McALLISTER

PSYCHOLINGUISTIC PROFILING OF A DEAF CHILD

HELEN MCALLISTER

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Department of Human Communication Science
University College London

ABSTRACT

In this study Stackhouse and Wells' speech processing model (1997), is used to create a psycholinguistic profile of a 9 year old boy, (MC), who has a moderate hearing impairment and has been identified as having additional literacy difficulties. The Rees-Coleman Procedure, a series of computer tests including real- and nonword repetition, lexical decision, etc. is used along with informal real- and nonword reading and writing tests to identify levels of breakdown for different contrasts and to see if any deficits identified could account for his literacy difficulties. Different levels of breakdown are identified for different contrasts which can be divided into four separate profile patterns. Even though it is found that input skills for all contrasts tested except for sh/ch are now generally accurate, MC does not always distinguish between them in his speech as he has not yet updated his motor programs for these phonemes at the beginning of words. Results indicate that some of MC's literacy difficulties can be explained by deficits identified in the Rees-Coleman Procedure due to these inaccurate motor programs. Additional difficulties are also identified which are more likely to be due to deficits in phonological awareness and/or the ability to make links between phonemes and graphemes, therefore supporting a diagnosis of dyslexia.

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LITERATURE REVIEW

Psycholinguistic approaches are increasingly being used to investigate and treat speech and language difficulties in children. At the simplest level they attempt to view and explain these difficulties as being derived from a breakdown of one or more of the three main aspects of speech processing: input (receptive processing), stored linguistic knowledge, (underlying representations) or output (production of words.) (Dodd, 1995, Stackhouse and Wells, 1997). Until the development of these models children's speech difficulties were viewed primarily as output problems.

Psycholinguistic models can be divided into two types. More recent models being developed are computer-based "connectionist models" mimicking the properties of neurons in the brain which are interconnected into a complex network and operate simultaneously and co-operatively, (Christiansen & Chater, 1999). Most of the earlier theories use box-and-arrow models: Boxes represent hypothesised levels of representations and processing whilst the arrows represent the relationships or routes between them. The number of boxes and arrows varies from model to model, for example Smith's single lexicon model, (1973), Spencer's two-lexicon model, (1986) where phonological information is divided into two lexicons; one for input and one for output, and Hewlett's more detailed model, (1990), all as cited in Baker, Croot, McLeod & Paul et al., (2001). Readers are referred to this paper for a detailed review of the development and success of some of these earlier frameworks.

Baker et al., (2001) favour one of the more recent box-and-arrow frameworks, Stackhouse and Wells' speech processing model (1997), depicted in appendix 1. This expands on earlier models by including more boxes and arrows to stand for more complex processes and representations. It is widely used in speech and language therapy services and in research into various difficulties (see below). In this model a stored lexical representation is divided into three boxes containing separate phonological, semantic and motor information. Processes requiring prior linguistic knowledge from these representations, e.g. lexical decision, are known as "higher level" whereas "lower level" processes, e.g.

nonword repetition, do not access any stored information. Processing skills are divided further into input and output skills. Input skills appear on the left of the model and are identified as peripheral auditory processing, speech/non-speech discrimination, phonetic discrimination and phonological recognition and output skills are on the right of the model and are separated into motor programming, motor planning and motor execution. Thick black arrows and shaded boxes on the model are processes hypothesised to take place offline. (See Stackhouse and Wells, 1997 for more detail.)

This model can be used to precisely identify faulty levels of speech processing causing children's speech difficulties. Stackhouse and Wells identified that all existing tests and published assessments tap different levels of psycholinguistic processing and most can therefore be related to the model, (Stackhouse and Wells, 1997). They also developed their own assessment structure which asks a series of questions about possible levels of breakdown and suggest tasks which test different levels of the model, e.g. they suggest that the question "can the child articulate real words accurately?" can be tested by a real word repetition task. No single task can identify the level of breakdown however, and only by completing a battery of input and output tests and comparing the results can the deficits be precisely located. In the above example of real word repetition, breakdown could be occurring at any of the levels and each one would have to be explored separately. If the child has input difficulties they may not hear the target precisely and therefore repeat the words as they hear them. In order to find this out an input test such as a picture yes/no judgement task would have to be carried out to see if the child accepts their own incorrect realisations as being correct when spoken by someone else. It is just as possible that the child has motor programming or motor execution difficulties. This could be tested by comparing the results of the real word repetition and naming task to see if they are similar.

