigate whether MC’s improved realisations of target consonants in word initial position in naming had generalised to word final position and to words with unusual spellings over the 5 month interval between Phase 1 and Phase 2.
In order to do this the 40 words named at T1 were divided into three groups:

Initial:	20 words with the target consonants in initial position (comprised of 10 words beginning with /s/ or /s/ clusters and 10 words beginning with /ʃ/ or /tʃ/).
Final:	10 words with the target consonants in final position.
Unusual:	10 words where the spelling of the target consonant was unusual.

Table 62 Groups of words at T1

Consonants rated with 1,2 or 3 were classified as “incorrect” and those rated as 4 were classified as “correct”. Realisations of consonants in the initial group were firstly compared to those in the final group and then to those in the unusual group. Classifications for the initial and final groups are shown in Table 63.

Consonant Group	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
Initial	11	9	20
Final	1	9	10
Total	12	18	30

Table 63 MC: Observed numbers of incorrect and correct realisations of target consonants for the initial group and final group

A Chi-squared analysis showed an association between consonant group and realisation of target consonant/s (X^2 (1, N = 30) = 5.625, p <.05). Inspection of the observed frequencies indicate that realisations of target consonants in initial position are more likely to be correct than those in final position. Classifications for the initial and unusual groups are shown in Table 64.

Consonant Group	Realisation of Target Consonant/s		
	Correct	Incorrect	Total
Initial	11	9	20
Unusual	5	5	10
Total	16	14	30

Table 64 MC: Observed numbers of incorrect and correct realisations of target consonants for the initial group the unusual group

A Chi-squared analysis showed no association between consonant group and realisation of target consonant/s (X^2 (1, N = 30) = 0.67, p =.796). Inspection of the observed frequencies indicates that realisations of target consonants in initial position are not more likely to be correct than those in words where the spelling of the target consonants was unusual.

Comparison of Assessments across Time Points

Elicitation Tasks

The elicitation tasks repeated at 4 time points were as follows:

- Naming
- Sentence Repetition
- Reading Passages
- Retelling Read Passages
- Making up Stories

Each task contained the same set of 40 words that elicited one target consonant or consonant cluster. Transcriptions of the target consonants for all the tasks in the assessments conducted at four different time points were rated using the Rees Rating Scale, as described in Chapter 4.

The following figure illustrates the change in ratings over the four time points for each elicitation task.

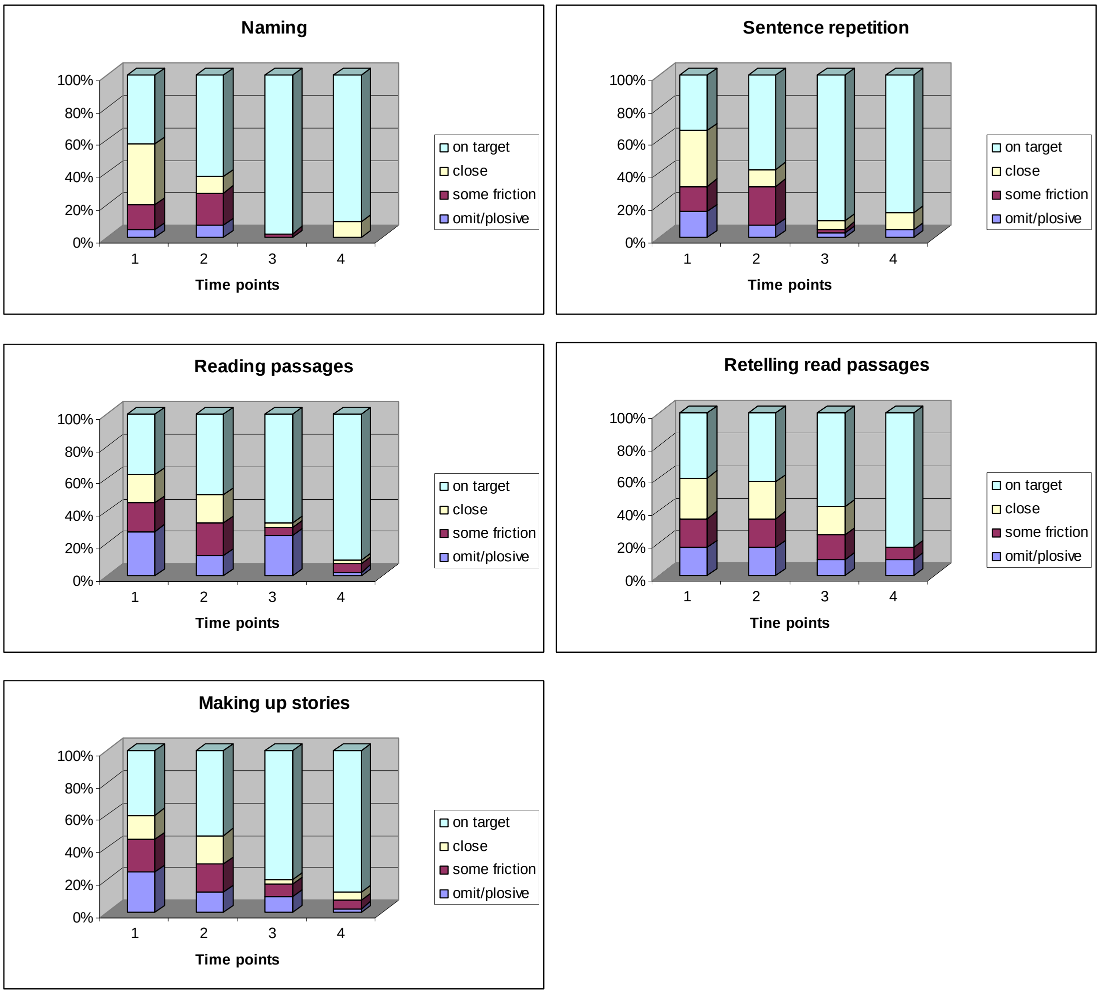


Figure 14 MC: Change in ratings for the five elicitation tasks

For each task the ratings of target consonants in MC's responses were compared across the four time points using the Friedman test. The results are shown in Table 65.

Task	*N*	X^2	d.f.	*p* Value
Naming	40	44.553	3	**<.001**
Sentence Repetition	38	32.731	3	**<.001**
Reading Passages	40	28.953	3	**<.001**
Retelling Read Passages	40	15.458	3	**.001**
Making Up Stories	40	29.314	3	**<.001**

Table 65 MC: Friedman tests comparing changes in ratings of target consonants for each elicitation task across the three time intervals

As the results for all tasks showed a significant difference the Wilcoxon test was used to measure any significant changes in ratings for each task during the following intervals:

- Time 1 to Time 2 (T1-T2) (no intervention period prior to intervention)

- Time 2 to Time 3 (T2-T3) (intervention period)
- Time 3 to Time 4 (T3-T4) (no intervention period following intervention)

As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Task	*N*	T1-T2		T2-T3		T3-T4	
		z Value	*p* Value	*z* Value	*p* Value	*z* Value	*p* Value
Naming	40	-0.623	0.533	-3.354	**0.001**	-1.000	0.317
Sentence Repetition	38	-1.374	0.169	-3.219	**0.001**	-0.586	0.558
Reading Passages	40	-2.265	0.023	-0.247	0.805	-2.637	**0.008**
Retelling Read Passages	40	-0.067	0.947	-1.674	0.094	-1.557	0.119
Making Up Stories	40	-2.452	**0.014**	-2.307	0.021	-1.983	0.047

Table 66 MC: Wilcoxon tests comparing changes in ratings of target consonants for each elicitation task across each time interval

For all tasks there were no significant changes for T1-T2 or for T3-T4, except for an improvement for Making Up Stories between T1 and T2 and an improvement for Reading Passages from T3-T4. There were significant improvements in ratings for two tasks during the therapy period, T2-T3: Naming and Sentence Repetition.

Conversation

The conversation data at each time point consisted of the first two minutes talking time from MC during a conversation with the tester. The child's realisations of all the target consonants and /z/ were rated with the Rees Rating Scale. /z/ was included as the therapy had involved encouraging the participants to realise this consonant accurately. Then consonants rated with 1,2 or 3 were classified as "incorrect" and those rated as 4 were classified as "correct".

The changes in percentages of correct ratings were compared over the four time points (see Figure 15).

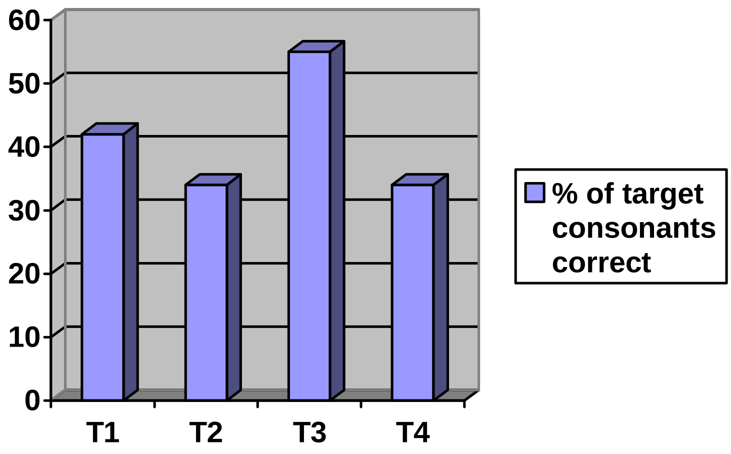


Figure 15 MC: Changes in percentages of target consonants correct during conversation at the four time points

All the classifications of the data from each of the four conversations conducted at each time point were compared using Chi-squared tests.

Classifications for T1 and T2 are shown in Table 67.

Time point	Realisation of Target Consonant/s		
	Incorrect	Correct	Total
T1	37	27	64
T2	41	21	62
Total	78	48	126

Table 67 MC: Observed numbers of correct and incorrect realisations of target consonants at T1 and T2

There was no association between time point and realisation of target consonant/s (X^2 (1, N = 126) = 0.924, p = .337). Inspection of the observed frequencies indicate that realisations of target consonants are not more likely to be correct at T2 than at T1. Classifications for T2 and T3 are shown in Table 68.

Time point	Realisation of Target Consonant/s		
	Incorrect	Correct	Total
T2	41	21	62
T3	33	41	74
Total	78	62	136

Table 68 MC: Observed numbers of correct and incorrect realisations of target consonants at T2 and T3

There was an association between time point and realisation of target consonant/s (X^2 (1, N = 136) = 6.307, p <.05). Inspection of the observed frequencies indicate that realisations of target consonants are more likely to be correct at T3 than at T2.

Classifications for T3 and T4 are shown in Table 69.

Time point	Realisation of Target Consonant/s		
	Incorrect	Correct	Total
T3	33	41	74
T4	29	15	44
Total	62	56	118

Table 69 MC: Observed numbers of correct and incorrect realisations of target consonants at T3 and T4

There was an association between time point and realisation of target consonant/s (X^2 (1, N = 118) = 5.027, p <.05). Inspection of the observed frequencies indicate that realisations of target consonants are more likely to be correct at T3 than at T4.

Response to Intervention

The structure of the eight therapy sessions and the range of tasks used are detailed in Chapter 6.

Since the end of Phase 1 MC's use of the target consonants in naming had deteriorated and so he needed some reminding and practice to improve this skill. By the fifth session he was producing the target consonants accurately in naming 92% of the time. He found the other tasks more demanding. In these tasks he often failed to produce the target sound accurately but when he saw the student therapist's pen move towards the "forgot" column he usually self-corrected successfully (and this second attempt was counted towards the score for the progress chart). He was interested in the compilation of the summary progress chart (see Table 70) and his ability to produce the target sounds accurately did gradually improve for all the tasks. By the last session he was achieving over 85% success for all the tasks and sometimes using the target sounds outside set activities.

SN	% Target consonants correct during tasks							Number of target consonants used correctly outside task
	Single Word Naming	Reading	Retelling Stories	Making Up Stories	Quiz	Card Game	Conver -sation Therap y Task	
1	-	60	62	49	90	-	59	
2	79	63	72	67	98	-	69	
3	-	59	68	76	100	-	58	
4	-	67	78	78	100	-	40	
5	92	56	78	68	-	-	72	
6	-	65	92	77	-	-	92	66
7	100	71	100	87	-	-	68 (with teache r)	75
8	-	96	100	87		86	92	91

SN = session number - = task not done during session

Table 70 MC: Summary Progress Chart

Intelligibility / Motivation Questionnaire

Details of the questions and responses to the intelligibility / motivation questionnaire at time points T1, T3 and T4 are outlined in Appendix 13. (Use of the questionnaire was accidentally missed at T2) A summary of this follows:

To describe his overall intelligibility MC chose "Most people understand everything I say" at T1 but at T3 and T4 he chose "Family, teachers, friends and strangers understand everything I say". He rated 6 out of 7 speaking situations as being "very easy" at T1 and rated all of them as being "very easy" at T3. At T4 his ratings had dropped to "quite easy" or a "bit difficult" for 4 of the 7 situations and the others remained at "very easy". In response to "How much would you like to improve your speech?" MC chose three different responses. At T1 he chose "Sometimes I think I'd like to improve my speech but I can't be bothered to change it". At T3 he chose "I really want to improve my speech and will work as hard as I can". At T4 he chose "I'd like to improve my speech if it's not too much work".

Summary

An analysis of the results of naming tasks at T1 indicated no evidence that either participant had generalised their use of improved realisations of target consonants from word initial position to word final position during the 5 month interval between Phase 1 and Phase 2 of this study. Realisations of target consonants in word initial position were more likely to be correct than those in final position. The effects of unusual spellings on generalisation were not clear. MC seemed to have been more successful at generalising accurate realisations to unusual spellings in that his realisations of target consonants were not more likely to be correct in word initial position in usual spellings than in words where the spelling of the target consonant was unusual. DA's realisations were less likely to be correct for unusual spellings. /s/ and /tʃ/ were not realised accurately in any of the seven words with unusual spellings of these consonants. The remaining three unusual spellings of /ʃ/ (**s**ugar, sta**t**ion, ti**ss**ue) were realised accurately but it should be noted that DA had some success in realising /ʃ/ accurately before Phase 1.

The degree to which speech skills acquired during Phase 1 of the study generalised to spontaneous speech as a result of the intervention programme in Phase 2, and were maintained after intervention, differed for the two participants. For DA, ratings of the target consonants improved significantly for all the speaking tasks during the intervention period, including conversation. At T2 DA was realising only 10% of target consonants accurately during conversation and this figure rose to 60% at T3. For all the speaking tasks there was no significant change in production between the other time intervals, indicating that generalisation had taken place during intervention and had been maintained during the 5 weeks following intervention. For MC, ratings of target consonants improved significantly during the intervention period for naming, sentence repetition and conversation but not for reading, retelling passages or making up stories. Two other significant improvements took place: between T3 and T4 for reading and between T1 and T2 for making up stories. The ratings for retelling read passages did not show any significant improvement. In conversation, although there was a significant change in accuracy of the target consonants between T2 and T3 (from 34% to 55%) there was a significant deterioration between T3 and T4 (from 55% to 34%) indicating that the improvement had not been maintained.

During intervention both participants responded well to therapy techniques that encouraged them to plan ahead and provided feedback and rewards for accurate production of target consonants. MC's performance in the formal tests at T3 and T4, where he was given no encouragement and no rewards for accurate production, differed greatly from his more successful performance during the last three final intervention sessions, where he realised target consonants accurately between 65% and 100% of the time.

DA's responses to the intelligibility / motivation questionnaire were consistent and indicated a moderate level of motivation, choosing "I'd like to improve my speech if it's not too much work" in answer to "How much would you like to improve your speech?" at all four time points. MC's responses were more inconsistent. At T1 he chose "Sometimes I think I'd like to improve my speech but I can't be bothered to change it". At T3 he chose "I really want to improve my speech and will work as hard as I can". At T4 he chose "I'd like to improve my speech if it's not too much work".

Addendum

Results from Phase 1 and Phase 2 seemed to indicate that DA was using an orthographic strategy to generalise his newly acquired speech skills. His input skills made minimal improvements in Phase 1 and so could not fully explain the improvement in his speech output skills and their transfer to words that were not used in intervention. Therefore it is possible that he was thinking of the orthography of the words he was about to say and then using his knowledge of grapheme-phoneme links and how to produce the phoneme in a more accurate way. During the intervention in Phase 2 he often had to be helped to apply his new speech skills to unusual spellings. The deliberation involved in his application of new speech skills at the end of Phase 2 suggested that he was still using this orthographic strategy, even in conversation. When he was asked how he was remembering to say words in the new way he just shrugged his shoulders. This is to be expected, as children of this age may not have the insight to explain the strategies they are using to generalise speech skills. Therefore this hypothesis about using an orthographic strategy to generalise speech skills was explored in an interview with JD, a 45-year-old deaf adult who had a severe hearing loss and intelligible speech. She was interviewed about how she had learnt to speak.

JD reported that she had always been highly motivated to improve her speech skills. For the first 18 years of her life she didn't use hearing aids and so heard "mainly vowels". When asked how she had learnt how words should be said she reported that she relied mainly on lipreading and then used the written form to fill in the gaps. A transcript of a section of the interview follows:

JD: / once I learnt to read I knew which sounds were in the words/ and I remember thinking that English was a very difficult language to learn because there were so many/ there were rules/ but so many exceptions to the rules/ illogicalities I call them/ so I would have to remember the rules/ and remember the illogicalities as I called them then/ the exceptions to the rules/ so I would have/ and still have in my head a running/ not quite a commentary/ it's almost like a reel in front of me/ where I'm preparing for what I'm trying to say/ and trying to remember all the sounds that come in that I need to pronounce in the words/

RR: / so you mean when you're speaking/ even now/ you're kind of seeing the written form/ in front of you/

JD: yes/ I still/ if I'm thinking about it/ see the written form/ and/

RR: / if you're thinking about it/ but you don't do that all the time/

JD: / I do it a lot less now than I used to/ right/ if I'm thinking about my speech/ if I'm just chatting I don't worry about it/ but I do notice when I don't pronounce things properly (meaning that she picks up non-verbal signals in the listener that indicate this)/ then that makes me aware that I haven't said it properly and I'll start to have this written form in my mind so I can see what I'm about to say/ so I make sure I put in the sounds/

(then later, when talking about how she had learnt to pronounce "x" as /ks/at the ends of words 10 years ago)

JD: I had to remember how it felt/ I still have to remember how it feels/ /ks/ /eks/)/ I don't like it/ it feels very unnatural/

RR: / you're not used to saying it like that/

JD: / that's right/ it feels strange and I – ergh – want to trip over myself/ but I know how to say "fox" now/ so I try really hard to remember for all those "x" sounds to put them in/

Chapter 9: Discussion

Speech difficulty, of no known etiology, encountered by hearing children is generally attributed to difficulties with auditory processing, oro-motor skills or cognitive-linguistic processing (Dodd, 2005). Recent evidence suggests that, for the majority of these children, who consistently use non-developmental error patterns, the speech difficulty is most often associated with difficulties in cognitive-linguistic processing (Dodd & McIntosh, 2008). The speech difficulties of deaf children are generally associated with auditory processing problems, although these may lead to the absence of consonants in the phonetic repertoire and difficulties in marking phonological contrasts. As discussed at the end of Chapter 2, the role of auditory and visual processing in the speech development of deaf children is not well understood and neither is the way in which they may use alternative strategies to update lexical representations. It is possible that some deaf children may additionally have difficulties encountered by the minority of hearing children who have significant speech difficulty.

This final chapter begins with what has been learnt from the whole study into deaf children's speech processing, particularly lexical representations and how they are updated. Evidence from each stage of the study, and how it led on to subsequent research questions (summarised below), is discussed in terms of comparison with other studies and implications.

Preliminary testing indicated that, as predicted, relationships between input skills, lexical representations and output skills varied for different consonant contrasts in the same deaf child and for different deaf children. Different types of profiles emerged for the range of contrasts tested. For contrasts that were marked accurately and consistently in naming, input skills were found to be intact. One unexpected profile involved evidence of lower level speech discrimination for a contrast (e.g. /st/ - /d/) in nonword discrimination tasks, despite no evidence of using this skill to reject inaccurate productions of words including the target consonant/s in tasks requiring access to phonological representations (e.g. rejecting /dɑ/ as a label for the picture of *star*). Other unexpected profiles involved evidence of motor ability to produce the target consonant, albeit inconsistently, in naming and/or repetition tasks, despite evidence of impaired input skills.

Observations of these different profiles at this stage suggested that the ability to detect a target consonant using hearing and/or lipreading was not necessarily related to the specification of that consonant in lexical representations or the production of that consonant in naming tasks.

Phase 1 of the main study aimed to explore what factors determine the specification of target consonants in lexical representations. Evidence from initial testing in this phase indicated that various factors led to their formation: hearing, lipreading, phonological awareness and knowledge of orthography and phoneme-grapheme links. This finding supported explanations offered for the results of other studies including those by Dodd (1976), Campbell (1992) and Leybaert (1993).

The intervention programme in Phase 1 aimed to explore further the contribution of these various factors to the updating of lexical representations when acquiring new speech skills. Evidence from this stage of the study suggested that input skills had played a limited role in comparison with other factors such as knowledge of orthography and phoneme-grapheme links. The additional roles of motor skills and tactile-kinaesthetic feedback were highlighted as being important in the acquisition of new speech skills. There was some evidence to suggest that the development of these skills could influence the ability to detect target consonants. This calls into question the assumption that the motor program depends on the phonological representation for its own specification (Stackhouse & Wells, 1997). A two-way connection between input and output stores would be a better explanation. The ability of participants to transfer newly acquired speech skills in naming to non-therapy words suggested that they were not updating output programs on a word-by-word basis. A better explanation would be an improvement in selecting updated speech segments for a transient output store that was aided by knowledge of phoneme-grapheme links and/or improvements in speech perception.