As new hypotheses are formed different tests can be carried out accordingly. It is difficult to further explore diagnosed disorders on the model as a group, e.g. dyspraxia, as on assessment children with the same presenting speech characteristics have been revealed as having different underlying processing deficits. (Stackhouse & Wells, 1997).

When assessments have been completed a profile of the child's processing abilities can be put together which then, with information gathered from other sources, forms the basis for planning intervention. Dent (2001) demonstrates the importance of obtaining additional information in her study using electropalatography to reveal different underlying processing deficits in two children with perceptually identical speech deficits. Relative strengths should be targeted as well as weaknesses. Waters (2001) cites the example of therapy for a child named Alan where his strengths in input were used to update his motor programs. Children often have different profiles for different contrasts tested and therapy may initially be targeted at the contrasts for which they have adequate input skills and which they are already beginning to mark, (Ebbels 2000).

Unlike some psycholinguistic models, e.g. Ellis and Young's cognitive neuropsychological model, (1988) Stackhouse and Wells' framework, (1997) takes a developmental perspective. As the child gets older, the focus of assessment and therapy shifts to reading and spelling and relating these to speech difficulties, e.g. case study of a child referred to as T in Popple and Wellington (1996). For younger children later literacy difficulties can be hypothesised and targeted earlier on therefore reducing their impact, as literacy depends on phonological awareness skills which themselves are dependent on phonological processing, (Stackhouse, 1997). The model can also identify hidden deficits in a child with dyslexia who has not been identified as having any speech and language difficulties.

Stackhouse and Wells' speech processing model (1997) is not confined to any specific group or groups of speech disorders and has been used in different ways in research to build profiles of individual children within these groups, e.g. a child with severe word-finding difficulties, (Constable, Stackhouse and Wells, 1997), a child with prosodic processing difficulties, (Wells and Peppé, 1999, cited in Stackhouse & Wells, 2001), children who stammer, (Nicholas, 1999, cited in Stackhouse & Wells, 2001), and children with hearing impairments, (Ebbels, 2000; Dent, 2001).

In her study Ebbels carried out tests to create a psycholinguistic profile for a 10 year old girl (TG) with a moderate-severe sensorineural hearing impairment. As well as finding out overall areas of difficulty, Ebbels aimed to establish whether there were different levels of breakdown for each phonemic contrast tested (as a hearing impairment can affect the perception of some phonemes more than others). She used words and nonwords of one to four syllables, testing contrasts in word initial, within word and word final positions. An initial naming task was carried out and then the contrasts which TG did not mark consistently were tested in a series of other input and output tests of single-word processing and the results were compared; realword repetition, nonword repetition (with and without lip cues) and reading. By ensuring that she used the same stimulus words and matched nonwords throughout, Ebbels could identify the exact level of breakdown for different contrasts.

Ebbels found that TG did obtain varying results for the different contrasts and that there were multiple levels of breakdown. Results showed that TG had some imprecise phonological representations which were not due directly to her hearing impairment. Although she could hear the difference between 64 out of 90 pairs of correct and incorrect realizations in the same/different task, in the lexical decision task she accepted a variety of these incorrect heard realizations as being correct. TG was also identified as having some output difficulties; in accessing the motor programs. In some contrasts TG had faulty motor programs even though her phonological representations were accurate. This was hypothesised to be due to the fact that she was in the process of updating her phonological representations but this had not yet spread to her motor programs. Further conclusions were also drawn but readers are referred to the original study (Ebbels, 2000) for more information.

Ebbel's study demonstrates the importance of examining different levels of input and output processing in children with a hearing impairment. Until recently most studies of deaf children's speech have focussed on output. Early studies took a phonetic based approach, describing errors and their effects on intelligibility. Later studies combined this with a phonological approach and examined the way in which deaf children mark phonemic contrasts, how their speech deviates from normal phonological systems and the degree of any delay. Dodd, (1976) found that congenitally deaf children do have some phonological rules consistent with those used by hearing children. Abraham, (1989) reached a similar conclusion and also constructed phonetic inventories for hearing impaired children, finding them to be similar in size and composition to hearing 3 year old children. The majority of these studies were group studies looking for similarities in the speech of hearing impaired children. Although they are useful for providing descriptions of phonological processes in general, they do not offer an explanation for the difficulties or as to why some children's speech deviates from these rules.

Published assessments of deaf children's speech have also focussed on output. One of the most recently developed tools which is widely used with hearing impaired children is The Phonological Evaluation and Transcription of Audio-Visual Language, PETAL (Parker, 1999). This aims to "describe the phonetic events which are observed in a typical sample of an individual's speech and to look for phonological patterns and relationships," (p23). Although it takes visible and audible factors into account it does not aim to assess input skills and therefore does not always identify why deaf children do not mark certain contrasts. Input skills are usually addressed separately by audiologists in hearing tests and even though they are being examined more with the development of cochlear implants, the stimuli are not matched across tests and the loci of breakdown are not identified on a psycholinguistic model. During intervention it should be checked that sounds targeted for therapy can be discriminated between (Murphy and Dodd, 95) but it is often not until this stage that any input skills are tested which is too late for selecting which contrasts to focus on in therapy. A more comprehensive initial assessment should lead to more effective therapy as it can be targeted more precisely. Also when evaluating therapy unless changes are evident in a child's speech output any progress in input skills will go unnoticed if purely output tests are used.

More recent studies of deaf children have focussed on their development of literacy skills and whether this is similar to that of hearing children. Most deaf children have difficulties in reading but exactly why this is difficult is still unclear (see Musselman, 2000 for review). According to Uta Frith's model of normal literacy development (Frith, 1985) children pass through three stages; a logographic, whole word recognition stage, an alphabetic stage using phoneme-grapheme conversion, and finally an orthographic stage. Deaf children are thought to have difficulty with the second stage as it is dependent on the development of accurate phonological representations and phonological awareness. There is conflicting evidence in the literature as to whether profoundly deaf children have access to phonology (see Perfetti and Sandak, 2000, for a detailed review) but as many do learn to read and write, even if their skills are at a lower level than hearing children, this suggests that either they do develop some phonological ability or that they adopt other strategies for successful literacy. Studies have addressed both of these questions.

Various methods have been used in research to establish whether deaf children have access to phonological coding. One of the earliest studies by Conrad (1979) found a phonological similarity effect when comparing deaf teenagers' short term memory for words which rhymed and words which were visually similar. He concluded that this was evidence that these children were using phonological coding. Other studies have looked at whether deaf children make phonological errors in spelling. Harris and Moreno (2004) found few such misspellings and more visual and transpositional errors and interpreted this to mean that deaf children do not make much use of phonological coding. Aaron, Keetay, Boyd, Palmatier, & Wacks (1998) came to a similar conclusion but some studies such as Leybaert and Alegria (1995) have obtained opposing results. Reading tasks have also been used; in a silent reading task examining similarity judgement between written pseudowords, Transler, Gombert & Leybaert (1993) found evidence for phonological assembly and decoding (but only in deaf children with the most effective speech.)

Although results are inconclusive as to how many deaf readers use phonology, it is generally accepted that many do have at least some access to it. Research such as Harris et al., (2004) indicates that phonological awareness and coding are strong predictors of reading ability in deaf children. Several theories have been put forward as to how profoundly deaf children acquire phonology, including use of lip-reading and articulation by converting graphemes into articulatory movements and retaining them in a visuo-spatial store, e.g. Chalifoux (1991). Leybaert, (2000) concluded that Cued Speech (Cornett, 1967), can be valuable in establishing accurate phonological representations in deaf children which are then essential for phonology-orthography mapping and therefore accurate spelling. This suggests that phonological representations are not restricted to sound but can be influenced by visual strategies such as Cued Speech or speech-reading. A recent study by Trezek and Malmgren (2005) concluded that a phonics treatment package (in which children were helped to articulate phonemes and associate them with symbols) was valuable in developing phonic and phonological awareness skills in children with varying degrees of hearing loss therefore demonstrating that these skills essential for literacy can be taught to some deaf children.

As some deaf children do not appear to be using phonological coding and some seem only to be using it inconsistently, this suggests that there is some other mechanism to enable successful literacy. Some people believe that visual errors made in spelling such as those identified by Aaron et al (1998) e.g. 'dook' for the target word 'book', 'ture' for the target 'true', are a sign that some deaf children rely on visual processing. Other evidence supports the idea that deaf readers rely more on contextual information. Many of the above studies focus on profoundly deaf children who have little or no residual hearing. Children whose hearing impairments are mild to moderate and who wear hearing aids or have a cochlear implant will hear more of the speech signal but, depending on the degree of hearing loss, are likely to have imprecise phonological representations.