Evidence from Phase 1 suggested that, although participants had updated lexical representations, these changes were not firmly established as the use of newly acquired speech skills was not automatic in spontaneous connected speech. Therefore the two single case studies of Phase 2 explored the processes that may increase automaticity when new speech skills are used. Evidence from both case studies suggested that repeated practice of motor patterns and use of feedback to aid motor planning helped to increase this automaticity to the extent that participants used their new speech skills in conversation in intervention sessions. Evidence from one case indicated that the participant (DA) was accessing the orthography of what he was about to say in order to generalise speech skills and that he could eventually do this, even when conversing at an acceptable rate of speech. Differences in degree of success in generalising speech between DA and MC could be explained by levels of motivation or that DA, who made more progress, had a superior cognitive-linguistic processing ability. In both cases informal observation suggested a lack of generalisation to everyday speech, which may have been associated with limited levels of self-motivation and/or insufficient practice in applying the newly learnt skills.

Evidence from all stages of the study are combined with a reflection on a range of relevant theories and models in order to review the Stackhouse and Wells model (1997) and suggested a revised model.

The chapter then discusses the effectiveness of the intervention programmes and evaluates aspects of the whole study in terms of their general quality and effectiveness. Implications for clinical and educational practice are discussed. Finally, areas warranting further research are outlined and concluding remarks are made.

Evidence from Preliminary Testing

This study began with the belief that a psycholinguistic approach to the investigation of deaf children's speech would provide useful information on the processing of consonant contrasts that are not marked appropriately in speech. It was decided to base the approach on individual consonant contrasts, as previous research in this area (Ebbels, 2000) had indicated that psycholinguistic profiles varied across consonant contrasts.

A novel assessment procedure (the Rees Coleman Profiling Procedure) was devised that was driven by the theoretical speech processing model developed by Stackhouse and Wells (1997) as this was already being used successfully with hearing children in the UK (Constable et al., 1997; Forth et al., 1996; Vance, 1997). A bank of tests with matched items was designed for a range of consonant contrasts in order to provide information about:

- lower level speech discrimination between the target consonant/s and incorrect realisations (where lexical representations were unlikely to be accessed),
- the integrity of phonological representations of words beginning with the target consonant/s,
- the integrity of motor programmes for words beginning with the target consonant/s and
- the motor execution of the target consonant/s.

The phonological representation was defined as being the information stored about a spoken word that enables it to be identified on the basis of auditory and lipreading cues and the motor program was defined as being the stored set of instructions for the pronunciation of the word (Stackhouse & Wells, 1997). The tests were designed to focus on the specification of the target consonants in these two types of representations.

Although the procedure was similar to that developed by Ebbels (2000), it was novel in being computer-based, designed to be used by a large number of deaf children and had audio-visual (AV) and audio-alone (AA) conditions for all the input tests.

The use of this procedure with six deaf children revealed that psycholinguistic profiles varied across children and across the consonant contrasts tested. Profiles emerged, each with a different combination of loci of difficulty.

For three of the participants tested (HA, FI and KC), input processing profiles were obtained for the contrast /p/-/b/, which all three were marking with 100% accuracy in naming tasks. This was done in order to learn something about the way in which a contrast marked successfully in output was processed. Each participant was able to discriminate this contrast in the AA and AV conditions in all the input tasks. This was in line with the expectation that input skills were fairly important for acquiring the ability to mark a contrast in speech output. Interestingly the percentage of accuracy in marking the contrast in repetition tasks (as opposed to naming tasks) ranged from 75-100%. This may indicate that these three participants' input skills were good enough for them to have developed accurate phonological representations, and that they had adequate motor execution skills to produce the contrasts, but that one or other or both of these skills were not strong enough for them to consistently recognise and reproduce the contrast in repetition tasks.

One of the identified profiles involved evidence of intact lower level speech discrimination (e.g. discriminating /stip/-/dip/ in a same/different task) with no evidence of ability to reject inaccurate productions of target words (e.g. not rejecting /dip/ as a label for *steep* in a picture yes/no judgement (PYNJ) task) in the AV or AA conditions. This could imply an incomplete phonological representation for the word *steep*, where /s/ is not accurately specified. This profile was found for the /st/-/d/ contrast for participant AE and the three following contrasts for KC: /sm/-/m/, /ʃ/-tʃ/ and /s -/d/.

The difference could not be explained by an increased demand on working memory as the same/different task involved making a judgement about two syllables in working memory whereas the PYNJ task involved making a judgement about one syllable (as all the stimuli contained one syllable). Another possible explanation is that the use of the picture in the task was encouraging the child to tolerate phonological variations, even though their phonological representation was well-specified. (This is discussed further in the section on Evaluation of the Study.) The PYNJ task included control items that were relatively easy to discriminate. In each case these were discriminated easily by the two participants, demonstrating that they understood the task procedure. Adequate input skills were inferred if performance on a task could not be explained by the chance factor. This could be problematic in that the difference in raw scores between an above chance performance and a chance performance could be minimal. For KC's /s/-/d/ contrast the difference in raw scores was minimal with the percentage difference in the raw scores being only 7% for the audio-alone condition and 2% for the audio-visual condition. However, in the three other cases where the profile occurred, the percentage difference was at least 13%. For example, the participant AE scored 23/24 and 22/24 for the Real Word Same/Different tasks for /st/ - /d/ and scored 10/24 and 15/24 for the Picture Yes No Judgement tasks with matched items.

Even though this profile may not be common, it may be important to identify it. The distinction between perception of speech segments and the recognition of words, and the links between them, is reflected in speech processing models such as the Stackhouse and Wells model (Stackhouse et al., 1997) and considered in the context of deafness (Bernstein & Auer, 2003). However, the link is usually discussed in terms of how difficulties with lower level discrimination lead to problems in forming accurate representations of words. Stackhouse and Wells (1997) discuss how perceptual skills are needed to lay down accurate phonological representations, and Bernstein and Auer (2003) note that word recognition tends to be more difficult for deaf people when perception of segments is problematic. It may also be important to consider a situation where the ability to perceive and discriminate segments has improved, due to cochlear implantation or more effective hearing aids, and yet phonological representations of words in the lexicon, formed prior to improved perception, remain inaccurate. If implanted children continue to have difficulty with particular consonant contrasts, it may be useful to investigate whether this can be explained by underspecified phonological representations despite good auditory discrimination skills. The strength of such a hypothesis is increased if tests used to tap the two levels contain matched items (as in the Rees Coleman Profiling Procedure). It is important to use a test that effectively assesses the integrity of phonological representations and it may be better to use a test that does involve lexical decision but does not use pictures. (For further discussion, see section on Evaluation of the Study).

Studies investigating speech input skills with deaf children following cochlear implantation tend to include assessments that involve accessing lexical representations but not assessments that investigate lower level discrimination of matched words or nonwords (e.g (Sarant, Blamey, Dowell, Clark, & Gibson, 2001; Berguson et al., 2002; Kirk et al., 2002). For example, children are asked to demonstrate their recognition of words by pointing to pictures in a minimal pairs task and/or a closed set task (where they have to access lexical representations) but they are not asked to complete same/different tasks with the same pairs of words or matched nonwords (where they are less likely to access their representations).

Three identified profiles involved evidence of motor ability to produce the target consonants, albeit inconsistently, in naming and/or repetition tasks, despite evidence of impaired input skills. For example, the participant AK produced /sn/ accurately 63% of the time in naming and between 25 and 50% of the time in repetition tasks, despite not achieving an above chance performance in any of the input tests for /sn/- /n/. These profiles were found for some or all of the contrasts tested for *all* participants. These identified profiles indicated that participants had learnt to use these consonants some of the time, despite having difficulty in recognising them in input tasks. Their performance on the input tasks varied and tended to be better in the AV condition. However, there were eight cases where children were producing target consonants accurately some of the time despite no evidence of input skills in *any* of the tasks (2 contrasts for HW, 3 contrasts for AK, 1 contrast for HA and 2 contrasts for KC). This suggests that deaf children may be able to acquire output speech skills for consonants they are unable to recognise in either the AA or AV condition. It is possible that they may have recognised the presence of the consonants in connected speech, as this was not tested. Often there are more cues available in connected speech such as a break in voicing to indicate the presence of /s/ in the utterance “a smile”. None the less it seems that deaf children can learn to produce consonants accurately when they have difficulty in detecting them in some contexts.

These differing patterns suggested that the ability to detect a consonant was not necessarily related to the specification of that consonant in lexical representations or the production of that consonant when naming. Phase 1 of the main study was set up to explore what factors may determine the specification of target consonants in representations.

Evidence from Initial Testing in Phase 1

The Role of Hearing

Consonants that the three participants had difficulty realising in speech output were classified according to the participants' ability to detect them in the following tasks from the Rees Coleman procedure: Nonword Discrimination (NWD) and Picture Yes/No Judgement (PYNJ), both in the Auditory Alone (AA) and Audio-Visual (AV) conditions.

The number of target consonants in the "Auditory Full" group (evidence of AV and AA skills for NWD and PYNJ) was related to degree of hearing loss. MC (AHL 53 dB) had eight out of nine targets in this group, whereas JB (AHL 71dB) had four out of eight targets in this group and DA (AHL – 91dB) had two out of nine targets in this group. This is not surprising for, as level of hearing loss increases, access to auditory speech signals decreases and, when a loss is severe or profound, increasing the amplitude of the signal with amplification does not always restore this access (Bernstein et al., 2003). DA and JB found it easier to detect the presence of /s/ in the AA condition when the consonant was followed by a continuant rather than a plosive. This does not imply that /s/ was heard as it may be heard by a hearing person and the difference detected could have been a change to the acoustic properties of the second consonant. The preceding /s/ could have modified the continuant in some audible way (for example, in terms of duration or formant transition) which did not arise for a following voiceless plosive (personal communication with Andrew Faulkner, UCL). None the less, some acoustic feature of /s/ or its influence on the acoustic nature of the following phoneme was detected in some contrasts for some tests. JB was able to detect /f/ in all tests in the AA condition and so was detecting some of its acoustic features or its influence on the acoustic features of the following phoneme in the same way. MC, who had a moderate hearing loss, was able to detect /s/ and /ʃ/ in all tests in all conditions and only had difficulty in detecting /tʃ/ in the Picture Yes/No Judgement task in the AA and AV conditions.

Therefore, depending on degree of loss, hearing had played a part in the development of phonological representations for all three participants.

The Role of Lipreading in Updating Phonological Representations

The input tests conducted with the Rees Coleman procedure for the main study indicated that only the deafest participant (DA – AHL 91dB) showed an advantage for the AV condition. For the two participants with more hearing (JB – AHL 71dB, MC –

AHL 53dB), performance in the AV condition was the same as that in the AA condition for all input tests, in that the scores for the each test were either at chance in both conditions or above chance for both conditions. However, for the deafest subject DA, performance was better in the AV condition than the AA condition for PYNJ for /sp/-/b/, /sm/-/m/ and /sk/-/g/ (three of the eight contrasts tested). For these contrasts, performance in the AA condition was at chance and the AV condition raw scores were 16/16, 16/16 and 14/16 respectively. This provides further evidence for an assertion made by Bernstein, Demorest and Tucker (2000) that was contrary to previous findings by other authors that hearing impairment is not associated with enhanced visual speech perception. Bernstein et al (2000) explained this discrepancy by noting that previous studies were conducted with individuals with acquired hearing loss or congenital hearing losses that were less severe than the losses of students in their study. In the Bernstein et al study the lipreading ability of 72 deaf students (aged 18-41 years) was compared with the lipreading ability of 96 students with normal hearing (aged 18-45 years). The majority of the deaf group had pure tone average hearing losses of 80dB or greater in their better ear. The results indicated greater sensitivity to visual phonetic information in the deaf group and when audiological records available for the deaf group, who scored in the upper quartiles on all measures, were examined, four of the participants had audiometric pure tone thresholds of 100 dB HL or greater. DA was able to make good use of acoustic cues for some contrasts (/sw/-/w/ and /sn/-/n/) indicated by his above chance performance in the AA condition as well as the AV condition. For other contrasts (/sp/-/b/, /sk/-/g/) , where acoustic cues were not adequate but he was able to make use of visual cues, his performance was above chance in the AV condition only. However, for the remaining contrasts (/s/-/d/, /st/-/d/, /ʃ/- /tʃ/), where he found insufficient visual information, he was unable to discriminate minimal pairs, even in the AV condition. These findings illustrate Massaro’s point that, when deaf people are integrating audio and visual information, the least ambiguous source of information is likely to have the most influence (Massaro, 1998; Massaro, 1998) and, for DA, when both sources of information were ambiguous, he was unable to make distinctions.

DA's pattern of performance provides further evidence for the observation made in the study by Berguson et al. that speech performance in deaf children is generally better under an audiovisual presentation (Berguson et al., 2001). However, as that study indicated, visual phonetic speech perception abilities vary across deaf subjects. Therefore, other deaf children with the same degree of hearing loss as DA would not necessarily be combining visual perception with auditory perception so successfully. Four of the participants tested during the development of the Rees Coleman procedure had similar degrees of hearing loss to DA (AE – AHL 86dB, HW - AHL 95dB, HA - AHL 83dB and KC - AHL 80dB). Of these four, AE and HA showed improvement in the AV condition for nonword same/different discrimination tests. KC's performance on the input tests varied but, for each test, there was no difference between performance in the AV and AA conditions. HW performed at chance level for all input tests in both conditions. Degree of hearing loss alone does not seem to determine ability to benefit from lipread information. Harris and Moreno (2006) found that two groups of children matched for degree of hearing loss and non-verbal intelligence varied in their ability to lipread. Lesser degrees of hearing loss could explain the lack of improvements in the AV condition for the other participants in the main study: JB and MC. Having more access to auditory signals, they could be less likely to rely on lipreading in general. MC, who had a moderate hearing loss, could distinguish all but one contrast for all tests in the AA condition. JB may have been less skilled at lipreading due to his problems with vision and/or his moderate learning difficulties. Elphick (1996) conducted a study comparing the lipreading skills of deaf and hearing students and noted that, although the variation in speech reading skills amongst the majority of the deaf participants seemed unrelated to nonverbal IQ, this was not the case for five of the 57 deaf participants who had moderate learning difficulties. The mean percentage scores for the lipreading tasks of this group were notably lower than the total group mean.

It seems likely that lipreading had not played a major role in the development of phonological representations for JB or MC. DA seemed to have been dependent on lipreading for the specification of certain segments of phonological representations. Harris and Moreno (2006) noted that the phonological code that is used by deaf children is likely to be different from the code used by hearing children as it may reflect distinctions that are unique to lipreading. Some of these distinctions are those that are also clearly visible to hearing people, such as place of articulation between labio-dental, bilabial and dental consonants. Other distinctions may be “invisible” to people with good hearing (Campbell, 1996). Summerfield (1991) gives the following example of this phenomenon: the distinction between a seen /m/ and a seen /p/ might be in the visible difference in speed and acceleration of cheek puffing in the two consonants. Since hearing people can easily detect the difference between these two consonants from the acoustic stream this visual difference may not be noticed. However a deaf person more reliant on lipreading may notice this distinction (Campbell, 1996). Studies comparing the silent lipreading abilities of hearing and deaf adults have found significantly superior lipreading skills in the profoundly deaf group (Elphik, 1996; Mohammed, Campbell, Macsweeney, Barry, & Coleman, 2006) and so it is likely that deaf children could be detecting facial movements not noticed by hearing children.

Therefore codes used by DA for some segments of phonological representations could have been developed on the basis of detailed lipread information.

The Role of Lipreading in Updating Motor Programs

As previously pointed out, DA may have coded some segments of his phonological representations in a unique way due to the nature of lipreading. Any unique features could influence the corresponding motor programs in the lexicon. According to Stackhouse and Wells (1997), the motor program depends on the phonological representation for its own specification as it encodes the gestures that are required to produce the word in such a way that it will be distinctive from other words in the child's vocabulary. When a child notices a difference in words that is stored in the phonological representations the child will try to replicate this distinction in their own speech. This production will be partly limited by the child's motor skills but also by the ways in which the child has made the distinction through the input channels.

Deaf children have the potential to produce, sequence and combine the phonemes of English, as the speech processing components of motor execution and motor programming are likely to be intact (Stackhouse et al., 1997). However, their production of phonemic contrasts and sequences of sounds will be affected by the way they have originally perceived them. If they are not able to perceive a contrast in any way, they may make no effort to produce the contrast. If they have perceived the contrast with more reliance on lipread information, the contrast may be produced in an alternative way that marks the visual difference but not in a way that is easy for the hearing listener to distinguish. For example, Parker (1999) gives examples of deaf children realising labio-dental fricatives as labio-dental plosives (e.g. /f/ → [p̪]) so that the /p/-/f/ contrast is realised as [p] - [p̪]. She also gives examples of deaf children producing silent articulations (e.g. /m/ → [(b)]) where a lip closure is made and released with no audible sound.

This phenomenon was also observed in DA and MC. During the PETAL naming test (Parker, 1999) DA consistently realised /f/ as [p̪] and /v/ as [b̪] and MC realised the word "purse" as [pɜh͍] where the liprounding for the vowel changed to a lipspread position to accompany the final fricative, which was barely audible. The identification of these examples relied on good observation skills in the transcriber. It may well be the case that deaf children are indicating phonemic contrasts by producing subtly different motor movements that are not evident to any hearing transcriber, no matter how skilled. This may be related to the distinctions in facial movements that are observed by some deaf people when lipreading but “invisible” to hearing people (Campbell, 1996). Experiments conducted with hearing children with speech difficulties indicate that they are sometimes making phonemic “covert contrasts” in their speech output that are only detected with instrumentation such as electropalatography (Gibbon, 1990) and spectrographic analysis (Scobbie, Gibbon, Hardcastle, & Fletcher, 1997; McGregor & Schwartz, 1992).

In a similar way, a deaf child relying partly on lipreading skills could be trying to signal some differences in phonemes by making motor movements that are not audible and/or intelligible to hearing people. Therefore a deaf child with good lipreading skills will not necessarily be more intelligible than a child with poor lipreading skills. This could explain the findings that, although literacy success and lipreading are related, neither is related to speech intelligibility (Harris & Moreno, 2006). A deaf child’s speech intelligibility is strongly associated with degree of hearing loss (Conrad, 1979). For some deaf children, it seems to be associated with ability to access phonology when reading and spelling. In the experiments reported in Leybaert (1993) deaf participants with poorer speech intelligibility showed less evidence of using a phonological code when reading than both deaf participants with good intelligibility and hearing participants. Hanson (1986) found that deaf students rated as having good speech intelligibility were more sensitive to spelling-sound regularity than were students with poorer speech intelligibility. However, other studies have found that speech intelligibility was not associated with speech reading or literacy skills. Even though the nine good readers in Harris and Moreno’s study had significantly superior speechreading skills to the poor readers, there was no difference between the groups in terms of speech intelligibility using a 5-point rating scale (Allen et al., 1998). This scale has five categories, ranging from “no words being intelligible to even someone familiar with the child” (1) to “connected speech being intelligible to all listeners” (5). The range and spread of ratings in both groups was remarkably similar and the mean for *both* groups was 2.3. Also speech intelligibility was not related to any of the other measures used: those for reading, spelling, or orthographic awareness (Harris et al., 2006). A study conducted by Leybaert in 2000 demonstrated that a group of 28 profoundly deaf children aged 6;8 years – 12;2 years, who had been exposed to Cued Speech at home from a mean age of 18 months, had spelling patterns that were comparable to a matched group of hearing children, indicating well specified phonological representations. However the speech intelligibility of this group varied according to a 6-point rating scale used by teachers. This scale ranged from “very poor" (1) to "perfect" (6). The range for this group of deaf children was 1 to 5 with a mean of 3.8.

The Role of Phonological Awareness and Orthography

For most deaf children, until they learn to read, the development of their phonological representations is dependent on speech that they can hear and lipread. However, once they develop some explicit phonological awareness, learn phoneme-grapheme links and begin to read, they have the possibility of using these skills to update phonological representations.

Studies conducted by Dodd (1976) led her to suggest that deaf children may use information from written representations as well as hearing and lipreading in order to form the phonological systems that influence speech output. It is useful to consider whether other more recent research evidence suggests that deaf children can use this third source of information and then consider whether this was the case for any of the participants prior to intervention.

Deaf children's ability to make links between phonology and orthography is usually investigated in studies that examine the use of phonological coding in reading and spelling tasks. The relevant parts of these studies will be reviewed in order to explore whether deaf children can use the links in this direction. Then the possibility of using the links in the reverse direction will be discussed.

Evidence indicates that profoundly deaf children do use phonological coding when reading and spelling (Campbell, Burden, & Wright, 1992; Dodd, 1987; Hanson & Fowler, 1987). Furthermore, access to speech sounds associated with letters can be fairly automatic. In reporting on a study conducted with Lovegrove, Dodd (1987) found that the deaf participants, like the hearing participants, when asked to check a piece of written text and cancel out every occurrence of the letter G, tended to miss "silent" Gs in words such as "night". The mean percentage of the 52 silent Gs missed was 25 for the group of 10 deaf children trained by total communication (aged 10 to 17 years) and 25.2 for the group of ten hearing controls (aged 12 to 13 years). Further evidence for this automatic access to phonology comes from experiments conducted by Leybaert and Alegria (1993). Tasks concerned with the Stroop Colour Word phenomenon were conducted with deaf and hearing participants. The deaf participants with intelligible speech, like the hearing participants, took longer to name the colour of a written word if it spelt out the name of a different colour or a nonword that would be pronounced in the same way (e.g. the word VERT (green) and nonword VAIRE both written in pink). The last experiment compared nonwords homophonic with the colour name (e.g. VAIRE), with nonwords not homophonic with the colour name but having a similar orthography (e.g. VOURE), in terms of the time taken to process the colour of the print. Both deaf and hearing subjects showed longer reaction time and made more errors with the homophonic nonwords. This strongly suggests that the links made between orthographic representations and phonological representations were sub-lexical as well as lexical (Leybaert & Alegria, 1993). In other words, links were made between segments of the orthographic representations and segments of the phonological representations as well as between the whole forms of the orthographic and phonological representations. Some deaf students also seem to be able to utilise these sub-lexical links in spelling. Campbell et al (1992) found that a group of profoundly deaf teenagers was highly sensitive to spelling regularity when asked to write the name of a presented picture, as their spelling of regular words (e.g. "spring") was better than their spelling of irregular words (e.g. "choir") and their errors confirmed this highly "alphabetic" pattern (e.g. "*skwrl*" for "squirrel"). Campbell et al (1992) noted that the deaf participants' spelling was better than expected given their reading age.