Hearing impaired children may still have some literacy difficulties even if they have good phonological awareness and phonological coding skills. Poor auditory discrimination (caused directly by the hearing impairment) is likely to have an effect on the whole speech processing system by leading to inaccurate phonological representations and/or motor programs. This may then cause inaccurate graphemic representations, e.g. a child may hear "sun" as [dʌn] and therefore write it as <dun>. A child may have an inaccurate phonological representation but still be fully aware of how it is split up (i.e. have good phonological awareness skills). For example their phonological representation for "sock" may be stored as /dɒk/ but they can detect that it is made up of d-ɒ-k. Stackhouse and Wells' speech processing model (1997) can be used to identify either difficulties in speech processing (such as inaccurate phonological representations) and/or phonological awareness difficulties and can therefore be used to identify the cause of literacy difficulties.

In this study Stackhouse and Wells' speech processing model, (1997) will be used to create a psycholinguistic profile of a 9 year old boy (MC) with a moderate hearing impairment who is making errors in his speech output. MC was selected for this study as he had already been identified as having mild dyslexia on top of his hearing impairment. The fact that he has dyslexia suggests that his literacy difficulties are not simply caused by phonological processing deficits due to his hearing impairment and that there are additional difficulties with phonological awareness. (Many deaf children have difficulties in reading and are not diagnosed with dyslexia.)

The focus of the study will be on detecting any underlying speech processing deficits caused by MC's hearing impairment. Additional reading and writing tests will be carried out to see if any errors can be explained by these hypothesised difficulties as if not it is likely that they are caused by further difficulties with phonological awareness. Errors will also be analysed according to the literature and theories reviewed above. It must be remembered however, that the majority of the above studies have concentrated on profoundly deaf children and that when wearing his hearing aids MC can hear much of the speech signal.

Tests will be carried out using the Rees-Coleman Procedure; a series of computer based tests, e.g. real and nonword repetition, targeting the different levels of processing in Stackhouse and Wells' model. The procedure was designed to profile hearing impaired children over 6 years old who are making errors in their speech production when naming single words. Tests profile consonant contrasts rather than vowels as Ebbels (2000) found that this is where the breakdown tends to be for deaf children. Further informal tests of MC's literacy use some of the stimuli from the Rees-Coleman Procedure.

The study therefore has three aims:

1.) **To see if psycholinguistic profiling can determine the levels of breakdown in MC's speech processing.**

2.) **To identify if there are differences in the levels of breakdown in MC's speech processing across the contrasts tested.**

3.) **To establish whether speech processing difficulties uncovered could account for MC's literacy difficulties.**

The following hypotheses were formed according to MC's realisations of phonemes in an initial picture naming task using pictures from the Rees-Coleman Procedure:

1.) **MC has different levels of breakdown in speech processing for different consonant contrasts.**

2.) **MC has good input skills for the contrasts which he marks in his speech, i.e. p/b and m/b.**

3.) **MC has poor input skills and therefore imprecise motor programs for the contrasts which he does not mark consistently in his speech, i.e. sm/m, st/d, s/d, ʃ/tʃ.**

4.) Poor input skills for these contrasts impact upon MC's literacy skills.

5.) MC has additional literacy difficulties which are not due to processing deficits caused by his hearing impairment.

METHODOLOGY

DESIGN

Using Stackhouse and Wells' speech processing model (1997), a single case study of a hearing impaired child was carried out in order to identify the precise loci of breakdown for different sound contrasts.

SUBJECT

Selection

The following criteria were given to speech and language therapists working in the local health district so that they could help select potential subjects for the study. This was to ensure that the subject's age, attention, degree of hearing loss and vocabulary was good enough to complete the tests and to avoid secondary age pupils because of greater difficulty in withdrawing them from classes for testing.

The subject needed to:

- be between 7 and 11 years of age
- have a sensori-neural hearing loss
- use speech as their main means of communication
- have hearing that is good enough to discriminate between some minimal pairs e.g. boot/boat, tea/me
- have difficulties with some consonants and/or consonant clusters at a single word level
- have an English vocabulary age of at least 4 yrs
- have suspected additional literacy difficulties to see if psycholinguistic profiling could help explain these.

Background

Once the speech and language therapist had selected a possible subject, (MC), subsequent testing of his receptive and expressive language skills was carried out by the researcher to confirm that he met the criteria. Results are summarised below:

Table 1: Standardised test results prior to psycholinguistic testing at CA 8.11y.

British Picture Vocabulary Scales (BPVS) (Dunn and Dunn, 1997):
Raw score: 85.
Age equivalent: 8.4 years. Low average band.
Renfrew Action Picture Test (RAPT) (Renfrew, 1997):
Information score, age equivalent: 7^{0-5}.
Grammar score, age equivalent: 6^{6-11}.
Renfrew Bus Story (Renfrew, 1997)
Sentence length: 8^{3},
Information score, 7^{6},
Subordinate clauses, 7^{7}-8^{0}
The Clinical Evaluation of Language Fundamentals (Celf Pre-school 3): (Semel, Wiig, Secord, 2000).
Expressive Language Score: 88
Receptive Language Score: 94
Total Language Score: 90
Age equivalent: $7^{6.}$ Average band.

These results show that MC's language skills are in the low average range for his age. Raven's Standard Progressive Matrices (Raven, 1956) were administered by the researcher when MC was 9 years and 2 months to assess his intellectual and non-verbal reasoning ability, results showed that he was in the 62nd percentile. All results suggest MC's speech errors cannot be attributed to poor intellectual ability or language skills and that he should not have any difficulty in understanding the test procedures. This confirmed that he was a suitable subject.

MC was aged 9:0 years when psycholinguistic testing began. He has a moderate bilateral congenital sensori-neural hearing loss which was diagnosed at 5 months of age. He was fitted with hearing aids at this time but did not wear them consistently for a further 18 months and now wears Phonak Supero 412 AZ digital hearing aids, fitted in 2002. MC attends a hearing impairment unit attached to a mainstream school and receives 5 hours support per week from a teacher of the deaf and 5 hours from an LSA. Reports from his school and educational psychologist indicate that he also has signs of mild dyslexia and poor phonological awareness skills, especially in the alliteration, spoonerism and naming speed and fluency tasks in the Phonological Assessment Battery, (Frederickson, 1995).

The naming test of The Phonological Evaluation and Transcription of Audio-Visual Language, PETAL, (Parker, 1999) was administered by a speech and language therapist when MC was 9 years and 3 months. This single word naming test elicits several tokens of all the English vowels and consonants and a large range of consonant clusters. MC produced all vowels and plosives correctly but produced all s-clusters, most fricatives and both affricates incorrectly and inconsistently, (see tables 2 and 3). He produced all other consonant clusters correctly.

Table 2: Summary of incorrect realisations of fricatives in the PETAL naming test:

/θ/	→ [f] x 2		
/s/	→ [θ] x 4		
/z/	→ [ð] x 2		
/ʃ/	→ [θ] x 2,	[ʃ] x 1,	[ʃʊ] x 1
/tʃ/	→ [d] x 3,	[t] x 1	
/dʒ/	→ [d] x 1,	[dʒ] x 1,	

MC always produced /f/ and /v/ correctly in word initial position in the test.

Table 3: Summary of incorrect realisations of /s/ clusters at the beginning of words in the PETAL naming test:

/sp/	→ [b] x 2		
/sw/	→ [w] x 2		
/sl/	→ [l] x 2		
/sk/	→ [g] x 3		
/st/	→ [d] x 2,	[s] x 1,	[st] x 1
/sm/	→ [m] x 2,	[m*m] x 1	
/sn/	→ [n*n] x 3		

m* = voiceless bilabial nasal with friction
n* = voiceless alveolar nasal with friction

MATERIALS

The Rees-Coleman Procedure was used to establish the levels of MC's breakdown in speech processing. This is a computer-based programme involving a series of input and output tests for ten consonant contrasts commonly causing trouble for deaf children, in word initial position in single syllable words and nonwords. Each test, except naming, has an audio (A) and an audio-visual (AV) version to control for effects of lip-reading. In the audiovisual version the computer plays a video clip of the word being produced and in the audio version a blank speech bubble is shown. The words used are based on those in the naming section of the PETAL (Parker, 1999) as this is a widely used assessment and the results can be compared across the two tests. Nonwords were made by changing the vowel in the real words, e.g. bath, /bɑ:θ/ → /bi:θ/ so that stimuli are matched as closely as possible across tasks. As stated by Stackhouse and Wells (1997) "this increases the strength of the conclusions that can be drawn from dissociations of performance." (p.317)

Nonword Discrimination (NWD): This test aims to establish whether the child can discriminate between speech sounds without reference to lexical representations. The computer plays two nonwords one after the other, e.g. /sɑ:/, /dɑ:/. As the word is spoken a box appears on the screen containing either the video clip or the blank speech bubble. The subject must decide whether the two words sound the same (in which case he presses the "m" key marked with a sticker) or if they sound different (when he presses the "z" key, also marked with a sticker.) The task consists of two pairs of nonwords for each contrast which are presented in four different combinations in a random order, see appendix 2 for stimuli.