A recent functional magnetic resonance image study comparing deaf and hearing adults indicated that, in deaf readers, there was higher activation in the brain regions required for rule-based letter-to-sound conversion during lexical and rhyming decision tasks (Aparicio, 2007). Aparicio et al (2007) suggested the explanation that hearing participants, where possible, used a strategy linking whole lexical forms whereas the deaf participants tended to overuse the more indirect strategy of linking sub-lexical forms, even when it was less efficient to do so. They suggested that this indirect strategy may allow deaf readers to overcome poorly specified phonological representations. The deaf adults in this study used hearing aids and communicated orally, but they were profoundly deaf and so were likely to have incomplete phonological representations for a large number of words.

In summary, a hearing loss, even a profound one, does not preclude deaf people from using phonological coding when reading and spelling and could even lead to a stronger reliance on sub-lexical links between stored phonological and orthographic forms. These links could potentially work in both directions so that deaf children could use information from reading and writing to enhance their phonological representations. Hearing children usually have intelligible speech and, generally, well-formed phonological representations when they begin to learn to read. However, deaf children often begin to learn to read when many of their phonological representations are impoverished opening up the possibility that they could use knowledge gained from reading to enrich their representations. As stated by Perfetti and Sendak (2000):

> "Experience with reading English could lead to richer representations of phoneme-grapheme correspondences and phonological representations more generally." (p45)

Campbell et al (1992) note that the phonological skills of deaf children seem to resemble those of reading-age, not real-age hearing controls suggesting that:

> "experience with reading and writing has generated the phonological skills that the deaf child shows." (p188)

Studies conducted by Leybaert and Alegria (1995), reported in Alegria (1998) showed that the role played by phonology in spelling tasks completed by deaf participants increases with age. One explanation for this is that the phonological representations improve with age and may be influenced over time by information gained from reading and spelling.

Leybaert (1993) noted that deaf people's dependence on reading and writing to develop phonological representations may lead them to develop non-standard phonological representations derived from orthography. She describes some incidental observations made during experiments that provide evidence for this, namely that deaf teenagers assigned regularized pronunciations to irregular French words, even in naming tasks. For example, they generally named a drawing of the word "tabac" as [tabak] even though it is an irregular French word that is pronounced as [taba].

Therefore it seems that deaf children can use their developing literacy skills to enrich their phonological representations and some may be more reliant on this source than hearing children. Was there evidence of this process in the three participants of the main study?

DA had age-appropriate literacy skills and teachers reported that he could use phonic strategies when reading. When tested for letter knowledge at T1, he gave names and sounds for all the consonant graphemes and, when shown the grapheme "s", he named it as [eʔh] and gave its sound as [dəʔ]. Therefore it seems that he was able to use phoneme-grapheme correspondence when reading. Reading and spelling were not tested at any of the time points, but his teachers reported that he used the grapheme "s" correctly when spelling words beginning with /s/, even though he did not produce the consonant when reading. Given DA's difficulties with speech discrimination in the AA condition and his ability to use phonics and spell, it is highly likely that he had relied partly on his literacy skills, as well as hearing and lipreading, to develop phonological representations. At T1 he named a picture of “stomach” as [dʌməʔʃ]. This is an example of the probable effect of non-standard phonological representations derived from orthography as described by Leybaert (1993). Therefore it is likely that /s/ was specified in some way in phonological representations. It is possible that /ʃ/ and /tʃ/ were specified differently in words beginning with these sounds as, in this position, /ʃ/ is usually written as “sh” and /tʃ/ as “ch”, although this distinction in specification could have been present in the orthographic representations only.

JB was at the early stages of literacy development but teachers reported that he was using phonic strategies when reading aloud. When tested for letter knowledge at T1 he gave names and sounds for all the consonant graphemes and, when shown the grapheme “s”, he named it as [eʔ] and gave its sound as [kx]. In naming tasks at T1 /s/ was realised as [d] in words beginning with /s/ + vowel and was generally omitted from initial clusters beginning with /s/. The exceptions were for words beginning with /sw/. The realisations for these words were:

swan→[pɸwɒn]	sweets→[kŋ̥wiʔ]
swim→[ɸwɪmin]	swollen→[kxwɪŋ]

His attempt to use friction in these realisations could reflect his ability to detect /s/ before [w] as demonstrated in Picture Yes/No Judgement tasks in the AA condition. Another possibility is that he was combining auditory knowledge with his knowledge of how the words were spelled, matched with his belief that [kx] is the sound that matches the grapheme “s”. However, he did not use [kx] for the other /s/ targets and so it is uncertain how much JB could be using his emerging literacy skills to update phonological representations.

MC’s literacy skills were lower than expected for his age and degree of hearing loss and he had been given a diagnosis of “mild dyslexia” by an educational psychologist when he was 7;5 years. During that assessment he was able to match sounds to letters for consonants. When letter knowledge was tested as part of this project he produced sounds for all the consonant graphemes. Most of the sounds were accurate in that they were within the phonemic category of the target. The exceptions were:

“b”→[də]	“d”→[bə]	“z”→[ɮ]
“sh”→[də]	“ch”→[də]	“x”→no response

The sounds produced for “b” and “d” are probably evidence of visual recognition difficulties reported by the educational psychologist. The other examples may reflect

MC's difficulty with speech discrimination of these consonants. Although MC is capable of using phonic strategies, his difficulties with visual recognition and recall could lead him to rely more on his hearing to develop phonological representations, especially as he only has a moderate hearing loss. In cases where he has difficulty with speech discrimination in the AA and AV conditions (e.g. /ʃ/-/tʃ/), it may be more difficult for him to specify these sounds differently in phonological representations and he may have more difficulty in using literacy skills as a support due to his problems with visual recognition and recall of graphemes.

It seems that, for DA and JB in particular, there is the possibility that they had used their knowledge of orthography and phoneme-grapheme links to update lexical representations. Although the potential role of orthography in developing phonological representations in acknowledged, very little is known about the process, especially in the context of deafness. Many studies with hearing participants have shown that knowledge of orthography has an impact on spoken word recognition (Taft, Castles, Davis, Lazendic, & Nguyen-Hoan, 2008). Tasks used in the studies reviewed by Taft et al (2008), such as rhyme judgement and auditory lexical decision tasks with priming, involved making decisions about target words. So it could be argued that the orthographic impact only arises strategically in order to make these judgements. Similar arguments have been made about the way in which deaf children use phonological coding when reading, indicating that most of the evidence comes from experiments where participants have to make explicit judgements about word forms (Leybaert, 1993).

Taft et al (2008) used a series of experiments with hearing adults where conscious strategic effects were minimised by masking the spoken primes in an auditory lexical decision task checking to see if participants were aware of the primes and then conducting a follow-up study where participants were asked to repeat the primed target words. The experiments examined whether auditory primes that were homographic with their spoken target (e.g. /drid/ as a prime that could be spelt in the same way as the matched target word "dread") produced greater facilitation than auditory primes that were equally phonologically related to the target word but could not be spelt in the same way (e.g. /ʃrid/ for "shred"). Thus this cleverly designed experiment was examining orthographic influence on the masked prime (as opposed to the target word that was used for the lexical decision task). Even when participants were unaware of the primes, there was a significantly greater facilitation with homographic primes in the auditory lexical decision tasks. When participants repeated the primed target words, they made more errors on words that were phonologically related to the primes that could not be spelt in the same way. However this interference was greatly reduced when the prime was homographic.

Taft et al (2008) took this evidence to imply that the orthographic impact on spoken word recognition is more automatic than previously thought. The authors offer two possible theories to explain the process of this impact in their study. Acoustic input could activate phonemically-based representations of segments of the nonword prime which in turn activate the associated orthographic representations. For example /drid/ would activate units such as /dr/, /id/, or /i/ and corresponding orthographic units such as /id/ → "ead" and "eed" and /i/ → "ea" and "ee". Then recognition of the target word, such as, "dread" would be facilitated.

A second possibility is that abstract phonological representations are influenced by orthography and so the orthographic priming effect arises solely within the phonological system. The proposed abstract representations can be seen as closer to the spelling of the word rather than the phonemic abstraction of the phonetic form of the word. This orthographically-moulded phonological representation could act as a mediator, both at input and output stages. This could explain the relatively automatic involvement of orthography in speech processing.

Hearing children and adults often develop inaccurate orthographically-based phonological representations for written words that they have only read and not heard. For example, thinking that "circumference" is pronounced as /sɜkəmˈfɜrəns/ rather than /səˈkʌmfrəns/. However, when the person hears the word spoken correctly in context, the phonological representation can be updated. The person then has the opportunity to store an accurate phonological representation that is more distinct from the stored orthographic form of the same word. Taft et al (2008) are proposing that some segments of the word in the phonological representation may remain influenced by orthography and that, even if words are acquired through speech before reading, familiarity with the orthography may change segments of the phonological representation. For example, a phonological representation of the word "lagoon" (/ləˈgun/) may become more like /læˈgun/ once a person becomes familiar with the written form of the word.

Some deaf children have fewer opportunities to hear or speechread the complete phonological form of a word in context and so their phonological representations are more likely to be moulded by orthography in this way. The proposal that the phonological representation amalgamates orthographic and phonological information

(Taft et al, 2008) complements proposals offered by authors studying deaf children: the original explanation given by Dodd (1976) regarding the sources of information for developing phonological systems, the comments made by Campbell et al (1992) on reading and writing generating phonological skills and Leybaert's reported observations on the effects of deaf children's dependence on reading and writing to develop phonological representations (Leybaert, 1993).

Summary

Evidence from initial testing at Phase 1 indicated that various factors had led to the formation of lexical representations: hearing, lipreading, phonological awareness, knowledge of orthography and phoneme-grapheme links. The intervention programme in Phase 1 aimed to explore further the contribution of these factors to the updating of lexical representations when acquiring new speech skills.

Evidence from Intervention in Phase 1

The Role of Input Skills

Even though the phonemes targeted in intervention may have had some form of specification in lexical representations, it could still have been the case that the participants' ability to discriminate them in speech input tasks in the AA and/or AV conditions could have influenced how successful they were in updating their specification of these phonemes in motor programmes.

For each participant, ratings of target consonants during naming tasks at each time point were compared and none of the ratings changed significantly during the periods of no intervention (T1-T2 and T3-T4). This applied to the group of consonants as a whole and to *each* of the input groups.

In contrast, for all three participants, the ratings improved significantly during the intervention period (T2-T3) and for each input group. Therefore, for all participants, the initial input grouping did not influence whether significant improvements were made to the ratings of the target consonants.

These improvements could have been explained by a corresponding change in input skills. As was the case for SR in the pilot study, improvements in output skills could be related to improvements in input skills. How did input skills change for each participant and could these changes explain changes in speech production?

There were some changes noted in DA's responses to the Rees Coleman input tests conducted at T3. At T3, each input test conducted at T1 in which DA had performed at chance was repeated.

Performance on the following tests had changed from being at chance level before intervention to being above chance level after intervention:

- Picture Yes/No Judgment Auditory-Alone for /sm/-/m/
- Picture Yes/No Judgement Audio-Visual for /st/-/d/
- Picture Yes/No Judgement for Audio-alone and Nonword Same/Different Discrimination for sk/g

These improvements could reflect the response to auditory training work which made up part of the intervention. Indeed the improvement in auditory training tasks for /sm/-/m/ was noted at the fourth session and for /st/-/d/ at the fifth session. However, by the third session, DA could already produce accurate realisations of /s/ in words beginning with /sm/ and /st/ when retelling a story, suggesting that output skills improved before input skills. This suggests an impact of output training on input skills of deaf children as was also found by Kosky and Boothroyd (2003). In this study production-focused training on the /s/-/ʃ/ contrast had an impact on the students' ability to produce and discriminate the contrast. It should also be noted that DA's performance on the other ten input tests, which were at chance level before intervention, remained at chance, including tests for the /ʃ/-/tʃ/ contrast. Therefore it seems that input skills before intervention had little influence on changes in DA's speech production and that any change in input skills during intervention were at least partly caused by improved production rather than vice versa.

JB's input skills did not show much improvement during the intervention period. Of the 10 input tasks retested at T3, responses to nine remained at chance level, with his ability to detect /s/ in the Picture Yes/No Judgement task for /sm/-/m/ in the AV condition showing some improvement.

MC's performance in input tasks before intervention was above chance in every test except for the Picture Yes/No Judgement task for /ʃ/-/tʃ/→/tʃ in both the AA and AV conditions. After intervention his performance was above chance for this test in both conditions. Therefore, in the case of MC, his improvements in speech production could partly be explained by improved input skills. However, his improvement in detecting

/tʃ/ in input tasks was only noted towards the end of the intervention programme when he had already achieved some success in producing /tʃ/ in some phonetic contexts.

Therefore the role of initial input skills did not seem very important in determining whether motor programs could be updated, and changes in speech output did not seem to be preceded by corresponding changes in speech input. Conversely, some improvements in speech input skills seemed to follow improved speech output skills. This evidence indicates that there could be two connections between input and output stores in a model of speech processing: one converting input into output and one converting output into input.

The Role of Motor Skills and Tactile-Kinaesthetic Feedback

The achievement of accurate, as opposed to improved productions, of target consonants seemed more reliant on motor skills than input skills. For JB, the only target consonant that he learnt to produce accurately was /f/. Although this consonant was in the "Auditory Full" group, no other target consonants in this group improved to a "correct" classification. For MC, the only target consonant that he had difficulty detecting in an input task was /tʃ/. After intervention he was able to detect it in this task but his realisation of this consonant did not reach a "correct" classification as he had difficulty in blending /tʃ/ to the following vowel.

These results suggest that the motor ability to execute the target consonants had more influence on whether an accurate production was achieved than whether the consonant was heard and seen clearly. DA, who had the greatest hearing loss and was unable to detect /s/ or the difference between /ʃ/ and /tʃ/ in many input tasks, was able to produce accurate realisations of all the target consonants after intervention. It seems that MC's difficulty with the motor skill of blending was influencing his ability to use target consonants in naming to a greater extent than were his speech input skills. JB had much more difficulty than DA and MC in learning to produce target consonants accurately. These difficulties did not seem to be related wholly to input skills and so other possible reasons will be explored.

The difference between JB's response to intervention for the consonants /f/ and /s/ seemed closely related to his motor skills. During the intervention JB had great difficulty in learning to imitate motor movements. This was even the case when he was imitating the silent movement of placing his upper teeth over his lower lip, where the visual model was clear. This was further evidence of conclusions drawn during his occupational therapy (OT) assessment at age 8;3 years that he had low muscle tone, difficulties with the control and planning of motor movements and kinaesthetic feedback. Evidence for difficulties with kinaesthetic feedback in the OT assessment was as follows: Although he was able to touch each fingertip to the tip of his thumb in turn at a slow speed, he was not able to do this above his head when he could not see his hands. Similarly, during the intervention study, his ability to imitate a labio-dental closure was aided by watching the therapist and himself in the mirror and using his hands to put the articulators in position. By working through carefully graded steps in the intervention JB eventually learnt to imitate /f/ successfully in isolation, blend it with vowels and other consonants in nonwords and then in words. However, it was much more difficult for him to learn to imitate /s/ because he was not able to see the place of articulation clearly and had great difficulty in copying tongue positions and movements. He even had difficulty in copying some tongue movements that he could see clearly. It is difficult to know whether these difficulties were more indicative of problems with muscle tone, planning and co-ordinating motor movements or limited tactile and kinaesthetic feedback from tongue positions. Based on the results of his occupational therapy assessment, it is likely to be a combination of all these. Once JB had eventually mastered how to produce /f/ in naming tasks, despite his motor and sensory difficulties, he maintained this skill well during the intervention period. This implies that the tactile and kinaesthetic feedback from the new production may have helped to reinforce the new speech pattern.

For many deaf people, the role of tactile-kinaesthetic feedback from speech movements could be crucial for storing representations of sounds and words, especially when auditory feedback is limited. This phenomenon is illustrated well by an anecdote described by LaSasso (1996). During a class where LaSasso was teaching reading methods to hearing and deaf adult students she asked the hearing students to sound out and guess the meaning of the following string of letters: KHAIRAKTURIZTIKULLEE. To her surprise, the first student to recognise the word "characteristically" was a profoundly deaf student with unintelligible speech, given the name "Sally". Sally signed the word accurately and accompanied it by a speech pattern that was unintelligible to all the class. When asked to describe the strategy she had used, she said that she had vocalized possible pronunciations of each of the consonants and vowels, blended them together sequentially, and determined which sequence of sensations came closest to an English word she had pronounced before. Of the different sequences she tried, only "characteristically" was meaningful to her. By using what LaSasso (1996) describes as a "tactile-kinaesthetic feedback system" (p7), she had stored a sequence of sensations corresponding to the (unintelligible) production of the word and then recognised this stored pattern when she produced the correct string of silent movements. This stored pattern was linked to the meaning of the word, which was accessed in order that she could sign the word. When asked to use the word in a sentence she signed “Characteristically, men are taller than women”.

As the participants in Phase 1 improved their production of target consonants they could have been storing the tactile-kinaesthetic feedback associated with them (as well as any acoustic cues). The additional knowledge of how the sounds were produced could have either added a segment to existing phonological representations or enriched any phonological specifications of segments already established. This may explain why the ability to detect a consonant sometimes improved after the participant had learnt to produce it more clearly.

The extent to which articulatory knowledge could influence phonological representations can be informed by studies that investigate whether speech perception involves activation of neural activity in the motor system. Watkins, Strafella and Paus (2003) conducted a transcranial magnetic stimulation (TMS) study demonstrating that speech perception, either by listening to speech or by visual observation of speech-related lip movements, enhanced excitability of the motor units underlying speech production. This link has been found to be specific to segments of the spoken word; another TMS study conducted by Fadiga, Craighero, Buccino and Rizzolatti (2002) showed an increase in motor-evoked potentials recorded from the listeners’ tongue muscles when listening to words that involved strong tongue movements (e.g. *birra* (beer)) as opposed to words involving less tongue movement (e.g. *baffo* (moustache)). Interestingly, there is now evidence that motor movement seems to be linked to a perception of a combination of visual and auditory information in an experiment illustrating the McGurk effect (McGurk et al., 1976). In an fMRI experiment Skipper, van Wassenhove, Nusbaum and Small (2007) showed that when participants were shown a video of a face producing /kɑ/ dubbed onto an audio /pɑ/, activity patterns in the frontal motor areas resulting from the illusory /tɑ/ percept were more similar to the activity patterns evoked by an AV /tɑ/ than they were to AV /pɑ/ or AV /kɑ/.

Galantucci, Fowler and Turvey (2006) proposed that the results of the TMS studies could be evidence for the original claim that perceiving speech is perceiving vocal tract gestures, which is part of the motor theory of speech perception (see Summerfield 1991 for a description). However, Skipper et al (2007) offer an alternative explanation which better suits the results of all three studies. They explain that the activity in areas of the motor system (e.g. those corresponding to the AV production of the illusory /tɑ/) occurs so that the sensory consequences associated with this production can be matched against the sensory consequences of the incoming signal which could be an integration of visual information (e.g. /kɑ/) and auditory information (e.g. /pɑ/). Therefore the input signal is processed first and then the motor areas are activated in order to make comparisons. This temporal order is also suggested by a study conducted by Nishitani and Hari (2002). Using magnetoencephalograhic cortical dynamics, they followed participants who observed still pictures of lip forms and found that the occipital cortex was activated before the primary motor cortex. However, in suggesting that the motor movements are activated as a check, Skipper et al (2007) are also implying that activation may alternate between the two areas.

These studies seem to strengthen the possibility that new articulatory knowledge could enrich input representations and therefore improve speech recognition. This again indicates that there should be two connections between input and output stores in a speech processing model, one of which involves output information influencing the input store. This process from output to input could involve tactile-kinaesthetic feedback.

The Role of Phonological Awareness and Orthography

As previously discussed, it is very unlikely that, for DA and JB, speech input skills were playing a major role in the improvement of their speech production during intervention. Results from testing before intervention indicated that DA was able to detect the presence of /s/ in some input tests and sometimes only in the AV condition. This could have led to him storing this consonant in a unique way which may have led to the use of covert contrasts, indicating the presence of /s/ in clusters in ways that were difficult to detect for the transcriber. However, there was no evidence of this. There was evidence to suggest that, for DA and JB in particular, emerging literacy skills had played an important part in the development of all the different forms of lexical representations (semantic, phonological, orthographic and motor). The target consonants seemed to be specified in their orthographic representations of words where these occurred in initial position. It is possible that this had led to the establishment of some form of specification of the target consonants in corresponding phonological representations before intervention. Whether target consonants were only specified in orthographic representations or also in phonological representations, it would still be possible for DA and JB to transfer any newly learnt motor patterns for consonants to other words, using their knowledge of phoneme-grapheme links. This possibility was investigated in Phase 1 by investigating whether any improvements in realisations of target consonants had generalised from words used in intervention to words not used in intervention.

For each participant, changes in ratings of target consonants during naming tasks for each time interval were compared for “Therapy” and “No Therapy” words. None of the ratings changed significantly during the periods of no intervention (T1-T2 and T3-T4) for the “Therapy” or “No Therapy” words.

For all three participants the ratings improved significantly during the intervention period (T2-T3) for “Therapy” and “No Therapy” words.

This would not be possible if participants had learnt new motor patterns on a word-by-word basis. Therefore it is more likely that the ability to select updated speech segments for a more transient output store had changed. In the case of MC, who performed at an above chance level in all the input tests at the end of intervention, generalising the selection of updated speech segments across words could be explained by improved input skills. Hearing a segment more clearly would lead to an awareness of where it occurs in other words. MC’s difficulties with literacy lessened the possibility of him using an orthographic strategy. In fact, at one stage of the intervention, MC had difficulty in knowing whether to use /ʃ/ or /tʃ/ when naming pictures of words beginning with these sounds and he commented that he didn’t think of the written form when deciding. Conversely, for DA and JB, this generalisation is less likely to be based on improved input as their ability to detect the target consonants in words in the AA and AV condition was still problematic for several consonants. Therefore it is very likely that they were relying heavily on their knowledge of sound letter rules to transfer the selection of updated speech segments across words. This is particularly surprising in the case of JB who had moderate learning difficulties and limited literacy skills.