Real Word Discrimination (RWD): As above but using real words therefore the child may have access to lexical representations.

Picture Yes/No Judgement (PYNJ): This tests the accuracy of a child's phonological representations. A picture is shown on the left hand side of the screen whilst the computer plays the spoken stimulus. Either the video or the speech bubble appears in a box on the right of the screen. The child must decide whether this spoken stimulus is correct for the picture (by pressing the "m" key) or incorrect (by pressing the "z" key). The correct form of the word corresponding with the picture, e.g. /pɪg/, and an incorrect form, /bɪg/ are each presented 4 times in a random order. There is one distant distractor with different lip patterns from the target, e.g. /lɪg/, which is not scored. For each contrast, two pictures beginning with the problematic consonant are included.

The problematic consonant is the one that is often realised incorrectly, i.e. for st/d – the problematic consonant is /st/. For ʃ/tʃ however both consonants are difficult therefore there are four pictures – two for each contrast. (See list of stimuli in appendix 2.)

<u>Naming:</u> The naming test requires the child to access their semantic representations and then motor programs of words. (If they do not yet have a motor program they may need to make one from their phonological representation). For each output test (naming, RWR and NWR) there are four words for each consonant or cluster in the pair, e.g. p/b: paul, path, pig, purse, ball, bath, big, bat. Each one is elicited twice so that there are sixteen elements to each test. Pictures of the stimuli are shown on the computer screen and the subject is asked to name them. His response is recorded on a Panasonic NVR2-15B compact VHS camcorder. The tester presses a button on the screen according to whether or not the child marked the contrast so that the computer can store the results. If the tester misses the response or is unsure of whether or not it is correct, there is an "unsure" button to record this.

<u>Real Word Repetition (RWR) and Nonword Repetition (NWR):</u> For the NWR task the child needs to create new motor programs to produce the words whereas for the RWR task he may use existing ones. Both tests also tap the child's input skills. Boxes containing either the video clip or the speech bubble appear on the screen at the same time as the spoken stimulus is presented. The child is asked to repeat the word/nonword. Responses are recorded as in the naming task.

Tests were carried out on a Dell *latitude* CPx laptop computer with one Yamaha MS101 II mono speaker (chosen as it efficiently amplifies all the frequencies in the speech range). The volume was set and maintained at mid-volume on the speakers and on the computer settings.

Five of the ten contrasts in the Rees-Coleman Procedure were selected for this study; p/b, s/d, ʃ/tʃ, st/d, sm/m. This includes one contrast, p/b, which MC produced correctly in the PETAL assessment, (Parker, 1999), to test whether all of his speech processing skills were intact for this phoneme or whether he had any hidden input deficits. Two contrasts which he produced incorrectly but still marking a contrast were included; s/d and ʃ/tʃ, (though for /ʃ/ he produced three different realisations and two for /tʃ/) along with two which he produced incorrectly and rarely marking a contrast, sm/m and st/d. (See tables 2 and 3 above.) Two further contrasts, sp/b and m/b were tested, but only with one output and input task, due to time constraints (naming and picture yes/no judgement tasks).

When the computer tests were completed, further tests of MC's literacy skills were carried out: real word reading, real word spelling, nonword reading, nonword spelling. Tests used a selection of the words from the above tests for the contrasts sm/m, st/d, s/d, ʃ/tʃ. Reading tasks consisted of lists of words/nonwords beginning with the above contrasts (each contrast had 3 words). For the spelling tasks MC was asked to spell the same words by writing them on a piece of paper. All words were presented in a random order and there were two practice items for each test to ensure MC understood the instructions. (See appendices 3 & 4 for stimuli).

PROCEDURE

Before the Rees Coleman procedure was administered MC's ability to produce letter names and sounds was tested by showing him written letters and asking him to name them and say what sound they make. If he was unable to answer or made an error, he was prompted by the researcher and asked to repeat her.

Tests were then carried out over a period of four weeks at the same time of day and in the same environment; a quiet room to reduce background noise or any distraction which could interfere with the results. At the time of testing MC was 9:0 years. The laptop was placed directly in front of MC, with the screen approximately 50 cms from his face and the speaker to the right, level with the back of the computer. MC wore both of his Phonak Supero digital hearing aids throughout testing (these were checked at the start of each session by asking

MC to cover his eyes and then repeat a colour spoken by the tester.) Eye contact was established with MC before delivering instructions which were spoken clearly before each test, (see appendix 5).