Summary

The role of input skills in the updating of output skills through intervention was discovered to be less important than predicted. One possible explanation for this finding is that the target consonants in all the input groups were already specified in some form in the phonological and/or orthographic representations for the words tested. When the participants were taught how to improve their production of the target consonants they were then able to store these motor segments and the sensory feedback related to producing them, regardless of previous input skills based on hearing and lipreading. The ability to select the updated speech segments for a transient motor store seemed to change, rather than motor program for each individual word. Improved output skills seemed to influence the ability to detect consonants. This indicates that there should be two connections between input and output stores in a speech processing model, one of which involves output information influencing the input store. This could explain why any improvements in input skills (for tasks requiring access to phonological representations) during intervention tended to occur after the development of output skills, indicating an influence in the opposite direction from that expected.

Even though there was evidence of updating of lexical representations for naming tasks and sentence repetition tasks, there was very little evidence that newly acquired speech skills had been transferred to spontaneous speech. Phase 2 of the intervention study was set up to explore what processes need to take place in order to ensure that motor programs were more permanently updated so that two of the participants from Phase 1 could generalise their newly acquired speech skills to spontaneous speech.

Evidence from Phase 2

Arguments have been made to suggest the strategies that DA and MC used to update representations. Both had possibly linked newly learnt motor patterns for the target consonants to graphemes and used knowledge of grapheme-phoneme links to transfer this pattern across words. Both participants had also possibly stored the sensory feedback associated with improved production. For both participants the feedback would involve a tactile-kinaesthetic aspect and, for MC especially, an auditory aspect. Phase 2 explored whether the participants could use these strategies to transfer their speech skills to word-final position, unusual spellings and a range of speaking situations, including conversation.

Generalisation to Word-Final Position and Unusual Spellings

Results of the initial naming task in Phase 2 were used to investigate whether improved realisations of target consonants in word-initial position in naming had generalised to word-final position and to words with unusual spellings, over the five month interval. Consonant realisations were classified as “correct” (within the phonemic category of the target consonant) or “incorrect” (all other realisations). Twenty realisations of word-initial consonants in regular spellings were compared to 10 realisations of the same range of consonants in word final-position and 10 realisations of the same range of consonants in unusual spellings (e.g. "**c**ircus, **s**ugar, pen**c**il). For both participants, realisations were more likely to be correct in word initial position than in word final position. For DA, realisations were more likely to be correct in word initial position in regular spellings than in unusual spellings. Realisations of all five examples of unusual spellings of /s/ and both examples of unusual spellings of /tʃ/ were incorrect. The three correct realisations were for unusual spellings of /ʃ/ (*sugar, station* and *tissue*) and DA had already had some success at realising /ʃ/ correctly before Phase 1. For MC, realisations were no more likely to be correct in initial position in regular spelling than in unusual spellings. Five out of the ten unusual spellings were realised correctly and neither the type of consonant nor the position in the word seemed to determine whether the target was correct.

The difficulty that both participants had with generalising to word final position was unexpected as there was a transparent link between orthography and production in the words tested (e.g. *bus*, *cross, fish).* One possible explanation for this finding is that both participants had practised blending the target consonants or clusters to vowels in word initial position during intervention in Phase 1 and had not practised blending vowels with the consonants in final position. Therefore the motor patterns and sensory feedback for blending in initial position were stored more securely and so could be retrieved more easily to attach to initial segments of words. This calls into question the nature of the speech segments that are referred to in a speech processing model. The segments may be configurations of gestures, as described by Browman and Goldstein (1995) because such configurations will vary according to position in the syllable. This is discussed further in the section on The Revision of the Stackhouse and Wells Model (1997).

Even though the results concerning unusual spelling were unclear they were further evidence that DA was more likely to be using a strategy of applying letter-sound rules to the transfer of selection of updated speech segments than MC.

Generalisation to Spontaneous Speech

At the end of Phase 1 the deliberation required to use the new speech skills probably prohibited the use of these skills in fast spontaneous speech. It was not clear whether repeated practice in using the motor patterns in appropriate words would reduce the degree of deliberation and lead to more spontaneous use. In theory, the sensory feedback from the repeated practice could serve to strengthen phonological representations and motor programs, and this sensory feedback need not be auditory but could be partly or wholly tactile-kinaesthetic.

Intervention in Phase 2 aimed to improve the production of the target consonants in a range of speaking tasks using a combination of techniques, including repeated practice of motor patterns and using feedback to encourage planning and self correction. The tasks included spontaneous conversation, which was judged to be the most spontaneous of the tasks. Ratings of the target consonants for the range of speaking tasks were compared across time points for each participant.

For DA, ratings improved significantly for all the tasks during the intervention period, including conversation. At T2 DA was realising only 10% of target consonants accurately during conversation and this figure rose to 60% at T3. For all the speaking tasks, including conversation, there was no significant change in production between the other time intervals indicating that the generalisation had taken place during intervention and changes had been maintained during the five weeks following intervention.

The student therapist reported that the subtle feedback given after every incorrect realisation of the target consonant was very effective in motivating DA to speak more slowly and deliberately, self-correct and attain accurate productions. She reported that he sometimes needed extra help with words with unusual spellings of /s/ (e.g. “except”), where she would use a “quasi-phonemic” script to indicate the position of the /s/ phoneme. The words used to assess unusual spellings of /s/ at each time point were *cinema, circus, ice, police* and *pencil*. With one exception, all 40 realisations of these words were rated as 1 (omit/plosive) at T1 and T2. The use of explanation and quasi-phonemic script seems to have been effective as, with one exception, all 40 realisations were rated as 4 (on target) at T3 and T4. The need to slow down, plan ahead and pay particular attention to words with unusual spellings are all evidence that DA was using the following orthographic strategies:

- thinking of the orthography of words he was about to say
- using his knowledge of grapheme-phoneme links to select the updated speech segments for speech output.

This strategy was put into words by JD, the deaf adult who was interviewed about updating her speech skills. She described an orthographic “reel” that allowed her to plan ahead. She said:

"It's almost like a reel in front of me…where I'm preparing for what I'm trying to say…and trying to remember all the sounds that come in that I need to pronounce in the words".

It seems that, with repeated practice, these strategies enabled DA to attain a high degree of accuracy in realising target consonants in speaking tasks including conversation during a testing situation. This was particularly impressive as conversation requires more planning and, as noted by Kahmi (2000), in a limited capacity system the resources required to plan what to say leave fewer resources available to focus on speech production. DA's achievement could have been a reflection of his superior phonological awareness and literacy skills and his moderate but consistent degree of motivation. On the intelligibility / motivation questionnaire conducted at all time points he consistently chose "I'd like to improve my speech if it's not too much work".

The maintenance of the accuracy of DA's speech production could have been due to the sensory feedback (auditory and/or tactile-kinaesthetic) that served to further strengthen his lexical representations. JD described how the tactile-kinaesthetic feedback from pronouncing "x" (/ks/) differently felt unnatural. She said:

"I had to remember how it felt...I still have to remember how it feels…/ks/ /eks/…I don't like it. It feels very unnatural"

Tactile-kinaesthetic feedback could be adequate to maintain speech skills, once established. Clinical observations show that people who acquire profound deafness in adulthood can often continue to speak intelligibly for decades. However, when the kinaesthetic feedback system is disrupted in hearing adults as a result of acquired kinaesthetic apraxia, adults develop great difficulty in articulating speech. In milder cases they tend to confuse phonemes that differ acoustically but only differ articulatorily in one feature (e.g. /m/, /p/, /b/) (Luria, 1976). Thus it seems that kinaesthetic feedback is more important than auditory feedback for the maintenance of established speech output skills. This ties in with conclusions reached by McReynolds (1987) that hearing children who are closer to automatizing their speech skills are less dependent on auditory feedback than children who are in the initial stages of acquiring new speech skills. This indicates that the later stages of maintenance of speech skills may be less dependent on auditory feedback and so may be more reliant on alternative forms of feedback (i.e. tactile and kinaesthetic feedback). Hence the disruptions of kinaesthetic feedback result in the sort of difficulties described by Luria (1976).

However, there was some deterioration in DA's use of accurate realisations of target consonants five weeks after intervention. In conversation the percentage of accuracy of realisations of target consonants dropped by 18% at T4 (to 42%), and at both T3 and T4, although his conversation was animated, his speech was still somewhat deliberate with a number of self-corrections and emphasis and lengthening of target consonants. Because there was no intervention between T3 and T4, DA would not have been asked to practise using his new speech skills and his moderate degree of motivation may have implied that he was less likely to do so of his own accord. His agreement that "Most people understand everything I say" at all four time points further indicates motivation that led to him making an effort to change his speech pattern in structured tasks but which may not lead him to doing so the rest of the time. Therefore, he would not have reinforced the new motor patterns or sensory patterns associated with them to a high degree. As proposed by Hewlett (1990), it could be that a high degree of motor dexterity to implement speech sounds at speed is necessary for a permanent updating of the motor program. Repeated practice in the generalisation programme could have led to two possibilities:

1. greater proficiency at accessing links between orthographic and phonological representations and/or
2. the establishment of an alternative set of updated phonological representations for more careful speech.

A lack of practice at using new motor patterns could reduce proficiency in using the orthographic strategies and/or may weaken any alternative set of phonological representations and make it less likely that this set become more permanent. Ehri and Wilce (1980) consider the possibility of multiple phonological representations being stored in memory when offering explanations of studies that show that dialect-speaking children can orally read a story in perfect standard English and then immediately retell the story in standard dialect English (Goodman & Buck 1976, cited in Ehri & Wilce 1980) . Ehri and Wilce (1980) suggest that the structure of the task may determine which representation is tapped. JD seemed to imply that she still used her orthographic "reel" when she thought the listener was having difficulty following what she said, as if she had a more careful mode of speech that she used in certain situations.

For MC, ratings of target consonants improved significantly during the intervention period in naming, sentence repetition and conversation but not for reading, retelling passages or making up stories. Two other significant improvements took place: between T3 and T4 for reading, and between T1 and T2 for making up stories. The ratings for retelling read passages did not show any significant improvement. In conversation, although there was a significant change in accuracy of the target consonants between T2 and T3 (from 34% to 55%), there was a significant deterioration between T3 and T4 (from 55% to 34%) indicating that the improvement had not been maintained.

The partial success achieved by MC could be explained by him incorporating new motor patterns into his output stores. As previously discussed, the transfer of this skill across words could be explained by use of auditory feedback as MC has a moderate hearing loss and at the end of Phase 1 was able to detect all the consonants targeted in the input tests – both in the AA and AV conditions. His specific difficulty with literacy could make him less likely to use an orthographic strategy. His student therapist did not report any particular difficulty with unusual spellings. Unlike DA, he produced accurate realisations of /s/ in the words *cinema, circus, ice, police* and *pencil,* in most tests at T1.

This more inconsistent pattern for MC could partly reflect his difficulty with updating the way he selected speech segments that he had learnt to produce differently. He could have been less able to extract the meaningful and relevant features of the speech segments he was now able to produce and use them in a meaningful way. These skills are involved in cracking the phonological code in speech development. There is evidence that, in comparison with hearing children with typical speech development, many hearing children with significant speech difficulties have more difficulties in using the kind of rule derivation that is required to crack the phonological code in this way (Dodd & McIntosh, 2008). MC could share this difficulty with the minority of hearing children and this could also be an explanation for his literacy difficulties. As literacy is a rule-governed system, difficulty with extracting and applying the phonological rules of speech may transfer to extracting and applying spelling rules (Dodd & McIntosh, 2008). Difficulties with rule derivation and other core abilities in executive function (e.g. concept formation) could also explain MC's difficulty with learning new phonological patterns when being taught new words. In Phase 1 post-intervention assessments, DA successfully named all the 13 words he had been taught at T3 and T4. JB, with moderate learning difficulties, successfully named nine of the 10 words he had been taught. However, MC only remembered nine of the 20 words he had been taught at T3 and T4. Even though an equal amount of time had been spent discussing the meaning and phonological make up of the remaining 11 taught words and practising how to produce them, MC was unable to produce any response for the corresponding picture items in the naming tasks. This general difficulty with storing new phonological forms could also explain comments made by his speech and language therapist about suspected word finding difficulties and his difficulties with literacy.

MC's inconsistent pattern could also be partly explained by low and fluctuating motivation to change his speech. When completing the intelligibility / motivation questionnaire before intervention he chose "Sometimes I think I'd like to improve my speech but can't be bothered to change it". Immediately after intervention his choice was "I really want to improve my speech and will work as hard as I can", but five weeks later he chose "I'd like to improve my speech if it's not too much work". The student therapist reported that it was sometimes difficult to maintain MC's attention, despite providing rewards and changing tasks frequently. Like DA's student therapist she reported that the subtle feedback given after every incorrect realisation of the target consonant was effective in motivating MC to speak more slowly and deliberately, self-correct and attain accurate productions. However, she noted that he was fairly dependent on this feedback. During the last two intervention sessions MC obtained 100% for accurate production of the target consonants during a story retelling activity when he was encouraged to plan and self-correct and rewarded for doing so. One week later when he was tested on story retelling and given no feedback or encouragement he obtained 58% for accurate production of the consonants. This indicates that when he was relying more on self-motivation to change his speech he was far less successful. The client's motivation to change seems to play a critical role in the success of an intervention programme (Weiss, 2004).

Summary

DA generalised the speech skills he had acquired in Phase 1 to conversation. He seemed to be using an orthographic strategy that involved thinking of the orthography of words about to be produced and using knowledge of grapheme-phoneme links and new articulatory knowledge. Sensory feedback from repeated practice could have strengthened input and output lexical representations. However, his use of updated speech skills was not totally consistent at T3 and there was a noticeable (but not significant) deterioration by T4. This indicates that any updated representations may have been an alternative set kept for certain speaking tasks and that these had been weakened by lack use after intervention. Another possibility is that DA became particularly proficient at using an orthographic strategy at the end of the intervention programme. MC did not generalise his speech skills as successfully as DA, despite having better auditory speech discrimination skills. There was evidence that he was relying more on auditory feedback than an orthographic strategy to achieve a moderate degree of generalisation. MC's more inconsistent use of his updated speech patterns could be explained by difficulties with core abilities in executive function (such as rule derivation). DA seemed to have more self motivation to improve his speech skills than

MC, but neither boy had a high degree of motivation. Both of them felt that most people understood everything they said and at T4 they both chose "I'd like to improve my speech if it's not too much work" in response to "How much would you like to improve your speech?" Whether children are using an orthographic strategy and/or using auditory feedback to generalise newly learnt speech skills, self-motivation to change their own speech patterns seems crucial in the success of the process.

Effectiveness of the Intervention Programmes

Both intervention programmes were effective in that all participants showed significant improvements in their speech production during the intervention periods and not during the periods before or after intervention. At the end of Phase 2, both participants were using their improved speech skills at least 55% of the time in conversation. They had achieved this level after 10-11 hours of individual intervention spaced over six weeks in Phase 1 and six hours of individual intervention spaced over five weeks in Phase 2. This does indicate that children of this age group can learn to use consonants in spontaneous speech, even when they still have difficulty detecting them in the speech of others.

It is difficult to know which of the techniques was most effective as an eclectic approach was chosen and so techniques were not separated. Improvements in output skills were noted before improvements in input skills, suggesting that techniques to improve output were effective and sometimes had an impact on input. This impact was also found by Kosky and Boothroyd (2003).

Explanations of how sounds were produced using visual and tactile feedback combined with feedback on the child's attempts to produce the sound often led to successful imitation of the target consonants in isolation. Even though this process sometimes happened very quickly, the use of integrated techniques took considerable skill on the part of the therapist. For example, DA learnt to imitate /s/ as [s̺] in the first intervention session but this required the therapist noticing that his first attempts were as [x], knowing about the difference in production between [s] and [x], demonstrating the difference between them, giving further instruction of how to modify the production and clear feedback about how close DA's imitations were to the target. A need for specialist skills from the therapist in these early stages was noted by Bernhardt (2004). She reported on studies she had conducted with Brooke and Major (Bernhart, Brook & Major, 2003; Major & Bernhart, 1998, both cited in Berhardt, 2004) on phonological intervention with hearing children which showed that the therapists' training in phonetics was related to the outcome of therapy. Children treated by a speech and language therapist with an undergraduate degree including a number of courses in phonetics and phonology and a Master's degree in speech-language pathology made significantly faster gains in word structure development than children whose therapists had had minimal linguistics undergraduate training.

In Phase 1 "quasi-phonemic" script was useful in explaining how /tʃ/ was produced. Writing it as "tsh" helped both DA and MC to know how it was pronounced. During intervention in Phase 2 DA was taught the rule that if written words begin with "ci" the "c" is pronounced as /s/. He applied this rule to the words *cinema* and *circus* during the naming tasks at T3 and T4. This combination of using techniques to encourage improved production of phonemes and linking these production to symbols and graphemes was successfully used in a phonics teaching programme described and evaluated by Trezek and Malgrem (2005). In this study deaf students aged 12 – 14 years were taught to produce sounds using "Visual Phonics", articulatory instruction and "Baldi" (Massaro et al., 2004). The Visual Phonics system used in the Trezek and Malgrem study (2005) is a system of 46 moving hand cues that provide cues about the production of the sound (International Communication Learning Institute, 1996). It is similar to "Cued Articulation" (Passy, 1993) which is often used in the U.K with hearing children with speech difficulties. "Baldi" (Massaro et al., 2004) provides computer animations of how the mouth shape, lip movement and tongue placement work in concert to produce specific sounds and words. The treatment teacher in the Trezek and Malgrem study noted that the students with more significant hearing losses expressed an increased interest in speech production and were particularly intrigued by learning the tactile differences between sounds. She commented that the "Baldi" technology was rarely needed to reinforce the production of individual sounds as once the students learned the verbal, visual and tactile characteristics of sounds, and associated them with the corresponding Visual Phonics cue, the cue alone was a sufficient aid for remembering the "proper" articulation. "Proper" was not defined but the evaluation noted an improvement in the children's ability to read words and nonwords in terms of showing "distinct mouth movements and vocal sensations for each word" (p262, (Trezek & Malgrem, 2005)).

One of the most effective techniques in the generalisation stage of intervention, Phase 2, seemed to be giving subtle cues to the accuracy of the production of consonants in a range of speaking tasks. This involved placing a tick in the column headed "Right" for accurate production or in the columns headed "Nearly Right" or "Wrong" for close or inaccurate production respectively. For the majority of the time, as soon as the student therapist's pen moved towards the "Nearly Right" or "Wrong" columns, the participants would self correct successfully. This whole process encouraged participants to slow down and plan their speech more carefully and, in the case of DA, allowed him to think about the orthography of the words he was about to say. Techniques to encourage planning also enhance generalisation treatment for hearing children with phonological disorders (Ruscello & Shelton, 1979).

Although neither of the participants in Phase 2 had high levels of self-motivation, they both improved their speech production in conversation. This may have been partly due to efforts to involve them in the therapy process, as this is thought to encourage children to see themselves as agents for change (Weiss, 2004). They were both particularly interested in working out the percentages of times they had remembered to use the target consonants in each session and were interested in seeing these figures change over time.

Revision of Stackhouse and Wells Model (1997)

The experiments in this thesis were originally based on the Stackhouse and Wells single word speech processing model (Stackhouse and Wells, 1997) (see figure 1 in Chapter 1). In this section various aspects of previous discussion are brought together with concepts and evidence from other speech processing models and theories to suggest a revised model. This revised model (see figure 16) would better explain some of the findings of the experiments and may form a better resource for clinicians working with deaf children who are updating their speech skills

The Stackhouse and Wells model (1997) partially explained some of the findings. The differences in performance within one child between a nonword same/different input task and a Picture Yes/No Judgement (PYNJ) task (with matched nonword items) could possibly be explained by the separation of the "phonological recognition" level, involved in comparing two phonetic patterns, and the "phonological representation", involving phonetic information about specific words. There was also a difference in performance between the pronunciation of specific words when imitating and being reminded (in the initial stages of therapy) and when producing the same words more spontaneously. This could also be explained by the use of a route that is likely to involve the lexicon less. The Stackhouse and Wells model (1997) includes a non-lexical route via motor programming, when temporary motor programs are established.

However, the model does clearly explain why the participants were easily able to generalise their production of more accurate speech segments to non-therapy words. If they had been updating motor programs on a word-by-word basis this would not have occurred. New articulatory knowledge on how to produce speech segments seemed to trigger the changes that took place in the speech processing systems of the participants. The participants gradually became more likely to select the updated segments for words in their lexicon. A model that explicitly refers to realising a stored word form by selecting speech segments into a transient output store would provide a better explanation for the transfer to non-therapy words. Although Stackhouse and Wells (1997) discuss the assembling of phonological units and temporary storage during the non-lexical route, the model itself does not include transient stores and does not explicitly separate output stores of information from processes (e.g. phonological encoding). Being more explicit about processes (e.g. comparison of a string of speech segments to lexical entries, selecting a string of speech segments) may give more emphasis to the role of speech segments. In the revised model all the stores (permanent and transient) are in bold.

It would be useful to include transient stores of information for both input processing and output processing. The box on the Stackhouse and Wells model labelled "phonological recognition" refers to the process of decoding the speech signal into a transient store of a string of speech segments that can be compared to stored lexical entries. It would be useful to separate out the three phenomena: the process of decoding for the transient input store, the transient input store itself and the comparison with lexical entries. The results of the PYNJ task could be explained by a difficulty with comparison to lexical entries, rather than problems with phonological representations. Using a picture could have led to a stronger activation of the semantic representation leading to more tolerance of phonetic variations when making comparisons. (For further discussion of the PYNJ task – see Evaluation of Study). Transient stores are sometimes referred to as "buffers", as in the models based on testing adults with aphasia proposed by Jacquemot and Scott (2006) and Nickels (Nickels, 2000). Both these models include phonological buffers for input and output. The transient output store can be formed from lexical entries by selecting a string of speech segments.