At the beginning of testing for a new contrast MC was given a familiarisation task on the computer. He was shown the pictures to be used in that section and asked to name them. The tester prompted him if he was unsure of any of the pictures and then rechecked them before beginning testing. All tests for one contrast were administered before moving to another contrast and no more than two contrasts were tested per session. After each test a personalised reward sequence flashed on the screen to maintain MC's interest. Output tests were recorded phonetically by the tester and then checked against the video recording. The computer stored all of MC's responses in his file so that these could be read and interpreted at a later date.

RESULTS

Results of the informal tests of MC's naming and sounding out of letters are presented in table 4 followed by the results of the input and output tests from the Rees-Coleman Procedure. For the input tests, the probability of scores occurring due to chance was calculated for each contrast using a binomial test (Siegel and Castellan, 1988). For the contrasts in which reading and spelling tests were carried out, these results are also presented.

TABLE 4: MC's naming and sounding out of letter names.

	NAME	SOUND
B	bi	də
C	θ̢i	kə
D	bi	bə
F	ef	fə
G	di	gə
H	heɪʔ	hə
J	deɪ	də
K	keɪ	kə
L	el	lə
M	em	mə
N	en	nə
P	pi	pə
Q	kju	kwə
R	ɑ	ɹə
S	eʔ	s̺ə
T	ti	tə
V	b̺ʸi	və
W	dəbəju	wə
X	ekʔ	-
Y	waɪ	jə
Z	ð͜ved	ɮ
SH	-	də
CH	-	də
TH	-	fə
NG	-	ɪŋ

KEY FOR PSYCHOLINGUISTIC TESTS
PYNJAA = Picture Yes/No Judgement Task Audio-Alone
PYNJAV = Picture Yes/No Judgement Task Audio-Visual
RWDAA = Real Word Discrimination Audio-Alone
RWDAV = Real Word Discrimination Audio-Visual

NWDAA = Nonword Discrimination Audio-Alone
NWDAV = Nonword Discrimination Audio-Visual
RWRAA = Real Word Repetition Audio-Alone
RWRAV = Real Word Repetition Audio-Visual
NWRAA = Nonword Repetition Audio-Alone
NWRAV = Nonword Repetition Audio-Visual
RWreading = Real Word Reading
NWreading = Nonword Reading
Naming.

p/b

TABLE 5: Scores of all input tests for p/b.

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA	8/8	8/8	16/16	.001*
PYNJAV	8/8	8/8	16/16	.001*
RWDAA	8/8	8/8	16/16	.001*
RWDAV	8/8	8/8	16/16	.001*
NWDAA	-	-	-	-
NWDAV	8/8	8/8	16/16	.001*

S/R = no. of same pairs or correct versions correctly judged
D/W = no. of different pairs or incorrect versions correctly judged
* significant at the 0.01 level.

MC scored 100% on all input tests for this contrast. The distractors /lɪg/ and /lɜ:s/ were rejected in the PYNJ tasks.

TABLE 6: Output tests for p/b

WORD STIMULUS	Naming	RWRAV	RWRAA	NONWORD STIMULUS	NWRAV
ball	bɔ:l bɔ:l	bɔ:l bɔ:l	bɔ:l bɔ:l	/ba:l/	bal bal
bath	ba:f ba:	ba:f ba:f	ba:f ba:f	/bi:θ/	bi:f bi:f
big	bɪg bɪg	bɪg bɪg	bɪg bɪg	/bu:g/	bu:g bu:g
bat	bæt bæt	bæt bæ	bæt bæt	/beət/	beət beət
paul	pɔ:l pɔ:l	pɔ:l pɔ:l	pɔ:l pɔ:l	/pa:l/	pal pal
path	pa:f pa:f	pa:f pa:f	pa:f pa:f	/pi:θ/	pi:f pi:f

pig	pɪg pɪg	pɪg pɪg	pɪg pɪg	**/pu:g/**	pu:g pu:g
purse	pɜ: pɜ:	pɜ: pɜ:	pɜ: pɜ:	**/pɔ:s/**	pɔ: pɔ:

MC produced p/b 100% correctly and consistently in all output tasks.

sm/m

TABLE 7: Scores of all input tests for sm/m.

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA	8/8	8/8	16/16	.001*
PYNJAV	8/8	8/8	16/16	.001*
RWDAA	8/8	8/8	16/16	.001*
RWDAV	8/8	8/8	16/16	.001*
NWDAA	8/8	8/8	16/16	.001*
NWDAV	8/8	8/8	16/16	.001*

* significant at 0.01 level.