Connections between the transient stores, lexical word forms and semantic representations develop over time. Lexical and phonological development are closely related and the integration is influenced by word frequency, neighbourhood density and phonotactic probability (Storkel & Morisette, 2002). The child's ability to decipher which strings of speech segments represent which objects and abstract concepts changes over time. This ability to identify features which are crucial to differentiation in the language involves solving a phonological code. The set of skills that are needed to do this are often listed as core abilities in executive function (including concept formation, rule derivation, temporal ordering) (Dodd, 2005; Dodd et al., 2008; Dodd et al., 2008). Evidence of children's emerging ability to extract phonological codes comes mainly from observations of regular patterns of errors in the speech of typically developing children. These errors cannot be solely explained by difficulties with input skills or oro-motor skills (Dodd, Holm, Crosbie, & Hua.Z., 2005; Dodd et al., 2008). The majority of linguistic theories attribute these regular error patterns to the occurrence of processes or rules (Barlow, 2001). An example of a process is "cluster reduction" and an example of a rule is "delete /s/ preconsonantally in a cluster". When lexical entries are selected to form a phonological plan this process is influenced by such realisation rules that change over time. A gradual change in realisation rules and subsequent error patterns may be influenced by an improvement in speech input and output skills and a subsequent increase in the phonetic repertoire but are also influenced by the development of other linguistic skills, such as vocabulary growth (Storkel & Morrisette, 2002) and other cognitive factors, such as the core abilities in executive function (Dodd & McIntosh, 2008).

In the Jacquemot and Scott model (2006) the transient output phonological buffer can also be formed from the input phonological buffer by using the same or a similar process (i.e. selecting a string of speech segments). This process is less likely to be governed by established realisation rules. This would explain why, at various stages of the intervention, the participants in this study seemed to be executing different output representations. This may be because the *process* of selecting strings of speech segments varied according to whether the updated segment or the original segment was selected. The process involved in recovering the stored lexical form may be more likely to select the original (inaccurate) segment for the target consonants as this process may be governed by an established realisation rule. The similar process involved in converting the transient input codes to transient output codes may be less influenced by these developmental processes and so the updated target segment is more likely to be selected.

There is neuropsychological evidence that there are two connections between these two transient stores: one converting input into output and the other converting output into input (Jacquemot, Dupoux, & Bachoud-Levi, 2007). These authors studied a 54-year-old woman, FA, with conductive aphasia whose speech perception was intact as shown by auditory discrimination tasks with words and nonwords. FA displayed a slight impairment in naming but a dramatic impairment in nonword as opposed to word repetition. This indicated a difficulty in converting transiently stored input codes into transiently stored output codes when taking the non-lexical route. Conversion in the opposite direction was cleverly tested by asking FA to compare auditory stimuli (including nonwords) spoken by the tester to her phonological knowledge of a word illustrated by a single picture in a rhyme judgement task. This involved her converting her knowledge of the form of the word illustrated into transient output codes and matching these with the transient input codes formed from the auditory stimuli. As her performance in this task was relatively good, Jacquemot et al (2007) suggested that the conversion mechanism in the opposite direction (converting output codes to input codes) was relatively unimpaired.

The presence of an arrow from the transient phonological output store to the transient phonological input store would explain the influence of output knowledge on input skills found in the experiments. If a speech segment was updated through newly acquired articulatory knowledge then this could be selected during the input to output conversion and its selection would be involved in the output to input conversion. The connection involving converting output information to input could involve all sensory information, including tactile-kinaesthetic feedback. This cycling of information between input and output stores may be an explanation for the TMS and fMRI studies that show activity in areas of the motor system when participants are perceiving speech (Watkins, Strafella, & Paus, 2003; Fadiga, Craighero, Buccino, & Rizzolatti, 2002; Fadiga et al., 2002; Skipper, van Wassenhove, Nusbaum, & Small, 2007). Skipper et al (2007) propose that the sensory consequences associated with production can be matched against the sensory consequences of the incoming signal through this backwards and forwards movement. Jacquemot and Scott (2006) propose that phonological short term memory (pSTM) arises from the recruitment of the two transient stores (input and output) and the cycling of information between them in the two directions. This gives pSTM a more central role in a speech processing model than has previously been the case, even though pSTM has generally been thought to facilitate language development (Jacquemot & Scott, 2006).

If the updated speech segment was present in transient input stores, this would ultimately influence the stored input lexical form (known in the Stackhouse and Wells model as the “phonological representation”). Jacquemot and Scott (2006) state that there may be an equivalent stored output form at the lexical level. Stackhouse and Wells (1997) define the motor program in their model as a series of gestural targets for the articulators which are stored in the lexical representations. This established program is accessed when the lexical route is taken in spontaneous speech and could explain why children may revert to their previous way of speaking when they have just learnt to use new speech skills in structured tasks. However, it may be the *process* of selection of the targeted speech segments (to form a transient output store) that is established. If the child updates a stored speech segment, this segment can be chosen during the process of selection, whatever word is being selected. The concept of an established process of selection, rather than an established motor program would partially explain why the participants in the experiments were able to transfer a motor execution skill (e.g. producing /ʃ/) from therapy to non-therapy words. It would also explain why their updated speech skills varied across situations (e.g. from naming to conversation) as it is likely that the additional use of other cognitive skills led them to revert to selecting segments they had chosen in the past which was part of a more automatic process. As previously discussed, this process of selection of speech segments may be influenced by the child's own realisation rules and changing/updating realisation rules may depend partly on the child's ability to "crack" and apply the phonological code (Dodd & McIntosh, 2008). When investigating 78 children with speech difficulty of no known origin, Dodd and McIntosh (2008) used an input processing task, the DEAP oro-motor tasks (Dodd, Zhu, Crosbie, Holm, & Ozanne, 2002) and two non-verbal tasks evaluating rule derivation to compare this group with 87 age-matched controls. Results indicated that rule derivation best discriminated the typically developing and speech difficulty groups. As the authors noted, this does not imply that the speech impaired children were not able to abstract rules (as their error patterns were often consistent) but their problem could lie in identifying the right phonological features as significant for the phonological system being learned. The speech impaired children did as well as controls when asked to identify two pictures out of three that "went together" when there were two possibilities for matching (e.g. a small blue teapot, a small red teapot and a medium-sized blue teapot). However, when they were asked to find another pair that went together (e.g. shifting attention from colour to size or vice versa) the children with speech difficulty had more difficulty than controls. So shifting perspective and cognitive flexibility may be important skills for cracking the phonological code. When deaf children are updating speech skills, their ability to select updated speech segments when mapping lexical and phonological forms could be influenced by these cognitive skills. The fact that DA was better able to generalise his newly acquired speech skills than MC, despite poorer auditory processing skills may be a reflection of the cognitive skills required to crack and apply rules. DA may have been better able to extract the meaningful and relevant features of the target consonants he was now able to produce and use them in a meaningful way. The fact that DA had age-appropriate literacy skills whereas MC had difficulties with literacy is further evidence that DA had superior problem-solving skills in terms of cracking and applying rules. As literacy is a rule-governed system, a good ability to extract and apply the phonological rules of speech may transfer to extracting and applying spelling rules (Dodd and McIntosh, 2008) and vice versa.

Transferring the selection of updated speech segments across words that include the same segment is also aided by the ability to hear the segment clearly. Hearing a segment clearly leads to awareness of where it occurs in other words. This is probably the only option available to very young children with no knowledge of orthography. DA's ability to detect or discriminate the target consonants in input tests showed very little improvement and so it is more likely that the transfer of his newly acquired speech skills to non-therapy words and more spontaneous speech was aided by orthographic knowledge.

A child with limited hearing ability could select an updated speech segment for output by accessing orthography so that the grapheme corresponding to the targeted speech segment is activated, increasing the likelihood of the activation of the updated speech segment with which it has been associated in intervention. This would be another way of explaining why DA, with superior literacy skills and possibly better code-cracking skills, was better able to generalise his speech skills. The Nickels model (2000) of the cognitive processes involved in the comprehension and production of single words includes a "phonological output lexicon" which is connected to the "orthographic output lexicon". The level of the transient "phonological output buffer" is connected to the "graphemic output buffer" by sound-letter rules. In the Nickels model (2000) the phonological stores are connected to the orthographic and graphemic stores by arrows going in one direction from the phonology. The Nickels model (2000) is a sketch that has been formed from neuropsychological data from adult participants with aphasia. As discussed in previous sections, orthography may be accessed fairly automatically in speech perception (Taft et al., 2008) and, particularly for deaf people, orthographic and phonemic knowledge may be used to update stored speech information. It may therefore be useful to include an orthographic word form and a graphemic output store in a model of speech processing and to include arrows moving from these to the phonological stores (as well as in the other direction). The encoding involved in writing and the processes involved in reading do not need to be included in a speech processing model.

In addition, especially in the context of deafness, the role of lipreading and its integration with auditory processing needs to be considered in the phonological decoding process that leads to the transient phonological input store. Phonological decoding arises from an integration of visual and auditory information.

The last proposed revision of the Stackhouse and Wells (1997) model concerns the nature of the speech segments that are selected during some of the processes. The Stackhouse and Wells model (1997) does not fully explain the transfer of a motor execution skill (e.g. producing /ʃ/) from therapy to non-therapy words when the consonant is in syllable-intial position but the limited transfer to syllable-final position. The process of “motor planning” does refer to gestural targets being assembled in real time, taking account of the contextual requirements (Stackhouse and Wells, 1997). However, the examples given of this process being put into operation refer to the *same* word being said in a variety of different phonetic and contextual contexts.

In the present study, the participants’ difficulty with transfer to syllable-final position could be explained by a realisation rule filter whereby the child’s own realisation rules are governing where an updated segment could be used. It could also be explained by reconceptualising the “speech segment” as in the theory of articulatory phonology described by Browman and Goldstein (1995). This theory proposes the articulatory gesture as the basic phonological unit. Consonants are made up of combinations of articulatory gestures so what children need to master is not just how to produce the gestures accurately, but also the relative timings of the gestures. In different contexts, the configurations of these gestures may vary, whilst the gestures themselves remain unaltered. One example of such a context is syllable position (Browman & Goldstein, 1995). For example, as described by Krakow (1989), cited in Browman and Goldstein (1995), in initial nasals (e.g. “see <u>m</u>ore”) the end of the velum lowering (one gesture) roughly coincides with the end of the lip closing movement (another gesture) whereas in final nasals (e.g. “see<u>m</u> ore”) it coincides with the beginning of the lip closing movement. Following this theory, if a child has learnt to execute one configuration of gestures, this new skill could be transferred to speaking contexts that require the same configuration, but not necessarily to contexts requiring a different configuration. Therefore the speech segments referred to in the model may best be described as configurations of gestures. The process of motor planning is still included in the revised model to account for the alterations to motor execution that are needed to place the same word in different phonetic contexts in connected speech and in different situations, where non-segmental features (e.g. intonation) will vary.

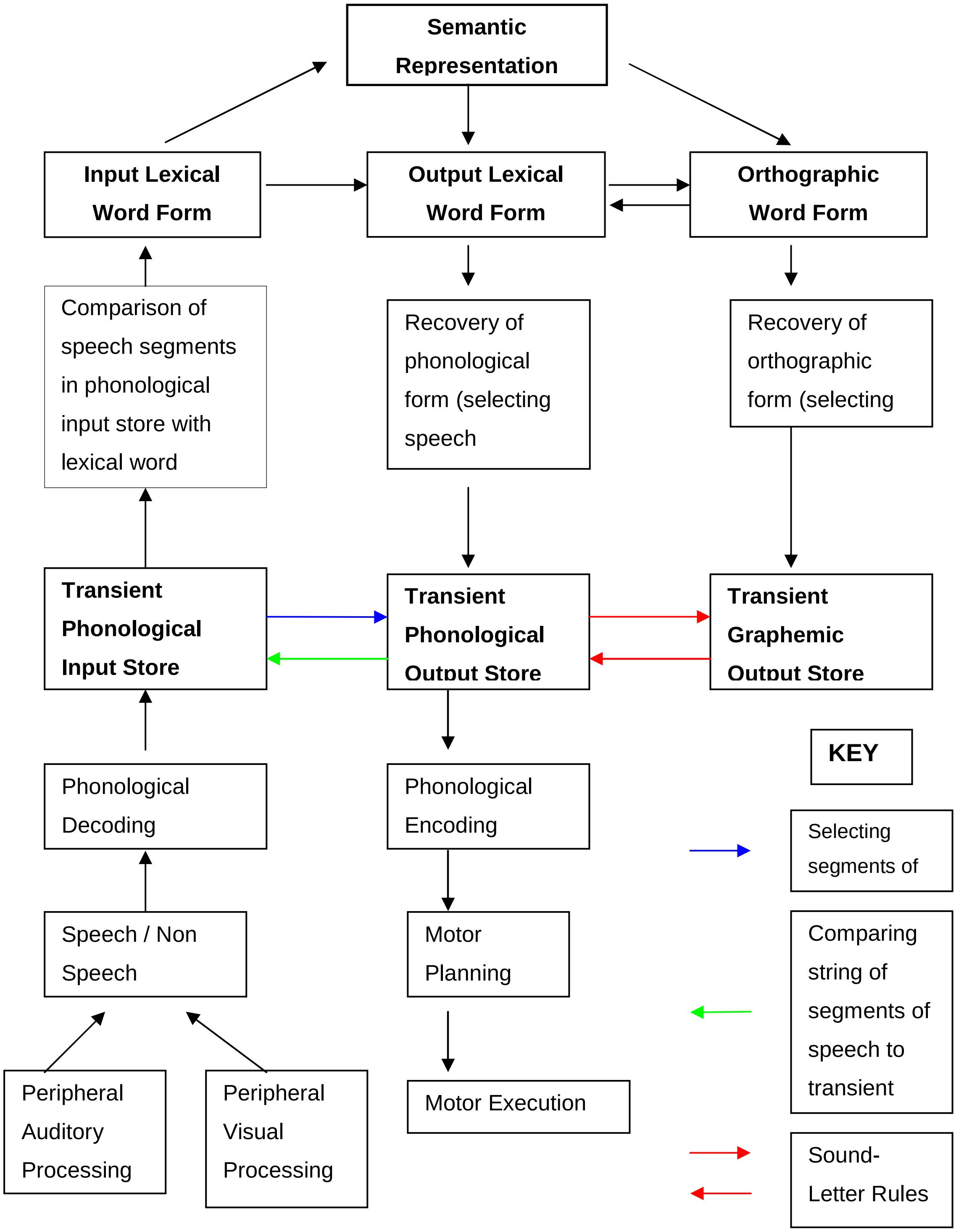


Figure 16: Revised model

Evaluation of Study

When this study began, its main aim was to assess the role of initial input skills in deaf children's ability to update lexical representations. This role was found to be less important than predicted and, as the study progressed, it was evident that other processes were important in updating lexical representations and generalising newly acquired speech skills. Therefore, in hindsight, it would have been beneficial to have investigated these processes more systematically. This and other aspects of the investigation will be evaluated.

The Rees Coleman Profiling Procedure

Basing the Rees Coleman procedure on consonant contrasts was effective in that patterns of loci of difficulty varied across contrasts. Testing each contrast in the AA and AV condition allowed an investigation of the role of lipreading in both speech discrimination and forming phonological representations. Separating out different /s/ clusters did indicate which contrasts were more difficult to hear and/or lipread. The procedure seemed relatively robust in that retesting of the same contrast within two weeks led to the same profile. Presenting the tests on a computer with on-screen rewards for completing subtests helped to keep the children's attention. The live stimuli were recorded with care to ensure clarity and minimum effects of non-tested variables e.g. facial movements, intonation. In general, calculating probabilities of input test results occurring by chance seemed an effective way to compare performance on different input tests. However, this difference sometimes relied on a small difference in raw scores between the two tests. In hindsight it would have been useful to include some testing of the detection of contrasts in connected speech where there may be additional acoustic and lipreading cues. Children may be able to detect consonants in this environment and not at the beginning of a single word. Matching items across tests revealed some interesting differences between performance on input and output skills. One type of input task was designed to involve access to the lexicon (the picture yes/no judgement (PYNJ) task) and another to involve less likelihood of access (the nonword same/different discrimination task). It was assumed that the PYNJ task was indicating the integrity of the phonological representations. However, a study conducted by Hemsley, Holm and Dodd (2006) suggest that this kind of test with pictures may not be the most effective way to assess the integrity of phonological representations. Therefore this PYNJ task will be analysed and evaluated as a method of assessment.

The Picture Yes/No Judgement Task

The phonological representation is defined by Stackhouse and Wells (1997) as the information stored about a word that enables it to be identified on the basis of auditory and lipreading cues. In this study the integrity of participants' phonological representations was investigated with a picture yes/no judgement (PYNJ) task, in which the child was shown a picture of a target word and was asked to judge whether the spoken stimuli presented were correct labels for the picture. The "incorrect" labels (where a "no" response constituted success) were generally chosen to correspond to the child's own production error (e.g. /wit/ for *sweet*).

One of the profiles identified during the initial testing involved evidence of intact lower level speech discrimination (e.g. discriminating /stip/-/dip/ in a same/different task) with no evidence of ability to reject inaccurate productions of target words (e.g. not rejecting /dip/ as a label for *steep* in the PYNJ task) in the AV or AA conditions. This could imply an incomplete phonological representation for the word *steep*, where /s/ is not accurately specified. This profile was found for the /st/-/d/ contrast for participant AE and the three following contrasts for KC: /sm/-/m/, /ʃ/-tʃ/ and /s -/d/.

The difference in task performance could not be explained by an increased demand on working memory as the same/different task involved making a judgement about two syllables in working memory whereas the PYNJ task involved making a judgement about one syllable (as all the stimuli contained one syllable).

The difference could be explained if some aspect of the PYNJ task was encouraging the child to accept the "incorrect" labels. This possibility will be explored by comparing the PYNJ task to other tasks that involve the child accessing their phonological representations in order to explore the different strategies a child may use to complete the different tasks.

The PYNJ task is similar to the speech production-perception test first designed by Locke (1980a; Locke, 1980b). Locke used a picture to ensure that the child was accessing their internal representation of the referent, and used the child's own speech error to investigate whether the child's incorrect realisation of a phoneme was related to how that specific phoneme may be represented in the internal representation of the referent (Locke, 1980b). When using this kind of procedure with pre-school children Locke (1980a) found that most children accepted correct phonemes and rejected their own incorrect forms. However some accepted their own incorrect forms which Locke

(1980a, 1980b) suggested was evidence of underdeveloped phonological representations.

Stackhouse and Wells (1997) also suggest the use of auditory detection of speech errors, following Locke's design (1980a, 1980b), as a means of assessing the accuracy of a child's phonological representations. Additionally, they suggest minimal pair picture discrimination and auditory lexical decision (ALD) tasks as alternative means of investigating the way words are stored to enable them to be recognised in their spoken form. In this study the purpose of testing the integrity of phonological representations was similar to the aim that instigated the design of Locke's speech production-perception task (1980a, 1980b): to investigate the specification of the segment/s that were realised incorrectly in production. Therefore, in general, the child's own speech errors were presented as the alternative versions of the target words. This meant that it was not possible to use minimal pair picture discrimination as the main assessment method because the participants' incorrect realisations often did not correspond to real words (e.g. *star* →/dɑ/). It was difficult to use ALD tasks as the method, as the participants' incorrect realisations of words sometimes corresponded to other real words rather than nonwords (e.g. *snail* →/neɪl/). However, this would have been a viable alternative method.

ALD tasks usually involve presenting spoken real words with an equal number of spoken nonwords in a random order,and asking the child to judge whether spoken stimuli are real words or not. Pictures are not usually used. These tasks are often used to test a child's ability to recognise words in their lexicon (Constable et al., 1997; Edwards & Lahey, 1996; Hemsley, Holm, & Dodd, 2006; Windsor & Kohnert, 2004). As Edwards and Lahey (1996) explain, the task involves holding a phonetic sequence in working memory and searching the lexicon for the corresponding underlying representation. As with the PYNJ task, a poorer performance on this task compared to a nonword same/different discrimination task can not be explained by difficulties in holding a sequence in working memory. Both the PYNJ task and the ALD task involve comparisons with underlying representations. However, in the PYNJ task the representation of the referent can be accessed before the spoken stimulus is heard, whereas in the ALD task (without pictures) the spoken stimulus triggers a search of the lexicon. Many researchers agree that in an ALD task adults use the first two or three phonemes of the spoken stimulus to activate a cohort of representations in the lexicon that begin with the same phonemes (Edwards et al., 1996).

If a child has a number of underspecified phonological representations of words, you would expect that both PYNJ and ALD tasks (without pictures) should prove difficult and that the "search and match" required for the ALD task may prove more difficult than the "match" required for the PYNJ task. This was suggested by the Constable, Stackhouse and Wells study (1997). In this study a seven-year-old boy with severe word finding difficulties, Michael, completed two versions of an ALD task, one without pictures and one where pictures depicting the referent of the target word were simultaneously presented with the auditory presentation of the target word, the matched non-word and distractor (another real word with a similar phonological structure). Other than the use of pictures, all aspects of the two ALD tasks were identical. The difference in Michael's performance on the two tests was not significant but in the task with pictures he rejected more nonwords (70% compared to 60%). In both tests his performance was significantly worse than the performance of two control groups of typical language learners: one matched for vocabulary age and one for chronological age.

However, some evidence from a study with bilingual students suggests that the use of pictures may encourage children to tolerate nonwords more readily. Hemsley et al (2006) found that a control group of monolingual 11-year-old students (matched for social class) performed significantly better than two groups of bilingual students on a "Receptive Picture Name Judgement" (RPNJ) task (with a similar format to the PYNJ task), but there was no significant difference between any of the groups on an ALD task (without pictures) or a nonword same/different task. Therefore, despite auditory discrimination skills that were similar to those of monolingual peers, the bilingual children were more likely to accept inaccurate phonological forms (e.g. /θənɒmətʌ/) for labels of pictures of familiar words (e.g. *thermometer*) than the monolingual children, even though they performed in a similar way to the monolingual children on the ALD task. The authors proposed that performance in the RPNJ task may not be an indication of poor storage of phonological representations but a reflection of a strategy encouraged by the test. They suggested that the pictures in the task may have encouraged the bilingual children to seek meaning in the spoken stimuli and so tolerate the nonwords, as parents of very young children focus on interpreting the meaning of the child's attempts to talk about a referent and so will often not notice their speech errors. They suggest that the language learning experiences of the bilingual children struggling to learn a second language in the classroom may lead them to use this "seek meaning" strategy more readily. This could also be true for deaf children. Activating the semantic representation for the word illustrated by the picture could cause a child to be less likely to analyze the phonological tokens of the spoken stimulus as carefully as they would in a nonword discrimination task or an ALD task (Hemsley et al., 2006).

Windsor and Kohnert (2004) found that a monolingual control group of 8 to 13-year-olds performed significantly better than bilingual and language impaired groups on an ALD task. The monolingual group correctly rejected more nonwords than the other groups. The ALD task in the Hemsley et al (2006) study had 20 pairs of real words and nonwords and the ALD task in the Windsor and Kohnert (2004) study had 80 pairs, possibly making their test more sensitive to differences. This alternative result supports the hypothesis that deficits in bilingual second language development are attributable to less elaborate lexical representations in the second language (Windsor et al., 2004) and this could explain the performance of the bilingual groups on the RPNJ test in the Hemsley et al (2006) study. The nonwords used in this RPNJ task were very similar to the matched words with one of the consonants in the word being altered in voice or place or manner (e.g. /dɑɪz/ matched with *dice* and /ɒstrɪʃ/ matched with *ostrich*) whereas the matching in the ALD task used in the Hemsley et al (2006) study involved more changes. In five of the pairs in the ALD task only one of the consonants was altered, but always in more than one feature (e.g. *merly* matched with *mercy*). In several pairs there were changes in more than one phoneme and/or the insertion of an additional consonant (e.g. *baranter* matched with *character*; *drister* matched with *sister, apisade* matched with *episode*). If a child has imprecise phonological representations s/he could find the more closely matched items more difficult to reject. However, the nonword same/different pairs in the Hemsley et al (2006) study were very closely matched (e.g. /teɪvək/-/teɪvəg/) and the bilingual children did as well in this task and the ALD task as the monolingual children of the same age. It is therefore possible that the RPNJ task was not actually tapping the integrity of the children's phonological representations.

The RPNJ task in the Hemsley et al (2006) study differed from the PYNJ task in this study. Both tasks involved the use of a picture and asking the child to decide whether spoken stimuli presented were correct or incorrect labels for the picture. However, in the RPNJ task there were 60 different pictures and for each picture only one spoken stimulus was presented. Twenty of these stimuli were accurate labels, 20 were semantic foils (e.g. "sleeve" for *collar*) and 20 were phonological foils (e.g. /ɒstrɪʃ/ for ostrich). Therefore the child had to make one decision for each picture. In the PYNJ task used in this study the child had to make 10 judgements for each picture as 10 spoken stimuli were presented. These consisted of four correct labels for the picture, four incorrect labels corresponding to the child's production errors(e.g. /wɪŋ/ for *swing*) and two incorrect control items (e.g. /lɪŋ/ for *swing*), presented in a random order. It may be possible that the child is more likely to use a "seek meaning" strategy when closely matched phonological foils alternate with semantic foils and accurate labels and only one judgement is made for each picture (perhaps making it more difficult to make comparisons of phonological form).

There is conflicting evidence about what strategies children may use to complete PYNJ tasks. The differences may be due to how the child has learnt language or the exact form of the test. However, it is still possible that the participants in this study were sometimes using a "seek meaning" strategy in the PYNJ task. This would mean that a relatively poor performance on this task (compared to nonword same/different discrimination) was not necessarily due to underspecified phonological representations.

It would be useful to investigate whether deaf children may find it easier to reject nonwords as words in ALD tasks than rejecting the *same* nonwords in a PYNJ task, with each task having the same design in terms of the number of items and judgements made. This would help to evaluate the use of PYNJ task as an indicator of the integrity of phonological representations.

Assessing phonological awareness and literacy skills

As the study progressed, the importance of phonological awareness and letter sound knowledge for updating representations became clear. Although some information on this was collected in the study it would have been useful to have assessed these skills more systematically. For example, for each of the target consonants / clusters, it would have been useful to test the children's spelling and reading of a selection of words that began with those sounds to see if they included the target consonant. If they included target consonants it would have been useful to point to the corresponding graphemes (e.g./s/) and ask them to sound them out. These kinds of tasks would have provided useful additional information on whether and how the consonants were specified in lexical representations.

Assessing the possibility of covert contrasts

When it became evident that participants seemed to be omitting consonants that they were detecting in input tasks, the possibility of covert contrasts was considered as the participants could have been realising a segment (e.g. /s/) in a way that was undetectable even to an experienced transcriber. This phenomenon would have been easier to detect if naming assessments in Phase 1 had included minimal pairs (e.g. *smile* / *mile, skate/gate*). This may have made it easier to detect any differences in production. Although the full Rees Coleman Profiling Procedure included naming and real word repetition items for at least one minimal pair for each contrast (e.g. *skate* and *gate*), only the input tasks were used in the main study and the naming tasks only elicited the target consonants. This made it more difficult to detect any use of covert contrasts.

Assessment Tasks and Procedures in the Main Study

Eliciting each target consonant or cluster in a large number of words in Phase 1 made it easier to measure any improvements in speech output skills and to compare "Therapy" and "No Therapy" words. Comparing these two groupings provided useful information on possible strategies used to update representations. At the end of the intervention programme in Phase 1 the participants were retested on any input tests where they had achieved a chance performance at the start of the study. This helped determine whether improvement in the use of target consonants could have been explained by an improvement in their detection. The use of target consonants was tested formally in sentence repetition at most time points but use in conversation was only observed informally. More formal testing in conversation during Phase 1 would have confirmed hypotheses about lack of generalisation to spontaneous speech.

Assessment of a range of speaking tasks in Phase 2 allowed observations to be made about differences in performance across the tasks, especially for MC.

At T1 it would have been useful to have a longer more detailed naming task that looked more systematically at the production of words with unusual spellings as this was an important way of testing out the hypothesis about the orthographic strategy. More examples of words with unusual spellings of all three consonants (/s/, /ʃ/ and /tʃ/). could have been elicited in word initial and word final position and then compared with usual spellings of these consonants in these same positions.

The Rees Rating Scale proved to be a useful way of measuring improvements in speech production, particularly in Phase 1. Some of the improvements would not have been discovered with a correct / incorrect classification. For example, JB's use of /s/ often improved from a rating of 1 (omit/plosive) to 2 (some friction) or 3 (close) but not to 4 (on target) and MC's use of /tʃ/ moved to a 3 rating at the end of Phase 1. This confirms Ertmer and Maki's observation that deaf children often progress from not producing a target correctly to producing closer though still inaccurate realisations (Ertmer et al., 2000). The check of inter-rater reliability for the scale showed good levels of agreement.

The intelligibility / motivation questionnaire indicated the difference between DA and MC in terms of self-motivation when their responses were combined with other observations. The intelligibility categories were very broad and did not reveal any changes after intervention.

The interview with the adult, JD, provided very useful information on strategies deaf children may use to develop their speech skills. DA was asked similar questions informally during intervention about how he was remembering to say the "new sounds" but just shrugged his shoulders, indicating that he didn't really know. However, a more skilled interview technique may be able to extract this kind of information from children.

The Intervention Programmes

The main reason for using intervention in this study was to "fast-track" speech development in order to assess how input skills were contributing to this process. This worked reasonably well as the speech output skills of all the participants improved to some degree and it was possible to investigate how improvements were associated with input skills for particular consonants before and after therapy. Assessing generalisation from therapy to non-therapy words informed the way the children may be updating their speech processing skills and led to a revision of the Stackhouse and Wells model (1997), as discussed in previous sections of this chapter. Observations made during the intervention indicated the possible influence of output training on input skills. Along with the findings of Kosky and Boothroyd (2003), this provided evidence for including arrows in two directions between the input and output stores in the revised model. More detailed records of input skills during the intervention might have provided further evidence to inform the connections between input and output stores. Another reason for using intervention was that observations on the effectiveness of different techniques could further inform how deaf children may be updating their speech skills. Techniques were combined in an eclectic approach to maximise the chance of their effectiveness. None-the-less it was possible to collect some evidence for the use of strategies, such as links to orthography. More detailed records of responses to different techniques during the intervention may have provided useful evidence.

As discussed in a previous section, both intervention programmes were effective in that all participants showed significant improvements in their speech production during the intervention periods and not during periods before of after intervention. However, there is no evidence that these improvements had generalised to other social situations or would be maintained over longer periods of time. The child with particularly low self motivation did not show evidence of maintaining the skills he had acquired five weeks after intervention. More involvement of family and teachers may have aided his progress. Involvement of the family and significant others is thought to be an important aspect of a therapy approach found to be particularly effective with pre-school hearing children: “Parents and children together” (PACT) (Bowen & Cupples, 1999). Although the mothers and teachers of DA and MC were kept informed of what the participants were learning in intervention sessions, they could have been more actively involved to promote generalisation to a wider range of social situations.

Implications for Clinical and Educational Practice

Even after using cochlear implants or digital hearing aids for several years, some deaf children continue to have difficulty in marking certain phonemic contrasts in an intelligible way when speaking. This study has shown that, for deaf children as young as eight-years-old, it is possible to learn to improve production and use of problematic consonants, even if there are difficulties in detecting them using aided hearing and/or lipreading. If the children have adequate phonological awareness and use of phonic skills, they can learn to associate the production of these consonants with graphemes and then use these skills to transfer the learnt motor patterns to a large number of words containing the same consonants. This study found that participants sometimes learnt to produce a consonant more accurately in words before they learnt to detect it in the speech of others. Therefore it seems that an improved production of a consonant can not only enrich the corresponding segment in output stores but also enrich the corresponding segment in input stores, using a tactile-kinaesthetic feedback loop. Thus we could argue that lexical input stores become moulded by articulatory knowledge as well as orthographic knowledge.

When speech and language therapists are selecting consonants or consonant contrasts to target for intervention they should not discount consonants that the child is unable to detect in input tasks. What seems more crucial in selecting targets that will be more attainable in intervention is to consider which ones can be imitated. The only participant in the intervention study who had difficulty in acquiring accurate productions of consonants was a child with difficulties with motor execution and tactile-kinaesthetic feedback. The success of the intervention may be determined by the child's motor abilities to imitate the consonant in the context of reduced auditory input. This abililty could be measured with a stimulability assessment that attempts to determine whether production of an erred sound is enhanced when elicitation conditions are modified (Powell, 2003). For hearing children, this modification usually means providing a clear auditory and visual model of the target sound in isolation or in CV, VCV or VC syllables that the child is asked to imitate (Powell, 2003). Assessing stimulability in deaf clients is more complex as they may have great difficulty imitating sounds missing from their phonetic repertoire if they are only given an auditory model and this would not imply the absence of motor skills to produce the sound. Although DA learnt to produce /s/ quickly in one session, explanation and tactile cues were needed to elicit the consonant. It took JB three intervention sessions to learn to imitate /f/ and during the whole intervention period he did not learn to imitate /s/ accurately. Therefore, degree of stimulability in the context of additional non-auditory cues needs to be assessed quite carefully with deaf children. Non-auditory cues could include tactile cues and some explanation of how the sound is made. A stimulability assessment for deaf children could include a set of graded steps where the number of additional cues is gradually increased.

Stimulability is often assessed with hearing children because many studies have shown that stimulable phonemes are acquired and generalised more easily than non-stimulable phonemes (Powell, Elbert, & Dinnsen, 1991; Miccio, Elbert, & Forrest, 1999; Rvachew, Refaat, & Martin, 1999; Powell, 2003). Some authors (e.g. (Hodson & Paden, 1991) have interpreted this finding to imply that it is better to target stimulable consonants in therapy, to increase chance of success. However, more recently, authors advise targeting unstimulable consonants that are less likely to be acquired spontaneously (Powell & Miccio, 1996; Powell et al., 1991). If a deaf child can imitate some consonants easily in isolation or in simple syllabic structures with just an auditory model, then this principle may still apply, as these consonants may well develop without intervention. However, in intervention it may be better to target consonants needing just one or two non-auditory cues, rather than those needing more cues or those that are not stimulable at all, even with a number of non-auditory cues.

If a child is using an orthographic strategy to transfer learnt motor patterns for a consonant across known words in his lexicon, one could argue that it makes sense to incorporate intervention aiming to improve speech production into the teaching of phonics. After consulting with members of the British Association for Teachers of the Deaf through their online forum, it seemed that there are no standard practices on the teaching of articulatory skills during phonics training for deaf children in the UK. This points to a possible area for further collaboration between speech and language therapists and teachers of the deaf. Some attention was paid to improving speech production in a successful phonics programme conducted in the USA ((Trezek et al., 2005). The treatment teacher, conducting the programme in the Trezek and Malgrem study, was aiming for mouth movements and vocal sensations for each phoneme that allowed them to be distinctive from those associated with other phonemes. This was a sensible aim in the context of teaching literacy where developing a set of distinct motor movements for each phoneme to link with graphemes is probably adequate. The fact that many of these movements are unintelligible need not prevent a deaf child from developing literacy. Sally, reported by LaSasso (1996), developed good literacy skills despite her speech being unintelligible. However, a phonics programme could also provide the opportunity to teach more accurate speech production skills for the individual phonemes. The present study suggests that, if the teacher has adequate training in phonetics and the child does not have specific difficulties with motor execution, teaching an accurate production of a consonant could be done in a short space of time (e.g. part of one 45 minute session). It seems that teachers of the deaf in the UK do not have the training and/or confidence to elicit more accurate realisations of consonants. One of DA's teachers reported that she did not feel she had the training to elicit consonants from children if they could not imitate them and, when teaching phonics, she tended to accept a realisation of the target phoneme that involved articulatory movements that were correct in terms of how they looked. Unfortunately, studies describing the teaching of phonics to deaf children in the U.K. (e.g. (Palmer, 2000; Watson, 2002; Grindal, 2004) give no detail on how the children are encouraged to produce any phonemes that they have difficulty articulating during this process. In fact the study by Grindal (2004) particularly states that correct pronunciation of phonemes was not a consideration in her investigation. In evaluating phonics teaching to two profoundly deaf children aged 8;10 years and 9;0 years in the U.K. Palmer (2000) notes that their letter-sound knowledge and reading improved but she does not give any detail on whether speech production had improved. However she noted that the speech and language therapist of one of the children had reported an improvement in speech as a result of the phonics training. Interestingly the help the child was receiving from the speech and language therapist was not integrated into the phonics teaching and this separation seems to be fairly standard practice in deaf education in the U.K.

Speech and language therapists, with more knowledge of phonetics and how to elicit more accurate realisations of consonants, could work more closely with teachers who are teaching phonics to deaf children. Alternatively or additionally, the training of teachers of the deaf could involve more training in phonetics and techniques to improve speech production. The way in which speech production training could be incorporated into the teaching of phonics for deaf children would need to be planned carefully, preferably by therapists and teachers working closely together. It would be useful to review similar work carried out with hearing children with speech impairments. A study conducted by Gillon (2005) showed that therapy targeting speech production could be successfully combined with activities to develop phonemic awareness and letter knowledge with 3-5-year-old hearing children with speech impairments. The results of this study suggested that intervention integrating skills in this way can result in all the skills improving significantly and concurrently.

Applying new knowledge about how to produce consonants in naming tasks to more spontaneous speech was greatly facilitated by a programme of intervention designed to promote generalisation. This programme was conducted over five weeks by speech and language therapy students with some knowledge of phonetics and very little clinical experience. This programme was effective in that the participants learnt to use their newly acquired speech skills in conversation at least 55% of the time. This degree of generalisation had not happened spontaneously after Phase 1. This suggests that any effort put into teaching the production of consonants during naming tasks may have no functional benefit unless it is followed by work specifically focusing on generalisation.

The degree of generalisation achieved at the end of Phase 2 still required a fairly deliberate production of speech. It is hard to know how much repeated practice of using new speech skills and the involvement of significant others outside the intervention session would contribute to automatic use of the new consonant realisations. It is possible that the degree of automaticity that many deaf children reach is limited due to storing of alternative phonological representations that are only accessed in some structured situations (Ehri & Wilce, 1980).

Some procedures developed and used in the study could be developed and used in clinical practice and further investigations. The Rees Coleman profiling procedure with matched items could be used to explore further the variation in patterns across consonant contrasts for other deaf children. It could also help to detect the possibility of lower level speech discrimination being relatively intact when performances on PYNJ tasks indicated underspecified phonological representations (although the use of the PYNJ task as an indicator of this integrity may need further investigation) . This phenomenon may be more likely to occur soon after cochlear implantation or the issue of new hearing aids and so it may be beneficial to use these kinds of matched tests at those times. The Rees Coleman procedure could be extended to include sets of stimuli in connected speech. The rating scales and statistical tests used in this project could be used to measure any improvements in speech production as a clinical outcome measure or in future research studies. Some of the intervention techniques that proved to be particularly effective could be used in similar clinical contexts.

Further Investigation and Conclusion

This study led to various hypotheses that may warrant further investigation. In order to seek a good indicator of the integrity of phonological representations, it would be useful to compare the PYNJ task with other tasks requiring access to the lexicon. The possibility that deaf children are using covert phonemic contrasts in their speech output could be investigated with studies involving instrumentation measures such as spectrographic analysis which may pick up undetectable distinctions the child is making. The extent to which deaf children are using orthographic strategies to update lexical representations and generalise speech skills could be investigated by similar studies with more detailed assessment of phonological awareness and literacy skills and/or by interviewing deaf children and adults about the strategies they are using or have used with appropriate methodologies for skilled interviewing. The role of core abilities in executive function and self motivation in updating speech skills could be explored further, including factors that may influence motivation. The notion of deaf children using multiple phonological representations for differing speaking tasks could be explored using methodologies similar to those used with dialect-speaking hearing children.

This study has shown that input skills do not necessarily determine whether a deaf child can learn to produce more accurate productions of consonants and generalise this skill to conversation. If a child has limited hearing, s/he may rely on an orthographic strategy to update speech skills and so needs to have the necessary phonological awareness skills and knowledge of grapheme-phoneme links. Improved output skills could enrich input stores leading to improved input skills. Intervention provided in this study was effective in two ways. It enabled the participants to improve their speech skills and was a means of learning something about deaf children's speech processing skills.

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APPENDICES

APPENDIX 1: STIMULI IN THE REVISED VERSION (2) OF THE REES COLEMAN PROFILING PROCEDURE

The full version (showing all the combinations of pairings and number of items) is shown for the first contrast and, for the other contrasts, only the main stimuli are listed (as the system of combining pairs and the number of each type of stimulus is identical).

Stimuli used in each test for the **/p/-/b/ contrast**:

Nonword Discrimination (NWD) - Audio-visual version (NWDAV) and audio- alone version (NWDAA)	
pug/bug x2 bug/bug x2 pug/pug x2 bug/bug x2	pɔs/bɔs x2 bɔs/pɔs x2 pɔs/pɔs x2 bɔs/bɔs x2
Real Word Discrimination (RWD) - Audio-visual version (RWDAV) and audio- alone version (RWDAA)	
pig/big x2 big/pig x2 pig/pig x2 big/big x2	path/bath x2 bath/path x2 path/path x2 bath/bath x2
Picture Yes/No Judgement (PYNJ) - Audio-visual version (YNJAV) and audio-alone version (YNJAA)	
Picture of ***pig*** pig x4 bɪg x4 lɪg x2 (not scored)	Picture of ***purse*** purse x4 bɜs x4 lɜs x2 (not scored)
Real Word Repetition (RWR) - Audio-visual version (RWRAV) and audio- alone version (RWRAA) and Naming	
purse x2 pig x2 Paul x2 path x2	bat x2 big x2 ball x2 bath x2
Nonword Repetition (NWR) - Audio-visual version (NWRAV) and audio-alone version (NWRAA)	
pɔs x2 pug x2 pɑl x2 piθ x2	beət x2 bug x2 bɑl x2 biθ x2

Stimuli used for other contrasts:

/m/-/b/

NWD	RWD	PYNJ	RWR and Naming	NWR
mʊt/bʊt məʊs/bəʊs	mike/bike mat/bat	*mat*/bæt/læt *mouse*/bɑʊs/laʊs	mat mouse man mike ball bat bath bike	mʊt məus mɒn mɜk bɜl bʊt biθ biθ

/s/-/d/

NWD	RWD	PYNJ	RWR and Naming	NWR
sɑ/dɑ sek/dek	sea/D suck/duck	*sea*/di/bi *sock*/dɒk/bɒk	sea sock sun saw duck D dog door	sɑ sek sɒn sɑ dæk dɜ deg dɑ

/ʃ/-/tʃ/ (There were 2 extra PYNJ tests for this contrast as participants' realisations could be in either direction i.e. /ʃ/→/tʃ/, /tʃ/→/ʃ/)

NWD	RWD	PYNJ	RWR and Naming	NWR
ʃɜ/tʃɜ ʃʌp/tʃʌp	share/chair shop/chop	*shoe*/tʃu/bu *shop*/tʃɒp/bɒp *chair*/ʃeə/beə *chip*/ʃɪp/bɪp	shoe shop ship shirt chair chip church cheese	ʃɜ ʃʌp ʃep ʃeət tʃɔɪ tʃʌp tʃitʃ tʃɜz

/sp/-/b/

NWD	RWD	PYNJ	RWR and Naming	NWR
spʊəd/bʊəd spin/bin	spell/bell spade/bade	*spade*/beɪd/leɪd *spoon*/bun/lun	spade spoon spell spider bell bath bus big	spʊəd spin spul spɔɪdi bul biθ bis bug

/sm/-/m/

NWD	RWD	PYNJ	RWR and Naming	NWR
smɒl/mɒl smɔɪk/mɔɪk	smile/mile small/mall	*smile/*maɪl/laɪl *smoke*/məʊk/ləʊk	smile smoke small smell mouse match mat moon	smɒl smɔɪk smul smul məʊs mɒtʃ mɒt mɜn

/sw/-/w/

NWD	RWD	PYNJ	RWR and Naming	NWR
swɑt/wɑt sweŋ/weŋ	swing/wing switch/witch	*sweet*/wit/lit *swing*/wɪŋ/lɪŋ	sweet swing switch swimming wing witch watch one	swɑt sweŋ swetʃ swɒmɪŋ weŋ wetʃ wætʃ wæn

/sn/-/n/

NWD	RWD	PYNJ	RWR and Naming	NWR
snɑ/nɑ snaʊl/nɑʊl	snail/nail snow/no	*snow*/nəʊ/bəʊ *snail*/neɪl/beɪl	snow snail snake snap no nail knife knee	snaɪ snɑʊl snɑʊk snep nɑ nɑʊl nəʊf nɜ

/st/-/d/

NWD	RWD	PYNJ	RWR and Naming	NWR
stɑʊ/dɑʊ stɪmp/dɪmp	steep/deep store/door	*star*/dɑ/bɑ *stamp*/dæmp/bəmp	star stamp stick stairs dog door deep duck	stɑʊ stɪmp stik stɑʊz deg dɔɪ dɑp dɜk

/sk/-/g/

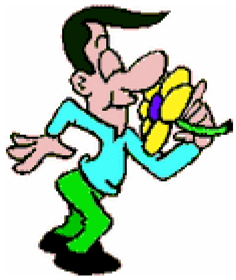
NWD	RWD	PYNJ	RWR and Naming	NWR
skil/gil skɜf/gɜf	school/ghoul skate/gate	*school*/gul/bul *scarf*/gaf/baf	school scarf skate skirt gate girl goat gun	skil skɜf skɔt skɑt gaɪt gɔl gɑt gen

/f/-/p/ (this test is not part of the computer version and was designed specifically for JB and performed live)

NWD	RWD	PYNJ	RWR and Naming	NWR
faɪk/paɪk fæʃ/pæʃ	fork/pork fat/pat	*fork*/pɔk/lɔk *fish*/pɪʃ/lɪʃ	fork fish fat four pig pat pen pea	fɑɪk fæʃ fɜt fɔɪ pɒg put pɜn pɑ

APPENDIX 2: EXAMPLE PICTURES FROM NAMING TASKS IN PHASE 1

Example Pictures from Naming Tasks in Phase 1 to elicit: ***sn**ack*, ***sn**ail*, ***sn**ake*, ***sn**eak*, ***sn**eeze*, ***sn**iff*, ***sn**ooze* and ***sn**ow.*

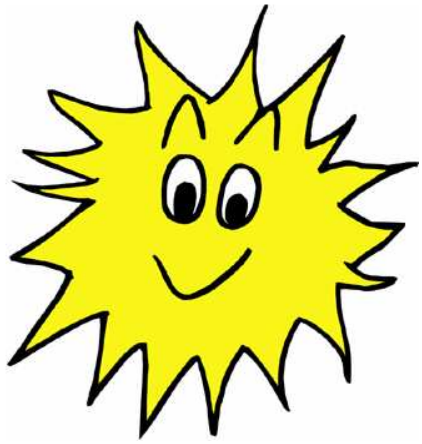
		
		
		

APPENDIX 3: SENTENCES USED IN SENTENCE REPETITION TASK IN PHASE 1

The elephant is **sad.** Some **sand** is in the wheelbarrow. The children are on the **seesaw**. The **sun** is shining. This is number **seven**.
The chair is too **small** for the man. The lady's **smelling** the flowers. Those socks are very **smelly**. The sun is **smiling**. There's **smoke** coming from the chimneys.
The **spade** is in the shed The boy is eating **spaghetti**. The **spider**'s made a web. Some point has **spilt**. There are two **spoons**.
The **swan** is in the water. Three of the **sweets** are big. The boy is **swimming**. The **switch** is on. The boy's on the **swing**.
The girl has a big **snack** before bed. The **snail** is wearing sunglasses. This **snake** is wicked! The house is covered with **snow.** The women are playing **snap**.
This **stamp** is not English. The horse is **standing**. The train's coming out of the **station**. The policeman says **stop**. The children like **storytime**.
The cat is **scared** The **scarf** is blue. This is a **school** bus. The squirrel is riding a **scooter**. The **sky** is blue.
This knife is **sharp.** The **ship** has hit ice. The **shoes** are new. The **shop** is closed. The elephant is **shy**.
The man's sleeping in the **chair.** This old house is **cheap.** The **children** are skipping. The dinosaur is made of **chocolate**. The woman is **choosing** which dress to buy.
The elephant is **falling** The man's driving **fast.** The boy is **fat**. The mice are **fighting**. The building's on **fire**.

APPENDIX 4: EXAMPLE PICTURES FROM SENTENCE REPETITION TASK IN PHASE 1

Examples Pictures from Sentence Repetition Task in Phase 1 to elicit:
The chair is too ***sm****all for the man, The woman is* ***sm****elling the flowers, Those socks are very* ***sm****elly, The sun is* ***sm****iling* and *There's* ***sm****oke coming from the chimneys.*



APPENDIX 5: RESPONSES TO LETTER KNOWLEDGE TEST FOR EACH PARTICIPANT IN PHASE 1

NAME: **DA**	DATE:
TESTER:	TIME: T2

WRITTEN LETTER/S	NAME	SOUND	(WITH PROMPTING?)
b	bi	bə	
c	di	də	
d	di	də	
f	ep̪	b̪ə	
g	ʒji	gə	
h	heɪʔʃ	hə	
j	jeɪ	çjə	
k	keɪ	kə	
l	el	lə	
m	em	mːə	
n	eŋ	nə	
p	pi	pə	
q	kju	kwə	
r	ɑ	rə	
s	eʔh	dəʔ	
t	tɪ	tə	
v	b̪i	b̪ə	
w	dəbəju	wə	
x	eək	ek	
y	wəɪ	jə	
z	ded	də	
sh		çjə	
ch		çʒjə	
th		t̪ə	
ng		ɪŋg	

NAME: **JB**	DATE:
TESTER:	TIME: T2

WRITTEN LETTER/S	NAME	SOUND	(WITH PROMPTING?)
b	bi	bə	
c	di	k	
d	du	də	
f	ep	bə	
g	tʃi	dʒə	
h	eɪkx	h	
j	gɣjeɪ	xji	
k	keɪ	k	
l	el	lə	
m	em	mə	
n	en	nə	
p	pi	p	
q	kju	kwə	
r	ɑ	ʋə	
s	eʔ	kx	xji
t	ti	k	
v	bə	pɸ	
w	dəʔəju	wə	
x	eʔ	eʔ	
y	waɪ	wə	
z	ded	tʃ	
sh		çː	
ch		tçː	
th		no response	
ng		ɪn	

NAME: **MC**	DATE:
TESTER:	TIME: T2

WRITTEN LETTER/S	NAME	SOUND	(WITH PROMPTING?)
b	bi	də	
c	θi	kə	
d	bi	bə	
f	ef	fə	
g	no response	gə	
h	heɪʔ	hə	
j	də	deɪ	
k	keɪ	kə	
l	no response	lə	
m	em	mə	
n	en	nə	
p	pi	pə	
q	kju	kwə	
r	no response	ʋə	
s	eʔ	s̺ə	$s^{ʃ}$
t	ti	tə	
v	b̪vi	və	
w	dəbəju	wə	
x	ekʔ	no response	
y	waɪ	jə	
z	ðed	ɮ	z^{3}
sh		də	
ch		də	
th		fə	
ng		ɪŋ	

APPENDIX 6: RECORDS OF RESPONSE TO INTERVENTION FROM PARTICIPANTS IN PHASE 1

DA Response to Intervention

No	/s/ and /s/ clusters		ʃ and tʃ	
	Input	Output	Input	Output
1	Distinguished between [x] and [s] in isolation in AV condition after explanation about how they were produced	Imitated /s/ as [x] and then later in session (after input work) as [s̪] or [sʃ]		
2		Realised /s/ as[s̪] or [θ] when reading words beginning with /sp/ and /st/		
3		Realised /s/ as [s̪] or [θ] when in words beginning with /sp/, /st/, /sm/ and /sw/ when retelling story		
4	Could distinguish between *sun* and /stʌn/ in AV condition	Found imitation of /s/ + vowel difficult – a few successful attempts at *sun* Realised /s/ as [s̪] when in words beginning with /sp/, /st/, /sm/ and /sw/ when naming in game		Trying to make difference between /s/ and /ʃ/ and /ʃ/ and /tʃ/ /ʃ/-/tʃ/ difference marked by [θ] - [tθ] or [k[- [kx]
5	Could distinguish between *smile* and *mile* in AA condition	Realised /s/ as [s̪] when naming all the therapy words with /s/ clusters in game. Realised /s/ as [s̪] in words beginning with /s/ + vowel when imitating and naming.		
6 and 7		Performance as in session 5 but we discussed that length of /s/ was sometimes too long and he successfully modified this. Found it hard to make a clear difference between a *sip / a ship / a chip*		Found it hard to make a clear difference between *a sip / a ship / a chip*

8		Made the following difference between s/ʃ/tʃ ː /s/ → [s̪] /ʃ/ → [ʆ], [ç] or [x] /tʃ/ → [t--ç] Needed reminding about difference between /s/ and /st/ but then could mark difference when naming		Made the following difference between s/ʃ/tʃ ː /s/ → [s̪] /ʃ/ → [ʆ], [ç] or [x] /tʃ/ → [t--ç]
9		Realised /s/ as [s̪] when naming all the therapy words with /s/ clusters and when making up sentences with the words in game.		Used /ʃ/ and /tʃ/ with 90% accuracy when naming in game
10		Retelling stories written with /s/ realised as [s̪]		Retelling stories written with /ʃ/ and /tʃ/ realised accurately most of the time

JB: SKILLS LEARNT AT EACH SESSION

* = double session

No	s and s clusters		f	
	Input	Output	Input	Output
1	In AV condition could distinguish between opposite ends of this continuum: [s] – [s^{ʃ}] – [ʃ^{s}] – [x] When sounds produced in isolation but not finer gradations			Imitated labiodental place when manipulating articulators with fingers and looking in the mirror
2	Could distinguish between *a spell* vs *a bell* and then *spell* vs *bell*	Imitated tongue tip and/or front of tongue rubbing against back of 4 front upper teeth		Imitated labiodental place when manipulating articulators with fingers and looking in the mirror and fingerspelling /f/ at same time
3*	Discriminated a smile/ a mile in AA condition and then, after practice *smile/mile* Both in AA condition	Had difficulty in copying exact position of tongue against upper teeth and didn't seen aware of difference between central and slightly lateral position of tongue		Imitated /ɑf/ and realised syllable final /f/ correctly when naming some words ending in /f/ Eventually managed 5 correct attempts at imitating /f/ + vowel as J2 tended to use [fpa] etc.

4	Discriminated *smile/ mile* in AA condition – but not *spell / bell* (but singing had started up in next room!)			/f/ realised correctly in word final syllable final position when naming. Still finds it hard to join /f/ to following vowel
5*		Imitation of /s/ tended to be [x] or [kx].Practised using this realisation for /s/ in words beginning with "sn", "sm" or "sp" – performance was successful with /s being realised as [x] or [kx] with a gap before the next consonant.		/SIWI /f realised correctly in repeating and naming of words "fat" and "fall"
6 *		Despite trying to use chocolate spread to encourage correct tongue position, imitations of /s/ in isolation were: [ç] or [x]		Tried hard not to include intrusive [b] when imitating and using words beginning with /f/ and was successful some of the time
7	Good recognition (in AV condition) of whether my attempts at /s/ in naming were correct or realised as[x]	Generally successful at realising /s/ as [ç] or [x] when naming		More frequent blending of /f/ with vowel when naming pictures of words beginning with /f/
8*	Generally knew (in AV condition) whether my production of words beginning with /f/ or /s/ were correct or not	Classified pictures into words beginning with /f/ and words beginning with /s/ for all therapy words except "spider" When naming these words /f/ was always realised correctly and /s/ was realised as [x], [kx] or [ç] (with an intrusive /t/ being used before the vowel when realising /s/ before a vowel.	Generally knew (in AV condition) whether my production of words beginning with /f/ or /s/ were correct or not	Classified pictures into words beginning with /f/ and words beginning with /s/ for all therapy words except "spider" When naming these words /f/ was always realised correctly and /s/ was realised as [x], [kx] or [ç] (with an intrusive /t/ being used before the vowel when realising /s/ before a vowel.
9*		Realised /s/ as [x], [kx] or [ç] (with an intrusive /t/ being used before the vowel when realising /s/ before a vowel) when reading a short story and retelling it. His performance was less consistent when reading and retelling to a teacher because of hi excitement – but he was able to correct himself with prompting.		When spontaneously naming words beginning with /f/, /f/ was generally realised correctly (just 2 exceptions – and three words were correctly imitated). Realised /f/ correctly when reading a short story and retelling it. His performance was less consistent when reading and retelling to a teacher because of his excitement – but he was able to correct himself with prompting.

MC: SKILLS LEARNT AT EACH SESSION

* = double session

No	s clusters		ʃ and tʃ	
	Input	Output	Input	Output
1				
2		Few successful attempts at imitating /s/ in isolation as [sɬ] or [s̬]		
3		Consistent imitation of /s/ as [s̪] in isolation and for words beginning with /sm/	Heard difference between *a ship / a chip*	
4		Consistent imitation of /s/ mainly as [s̪] or [sʃ] in words beginning with /sm/		Produced clear and accurate difference between *mash* and *match* when imitating
5		Read words beginning with /sm/ using [sʃm]	Heard difference between *a mash / match* when difference exaggerated	Difficulty imitating /ɑtʃɑ/
6 *	Could identify when I was omitting /s/ for words beginning with /sw/ and /sm/ when telling story	Realised /s/ as [sʃ] for *horse* and for words beginning with /sw/ and /sm/ when retelling story		A few successful attempts at imitating /ɑtʃɑ/
7			Could identify when I was realising /tʃ/ as /ʃ/ for *a chair* in a sentence	Many successful attempts at imitating *a chair*
8		Realised /s/ as [sʃ] when naming pictures of all therapy words beginning with /sp/ and /sk/	Could hear difference between *a chip* and *a ship* but NOT between *chip* and *ship*	Good imitations and spontaneous productions of *a chair, a chimney*(still finds *a chip* difficult)
9*		Realised /s/ as [sʃ] when naming pictures of all therapy words		80% success in classifying words into those that start with /ʃ/ and those that start with /tʃ/ and could then contrast these sounds when naming – usually leaving slight pause between /ʃ/ and vowel and /tʃ/ and vowel

10		Realised /s/ as [s^{ʃ}] when reading words beginning with /s/ clusters in a poem		Realised /tʃ/ correctly (sometimes with pause before vowel) when reading words beginning with /tʃ/ in a poem
11*	Could recognise when I omitted /s/ from therapy words when I said them in a sentence	Realised /s/ as [s^{ʃ}] when naming pictures of all therapy words and when using words in sentences	Distinguished between *ship/chip* and *share/chair* in AA condition	In general realised /ʃ/ and /tʃ/ correctly when naming pictures of all therapy words – just needed some reminding
12		A few attempts at including /s/ in general conversation e.g. for *yes* and *dragons*		A few attempts at including /ʃ/ and /tʃ/ in general conversation e.g. for *Chessington, Chinese*

APPENDIX 7: INTELLIGIBILITY / MOTIVATION QUESTIONNARE IN PHASE 1: BLANK FORM AND RESULTS FOR DA AND MC

Pre/Post Therapy Questionnaire on Speech Intelligibility: Student Version
Completed at T2 and T3

Student: Date:

How would you describe your speech (**when you are not signing at the same time)*?
(Just tick ONE box)

Family, teachers, friends and strangers understand everything I say (I never have to repeat anything).	
Most people understand everything I say.	
Most people understand most of what I say.	
Some people understand most of what I say.	
Some people understand some of what I say.	
People usually have difficulty understanding what I say.	

How easy is it to make yourself understood in these situations, when you are not signing?

5 = very easy (don't have to repeat anything
4 = quite easy (occasionally have to repeat)
3 = a bit difficult (often have to repeat)
2 = difficult (sometimes have to repeat)
1 = very difficult (sometimes they don't get what I say even if I repeat and show)
0 = impossible!

Put a number in EACH box:

Asking family and friends for something to eat or drink.	
Telling family and friends about something I saw or did.	
Calling out to friends in games (e.g. football).	
Explaining a game to a friend.	
Talking to a stranger when it is noisy.	
Telling a story/joke to a group of people.	
Asking a question in a big class.	

Are there any words or sentences you say (when not signing) that are difficult for others to understand (people keep asking you to repeat them)?

If yes, they are:

Are there any sounds that are hard for you to say?

If yes, they are:

For T2 ONLY:

Do you want your speech to be clearer?
(Just tick ONE box)

Definitely	
It would be good.	
Maybe.	
I think so ? I don’t mind.	
I don’t care.	
No.	

Please give reasons for your answer:

What do you think you have to do to make your speech clearer?:

For T3 ONLY:

What have you learnt to do in the speech and language therapy lessons this term?

Any other comments?

DA Intelligibility / Motivation Questionnaire in Phase 1

Questions and responses to the intelligibility / motivation questionnaire at T2 (before intervention) and T3 (after intervention) are as follows:

How would you describe your speech (when you are not signing at the same time)? (Just tick ONE box)

	T2	T3
Family, teachers, friends and strangers understand everything I say (I never have to repeat anything).		
Most people understand everything I say.	√	√
Most people understand most of what I say.		
Some people understand most of what I say.		
Some people understand some of what I say.		
People usually have difficulty understanding what I say.		

How easy is it to make yourself understood in these situations, when you are not signing?

5 = very easy (don't have to repeat anything
4 = quite easy (occasionally have to repeat)
3 = a bit difficult (often have to repeat)
2 = difficult (sometimes have to repeat)
1 = very difficult (sometimes they don't get what I say even if I repeat and show)
0 = impossible!

Put a number in EACH box:

	T2	T3
Asking family and friends for something to eat or drink.	4	5
Telling family and friends about something I saw or did.	4	4
Calling out to friends in games (e.g. football).	3	5
Explaining a game to a friend.	4	3
Talking to a stranger when it is noisy.	3	2
Telling a story/joke to a group of people.	4	4
Asking a question in a big class.	5	4

Are there any words or sentences you say (when not signing) that are difficult for others to understand (people keep asking you to repeat them)?
T2: *Can't think of any* T3: *No*
Are there any sounds that are hard for you to say?
T2: *s and sh* T3: *s and g*
I

At T2 only:

Do you want your speech to be clearer?

	T2
Definitely	
It would be good	
Maybe	
I think so. I don't mind	√
I don't care	
No	

Please give reasons for your answer:
Cos I can hear well and I can speak well my mum says
What do you think you have to do to make your speech clearer?
Don't know

At T3 (only):

What have you learnt to do in the speech and language therapy lessons this term?
How to say s, sh, ch
(Then asked "Can you say them no? and DA replied *"Most of the time".*)

<u>MC Intelligibility / Motivation Questionnaire in Phase 1</u>

Questions and responses to the intelligibility / motivation questionnaire at T2 (before intervention) and T3 (after intervention) are as follows:

How would you describe your speech? (Just tick ONE box)

	T2	T3
Family, teachers, friends and strangers understand everything I say (I never have to repeat anything).		
Most people understand everything I say.	√	√
Most people understand most of what I say.		
Some people understand most of what I say.		
Some people understand some of what I say.		
People usually have difficulty understanding what I say.		

How easy is it to make yourself understood in these situations, when you are not signing?

5 = very easy (don't have to repeat anything
4 = quite easy (occasionally have to repeat)
3 = a bit difficult (often have to repeat)
2 = difficult (sometimes have to repeat)
1 = very difficult (sometimes they don't get what I say even if I repeat and show)
0 = impossible!

Put a number in EACH box:

	T2	T3
Asking family and friends for something to eat or drink.	5	5
Telling family and friends about something I saw or did.	5	3
Calling out to friends in games (e.g. football).	4	0
Explaining a game to a friend.	3	1
Talking to a stranger when it is noisy.	4	0
Telling a story/joke to a group of people.	*2/5	4
Asking a question in a big class.	5	5

* 2 to children and 5 to adults

Are there any words or sentences you say that are difficult for others to understand (people keep asking you to repeat them)?
T2: *lots of words together to my neighbour. He asks me to repeat them and then, when I repeat them again he repeats back what I've said*
T3*: Yes*
If yes, they are:
T3: *don't know*
Are there any sounds that are hard for you to say?
T2: *s in a word* T3: *no*
I
At T2 only:

Do you want your speech to be clearer?

	T2
Definitely	√
It would be good	
Maybe	
I think so. I don't mind	
I don't care	
No	

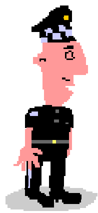
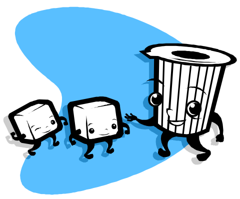
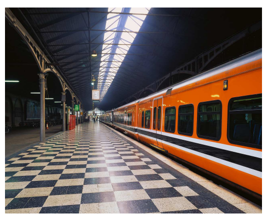
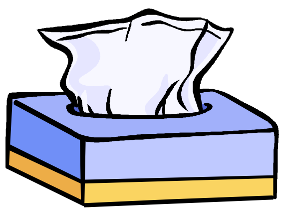
Please give reasons for your answer:
If I was meeting a new friend they can understand me properly.
What do you think you have to do to make your speech clearer?
Do more speech therapy
If I didn't get my speech clearer I would have to learn to sign. (Asked "Do you want to learn to sign? And answered "*I already do*")

At T3 (only):

What have you learnt to do in the speech and language therapy lessons this term?
Nothing (grinning)
(Then asked "Is your speech the same? and MC replied *"No*". Then asked "How is it different?" and he replied *"Don't know."*))

APPENDIX 8: EXAMPLE PICTURES FROM NAMING TASKS IN PHASE 2

Example Pictures from Naming Tasks in Phase 2 to elicit: **ice**, poli**ce**(man), **c**ircus, pen**c**il, **c**inema, **s**ugar, sta**ti**on, ti**ss**ue, ques**ti**on, pic**t**ure

APPENDIX 9: SENTENCES USED IN SENTENCE REPETITION TASK IN PHASE 1

The man is **sad**.

The **children** are on the seesaw.

This is number **seven**.

The **chair** is too small for the man.

Those socks are very **smelly**.

The **spider**'s made a web.

Three of the **sweets** are big.

The **switch** is on.

This **snake** is wicked!

The house is covered with **snow**.

The **horse** is standing.

The train's coming out of the **station**.

The **police** say **stop**.

The cat is **scared**.

This is a **school** bus.

The squirrel is riding a **scooter**.

The **ship** has hit **ice**.

The **shop** is **shut.**

The dinosaur is made of **chocolate**.

The woman is **choosing** which dress to buy.

The man's **cross**.

The boy ate too much **sugar**.

Let's make **cheese** on **toast.**

The **mask** has a green feather.

The **fish** jumped out of the bowl.

The man painted a **picture** with his **brush**.

This **watch** is new.

This **circus** has a lion.

The dark **cinema** was full of **shadows**.

He wrote a letter with his **pencil**.

The train is in the **station**.

Mum is putting **shampoo** on the baby.

Have a **tissue**.

(**question** was accidentally missed from the stimuli in this task.)

APPENDIX 10: EXAMPLE PICTURES FROM SENTENCE REPETITION TASK IN PHASE 2

Examples Pictures from Sentence Repetition Task in Phase 1 to elicit:

The **police** say **stop**.	The cat is **scared**.
This is a **school** bus.	The squirrel is riding a **scooter**.
The **ship** has hit **ice**.	The **shop** is **shut.**

APPENDIX 11: STORIES FOR READING AND RETELLING IN PHASE 2

Practice Story for T1 only:

There were two cats called Henry and George. Henry was a lazy cat who ate all day and George was a busy cat. One day two naughty mice moved into their house and they ate all of the food. George chased them until he was so tired he couldn't run anymore. George told Henry he must help. The mice stole all of Henry's food and he got so cross he chased them out of the house, down the street and across the park. The mice never came back and Henry was never lazy again.

Assessed Stories for all Time Points:

One day Jimmy went to the **cinema** on his **scooter**. When the film started the lights were **switch**ed off. Then a thief came and sat next to him. The thief stole his **watch** and ran out of the cinema. Jimmy was **cross** and shouted '**Stop**!'. A policeman was outside and caught the thief. The policeman took him to the **police** station. The other policemen were having tea and **toast**. The policeman asked the thief **questions**. The thief was **scared**. He said he would never steal again.

Billy had a **horse** called **Sugar**. It was winter and there was lots of **ice** and **snow** so Sugar got dirty and **smelly**. He needed a **wash** and a **brush**. Billy got on the **bus** to go and see Sugar to give him a wash. Sugar was so big Billy had to stand on a **chair** to wash him. Afterwards Billy gave him some **chocolate** because he had been such a good horse.

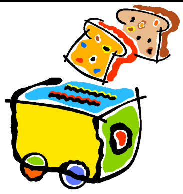
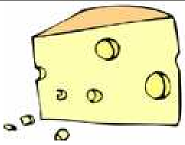
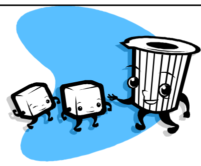
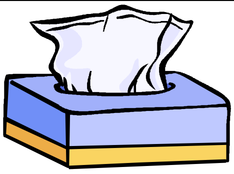
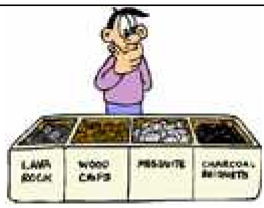
Once there was a **snake** called Sid. His nasty owner would make him sharpen **pencils** all day. He was so **sad** that he would cry all night – cry so much that he used a whole box of **tissues**. One day he met a **spider** who was going to the train **station**. The spider was going back to the **circus** where he worked as a clown. He showed Sid the **pictures** of him juggling **sweets** and wearing a clown **mask**. He wanted Sid to come too. Sid agreed. They both caught the train to the circus and Sid was never sad again.

On the way home from **school** two **children** stopped in the park to eat their **cheese** sandwiches. Then they saw a new pet **shop**. In the window was lots of dog **shampoo** and a tank of **seven fish**. One of the fish was all black and he was swimming around a little pirate **ship**. The shop was going to **shut** so they quickly went inside. The shop keeper asked them to **choose** a fish. He told them the black one was called **Shadow**. They took Shadow home were he had an even bigger pirate ship to swim in.

APPENDIX 12: GROUPS OF WORDS AND PICTURES FOR MAKING UP STORIES

IN PHASE 2

Story 1: *wash, toast, cheese, sugar, tissue, scooter, stop, shop, choose, sweets*
Story 2: *children, cinema, circus, bus, station, horse, shampoo, snow, spider, chocolate*
Story 3: *picture, pencil, chair, switch, ship, seven, mask, sad, police, cross*
Story 4: *brush, fish, wash, shadow, snake, scared, question, smelly, ice, shut*
PICTURES TO ELICIT STORIES WITH *wash, toast, cheese, sugar, tissue, scooter, stop, shop, choose, sweets.*

 wash	 toast
 cheese	 sugar
 tissue	 scooter
 stop	 shop
 choose	 sweets

APPENDIX 13: INTELLIGIBILITY / MOTIVATION QUESTIONNARE IN PHASE 2: BLANK FORM AND RESULTS FOR DA AND MC

Pre/Post Therapy Intelligibility / Motivation Questionnaire Student: Date:

* for DA only
How would you describe your speech (*when you are not signing at the same time)?
(Just tick ONE box)

Family, teachers, friends and strangers understand everything I say (I never have to repeat anything).	
Most people understand everything I say.	
Most people understand most of what I say.	
Some people understand most of what I say.	
Some people understand some of what I say.	
People usually have difficulty understanding what I say.	

How easy is it to make yourself understood in these situations, when you are not signing?

5 = very easy (don't have to repeat anything
4 = quite easy (occasionally have to repeat)
3 = a bit difficult (often have to repeat)
2 = difficult (sometimes have to repeat)
1 = very difficult (sometimes they don't get what I say even if I repeat and show)
0 = impossible!

Put a number in EACH box:

Asking family and friends for something to eat or drink.	
Telling family and friends about something I saw or did.	
Calling out to friends in games (e.g. football).	
Explaining a game to a friend.	
Talking to a stranger when it is noisy.	
Telling a story/joke to a group of people.	
Asking a question in a big class.	

How much would you like to improve your speech?

I don't want to improve my speech at all.	
Sometimes I think I'd like to improve my speech but I can't be bothered to change it.	
I'd like to improve my speech if it's not too much work.	
I'd like to improve my speech – even if I have to work quite hard.	
I really want to improve my speech and will work as hard as I can.	

DA Intelligibility / Motivation Questionnaire in Phase 2

Pre/Post Therapy Questionnaire on Speech Intelligibility: Student Version	
Student:	D1
Date:	Across the four time points in the generalisation study

How would you describe your speech (when you are not signing at the same time)? (Just tick ONE box)

	T1	T2	T3	T4
Family, teachers, friends and strangers understand everything I say (I never have to repeat anything).				
Most people understand everything I say.	*	*	*	*
Most people understand most of what I say.				
Some people understand most of what I say.				
Some people understand some of what I say.				
People usually have difficulty understanding what I say.				

How easy is it to make yourself understood in these situations, when you are not signing?

5 = very easy (don't have to repeat anything
4 = quite easy (occasionally have to repeat)
3 = a bit difficult (often have to repeat)
2 = difficult (sometimes have to repeat)
1 = very difficult (sometimes they don't get what I say even if I repeat and show)
0 = impossible!

Put a number in EACH box:

	T1	T2	T3	T4
Asking family and friends for something to eat or drink.	5	5	5	5
Telling family and friends about something I saw or did.	4	5	4	5
Calling out to friends in games (e.g. football).	5	3	4	5
Explaining a game to a friend.	3	3	3	3
Talking to a stranger when it is noisy.	2	4	4	4
Telling a story/joke to a group of people.	4	3	4	4
Asking a question in a big class.	4	4	3	4

How much would you like to improve your speech?

	T1	T2	T3	T4
I don't want to improve my speech at all.				
Sometimes I think I'd like to improve my speech but I can't be bothered to change it.				
I'd like to improve my speech if it's not too much work.	*	*	*	*
I'd like to improve my speech – even if I have to work quite hard.				
I really want to improve my speech and will work as hard as I can.				

Reasons given:
T2: People will understand me

What do you think you have to do to make your speech clearer?:
T2: Remember the sounds

MC Intelligibility / Motivation Questionnaire in Phase 2

Pre/Post Therapy Questionnaire on Speech Intelligibility: Student Version Student: M3 Date: Across the time points in the generalisation study (questionnaire not completed at T2)

How would you describe your speech (when you are not signing at the same time)? (Just tick ONE box)

	T1	T2	T3	T4
Family, teachers, friends and strangers understand everything I say (I never have to repeat anything).			*	*
Most people understand everything I say.	*			
Most people understand most of what I say.				
Some people understand most of what I say.				
Some people understand some of what I say.				
People usually have difficulty understanding what I say.				

How easy is it to make yourself understood in these situations, when you are not signing?

5 = very easy (don't have to repeat anything
4 = quite easy (occasionally have to repeat)
3 = a bit difficult (often have to repeat)
2 = difficult (sometimes have to repeat)
1 = very difficult (sometimes they don't get what I say even if I repeat and show)
0 = impossible!

Put a number in EACH box:

	T1	T2	T3	T4
Asking family and friends for something to eat or drink.	5		5	5
Telling family and friends about something I saw or did.	5		5	5
Calling out to friends in games (e.g. football).	3		5	5
Explaining a game to a friend.	5		5	3
Talking to a stranger when it is noisy.	5		5	4
Telling a story/joke to a group of people.	5		5	4
Asking a question in a big class.	5		5	4

How much would you like to improve your speech?

	T1	T2	T3	T4
I don't want to improve my speech at all.				
Sometimes I think I'd like to improve my speech but I can't be bothered to change it.	*			
I'd like to improve my speech if it's not too much work.				*
I'd like to improve my speech – even if I have to work quite hard.				
I really want to improve my speech and will work as hard as I can.			*	

APPENDIX 14: EXTRA STATISTICAL RESULTS FOR PHASE 1

DA

Analysis with Correct/Incorrect Coding:

The McNemar test was used to measure any significant changes during the following intervals:

- T1-T2 (no intervention period prior to intervention)
- T2-T3 (intervention period)
- T3-T4 (no intervention period following intervention).

There were no significant changes for T1-T2 (*N* = 136, *p* = 0.180) or for T3-T4 (*N* = 136, *p* = 0.754). However there was a significant improvement in ratings during the intervention period, T2-T3 (*N* = 136, *p* <0.001).

The data was split into input groups (None, Audio-Visual Only, Auditory-Nonwords Only, Auditory Full) in order to see whether evidence of input skills relating to target consonants prior to therapy had influenced a change from “incorrect” to “correct” realisations of those consonants.

A McNemar test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for all the input skills groups. As three statistical tests were used as a follow-up, the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*p* value
T1-T2	None	82	.18
	Audio-Visual Only	31	#
	Auditory-Nonwords Only	6	#
	Auditory Full	17	#
T2-T3	None	82	**<.001**
	Audio-Visual Only	31	**<.001**
	Auditory-Nonwords Only	6	.031
	Auditory Full	17	**<.001**
T3-T4	None	82	.754
	Audio-Visual Only	31	#
	Auditory-Nonwords Only	6	#
	Auditory Full	17	#

Statistical tests were not needed as the scoring for each item was identical at each time point.

Table 71 DA: McNemar test comparing consonant realisations for the three time intervals for each input group

For all input groups except Auditory Nonwords Only, the significant improvements from incorrect to correct realisations of target consonants occurred during the therapy period (T2-T3). The improvement in Auditory Nonwords Only did not qualify as significant with the adjusted level. However, all the six ratings of consonants in this group changed from incorrect at T2 to correct at T3.

In order to see whether any changes from "incorrect" to "correct" realisations of the target consonants were influenced by whether the particular words containing them had been used in therapy, the whole data set was spit into:

- words used in therapy and
- words not used in therapy.

A McNemar test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the words used in therapy and those not used. As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Therapy vs No Therapy	*n*	*p* value
T1-T2	Therapy	73	.07
	No Therapy	63	1.000
T2-T3	Therapy	73	**<.001**
	No Therapy	63	**<.001**
T3-T4	Therapy	73	.250
	No Therapy	63	.5

Table 72 DA: McNemar test comparing consonant realisations for the three time intervals for each word group

All the significant improvements occurred during the therapy period (T2-T3) for both sets of words. Whether words containing the target consonants had been used in therapy did not influence whether D1 learnt to produce the correct realisation of the consonant.

<u>Analysis of Sentence Repetition Data</u>

In order to see whether changes in ratings also occurred in the sentence repetition tasks the ratings of target consonants in DA's responses to these tasks were compared across T2, T3 and T4 using the Friedman test. Results showed a significant difference (X^2 (2, N = 44) = 84.000 p <.001).

Therefore the Wilcoxon test was used to measure any significant changes in ratings during the following intervals:

- Time 2 to Time 3 (T2-T3) (intervention period)
- Time 3 to Time 4 (T3-T4) (no intervention period following intervention).

Time Interval	*N*	*z* value	*p* value
T2-T3	44	-5.976	**<.001**
T3-T4	44	0.000	1.000

Table 73 DA (Sentence Repetition): Wilcoxon test comparing ratings of consonant realisations for the three time intervals

A significant improvement took place in the intervention period, but not between T3 and T4.

The data was split into the input groups (None, Audio-Visual Only, Auditory-Nonwords Only, Auditory Full) in order to see whether evidence of input skills relating to target consonants prior to intervention had influenced a change in the ratings of their production in the sentence repetition tasks.

The Friedman test was used to compare the ratings of the consonant realisations across the three time points for every input group.

Input Type	*n*	X^2	d.f.	*p* value
None	20	36.000	2	**<.001**
Audio-Visual Only	10	20.000	2	**<.001**
Auditory-Nonwords Only	4	8.000	2	.018
Auditory Full	10	20.000	2	**<.001**

Table 74: DA (Sentence Repetition): Friedman test comparing ratings of consonant realisations for each input group across the three time points

There were significant effects across time points for all the input groups except “Auditory Nonwords Only”.

A Wilcoxon test was used to measure any significant changes in the two time intervals (T2-T3 and T3-T4) for all the input skills groups. As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*z* value	*p* value
T2-T3	None	20	-3.810	**<.001**
	Audio-Visual Only	10	-3.051	**<.001**
	Auditory-Nonwords Only	4	-2.000	<.046
	Auditory Full	10	-3.051	**<.002**
T3-T4	None	20	0.000	.275
	Audio-Visual Only	10	0.000	1.000
	Auditory-Nonwords Only	4	0.000	1.000
	Auditory Full	10	0.000	1.000

Table 75 DA (Sentence Repetition) Wilcoxon Test comparing consonant realisations for the two time intervals for each input group

All the significant improvements in ratings of target consonants occurred during the therapy period (T2-T3) for all the groups of input variables, except Auditory-Nonwords Only. However, the ratings for all for consonants in this group changed from 1 (omit/plosive) at T2 to 4 (on target) at T3. As with the single word naming tests, the input variable did not influence whether significant improvements were made to the ratings.

JB

<u>Analysis with Correct/Incorrect Coding:</u>

The McNemar test was used to measure any significant changes during the following intervals:

- T1-T2 (no intervention period prior to intervention)
- T2-T3 (intervention period)
- T3-T4 (no intervention period following intervention).

There were no significant changes for T1-T2 (as all items were scored as incorrect at both time intervals and so no statistical test was necessary) or for T3-T4 (N = 59, p= 1.000 (two-tailed)). However there was a significant improvement in ratings during the intervention period, T2-T3 (N = 59, p <0.001(two tailed)).

The data was split into the two input groups (None and Auditory Full) in order to see whether evidence of input skills relating to target consonants prior to therapy had influenced a change from “incorrect” to “correct” realisations of those consonants.

A McNemar test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for all the input skills groups. As three statistical tests were used as a follow-up, the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*p* value (two-tailed)
T1-T2	None	28	#
	Auditory Full	31	#
T2-T3	None	28	**#**
	Auditory Full	31	**<.001**
T3-T4	None	28	#
	Auditory Full	31	1.000

Statistical tests were not needed as every score at both time points was identical.

Table 76 JB: McNemar test comparing consonant realisations for the three time intervals for each input group

The only significant improvement that took place was for the Auditory Full group. The only consonant that was given a correct score was /f̣/ and this consonant was in the Auditory Full Group. The other consonants in the Auditory Full group were scored as incorrect at all time points.

In order to see whether any changes from “incorrect” to “correct” realisations of the target consonants were influenced by whether the particular words containing them had been used in therapy, the whole data set was spit into:

- words used in therapy and
- words not used in therapy.

A McNemar test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the words used in therapy and those not used. As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Therapy vs No Therapy	*n*	*p* value
T1-T2	Therapy	29	#
	No Therapy	30	#
T2-T3	Therapy	29	**<.016**
	No Therapy	30	**<.002**
T3-T4	Therapy	29	1.000
	No Therapy	30	1.000

Statistical tests were not needed as every score at both time points was identical.

Table 77 JB: McNemar test comparing consonant realisations for the three time intervals for each word group

All the significant improvements occurred during the therapy period (T2-T3) for both sets of words. Whether words containing the target consonants had been used in therapy did not influence whether JB learnt to produce the correct realisation of the consonant.

MC

Analysis with Correct/Incorrect Coding:

The McNemar test was used to measure any significant changes during the following intervals:

- T1-T2 (no intervention period prior to intervention)
- T2-T3 (intervention period)
- T3-T4 (no intervention period following intervention).

There were no significant changes for T1-T2 (N = 100, p = 0.508) or for T3-T4 (N = 100, p = 1.000). However there was a significant improvement in ratings during the intervention period, T2-T3 (N = 100, p < 0.001).

The data was split into input groups (None, Audio-Visual Only, Auditory-Nonwords Only, Auditory Full) in order to see whether evidence of input skills relating to target consonants prior to therapy had influenced a change from “incorrect” to “correct” realisations of those consonants.

A McNemar test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both input skills groups (Auditory Nonwords Only and Auditory Full). As three statistical tests were used as a follow-up, the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*n*	*p* value (two-tailed)
T1-T2	Auditory Nonwords Only	11	#
	Auditory Full	89	.508
T2-T3	Auditory Nonwords Only	11	#
	Auditory Full	89	**< .001**
T3-T4	Auditory Nonwords Only	11	#
	Auditory Full	89	1.000

Statistical tests were not needed as every score at both time points was identical.

Table 78 MC: McNemar test comparing consonant realisations for the three time intervals for each input group

For all input groups except Auditory Nonwords Only, the significant improvements from incorrect to correct realisations of target consonants occurred during the therapy period (T2-T3). The improvement in Auditory Nonwords Only did not qualify as significant with the adjusted level. However, all the six ratings of consonants in this group changed from incorrect at T2 to correct at T3.

In order to see whether any changes from “incorrect” to “correct” realisations of the target consonants were influenced by whether the particular words containing them had been used in therapy, the whole data set was spit into:

- words used in therapy and
- words not used in therapy.

A McNemar test was used to measure any significant changes in the different time intervals (T1-T2, T2-T3 and T3-T4) for both the words used in therapy and those not used. As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Therapy vs No Therapy	*n*	*p* value (two-tailed)
T1-T2	Therapy	42	1.000
	No Therapy	58	.625
T2-T3	Therapy	42	**<.001**
	No Therapy	58	**<.001**
T3-T4	Therapy	42	.791
	No Therapy	58	1.000

Table 79 MC: McNemar test comparing consonant realisations for the three time intervals for each word group

All the significant improvements occurred during the therapy period (T2-T3) for both sets of words. Whether words containing the target consonants had been used in therapy did not influence whether MC learnt to produce the correct realisation of the consonant.

Analysis of Sentence Repetition Data

In order to see whether changes in ratings also occurred in the sentence repetition tasks the ratings of target consonants in MC’s responses to these tasks were compared across T2, T3 and T4 using the Friedman test. Results showed a significant difference (X^2 (2, N=42) = 24.574 p<.001).

Therefore the Wilcoxon test was used to measure any significant changes in ratings during the following intervals:

- Time 2 to Time 3 (T2-T3) (intervention period)
- Time 3 to Time 4 (T3-T4) (no intervention period following intervention).

Time Interval	*N*	*z* value	*p* value
T2-T3	42	-3.724	**<.001**
T3-T4	42	-2.054	.040

Table 80 MC (Sentence Repetition): Wilcoxon test comparing ratings of consonant realisations for the three time intervals

A significant improvement took place during the intervention period and a smaller, but significant improvement also took place after intervention, from T3 – T4.

The data was split into the input groups (Auditory-Nonwords Only, Auditory Full) in order to see whether evidence of input skills relating to target consonants prior to therapy had influenced an improvement in the ratings of their production in the sentence repetition tasks.

The Friedman test was used to compare the ratings of the consonant realisations across the three time points for every input group.

Input Type	*n*	X^2	d.f.	*p* value
Auditory-Nonwords Only	38	23.15.	2	**<.001**
Auditory Full	4	4.667	2	.097

Table 81: MC (Sentence Repetition): Friedman test comparing ratings of consonant realisations for each input group across the three time points

There were significant effects across time points for “Auditory Full” but not “Auditory Nonwords Only”.

A Wilcoxon test was used to measure any significant improvements in the two time intervals (T2-T3 and T3-T4) for both input skills groups. As three statistical tests were used as a follow-up the Bonferroni correction was used to decrease the 0.05 level of significance to 0.0167 (by dividing it by 3).

Time Interval	Input Group	*N*	*z* value	*p* value
T2-T3	Auditory-Nonwords Only	4	1.000	,317
	Auditory Full	38	-3.816	**<.001**
T3-T4	Auditory-Nonwords Only	4	-1.333	.102
	Auditory Full	38	-1.627	.104

Table 82 MC (Sentence Repetition) Wilcoxon Test comparing consonant realisations for the two time intervals for each input group

The only significant improvement in ratings of target consonants occurred during the therapy period (T2-T3) for “Auditory Full” group.