MC scored 100% for all input tests for this contrast. The distractors /laɪl/ and /ləʊk/ were rejected in the PYNJ tasks.

TABLE 8: Real word output tests for sm/m

Word Stimulus	Naming	RWRAV	RWRA	RW reading	RW spelling
mouse	maʊX maʊX	maʊX maʊh	maʊ maʊX	maʊθ	moseu
match	mæʔ mæʔ	mæX mæʔ	mæX mæʔ	-	-
mat	mæt mæ	mæt mæt	mæt mæt	mæt	mat
moon	mu:n mu:n	mu:n mu:n	mu:n mu:n	mu:n	moon
smoke	məʊk m̥əʊk	məʊk m̥əʊk	m̥əʊk m̥əʊk	m̥əʊk	smook
smile	m̥aɪl maɪl	m̥aɪl maɪl	m̥aɪl m̥aɪl	m̥aɪl	smiyall
small	m̥ɔ:l m̥ɔ:l	m̥ɔ:l mɔ:l	mɔ:l mɔ:l	-	-
smell	mel mel	mel mel	mel mel	m̥el səmel	small

TABLE 9: Nonword output tests for sm/m

Nonword Stimulus	NWRA	NW reading	NW spelling
/məʊs/	məʊX məʊX	-	-
/mɒtʃ/	mɒʔ mɒʔ	-	-
/mel/	mel mel	-	-
/mɜ:n/	mɜ:n mɜ:n	men	mune
/smɔɪk/	m̥ɔɪk m̥ɔɪk	m̥ɪk	smocke
/smɒl/	m̥ɒl mʌl	-	-
/smu:l/	mu:l m̥u:l	-	-
/smɑ:l/	mɑ:l m̥ɑ:l	m̥ɑ:l	smull
/smɜ:n/	–	m̥en	smune
/mɔɪk/	–	mɒk	-
/mɑ:l/	–	mæl	-

MC produced /m/ correctly as [m] in 100% of the output tests. Although he did not produce /sm/ accurately he marked the contrast between /s/ and /sm/ 16/32 times by realising /sm/ as [m̥]. The rest of the time he realised /sm/ as [m] therefore not marking the contrast. When reading both real- and nonwords, MC realised /sm/ as [m̥] for all the words beginning with 'sm'. There is no significant difference between the audio and audiovisual versions of RWR and no difference between real and nonwords. He spelled words beginning with 'sm' beginning with the correct letter, though he did not spell the rest of the word correctly, e.g. 'smoke' → <smook>.

Table 10: Summary of MC's realisations of /sm/ and /m/

	/m/ realised correctly	/sm/ realised correctly	Alternative realisations of /sm/	
			sm→m	sm→m̥
RWRA	8/8	0/8	4/8	4/8
RWRAV	8/8	0/8	5/8	3/8
Naming	8/8	0/8	4/8	4/8
NWRAV	8/8	0/8	3/8	5/8
RWreading	3/3	0/3	0/3	3/3
NWreading	3/3	0/3	0/3	3/3

st/d

TABLE 11: Scores of all input tests for st/d.

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA	7/8	8/8	15/16	.001*
PYNJAV	8/8	8/8	16/16	.001*
RWDAA	8/8	8/8	16/16	.001*
RWDAV	8/8	8/8	16/16	.001*
NWDAA	8/8	7/8	15/16	.001*
NWDAV	8/8	7/8	15/16	.001*

* significant at the 0.01level.

MC scored 15 or 16/16 (statistically significant) for all input tasks with no difference between audio and audiovisual tests. He rejected both distractors; /bɑ:/ and /bæmp/ in PYNJ.

TABLE 12: Real word output tests for st/d

Word Stimulus	Naming	RWRAV	RWRA	RWreading	RW spelling
door	dɔ: dɔ:	dɔ: dɔ:	dɔ: dɔ:	dɔ:	door
dog	dɒg dɒg	dɒg dɒg	dɒg dɒg	dɒg	dog
duck	dʌk dʌk	dʌʔ dʌk	dʌʔ dʌʔ	dʌk	duak
deep	di:p di:p	di:p di:p	di:p di:p	-	-

star	dɑ: dɑ:	d̥ɑ: stɑ:	d̥ɑ: d̥ɑ:	dɑ:	sture
stick	d̥ɪk d̥ɪk	d̥ɪk d̥ɪk	d̥ɪk dɪk	daɪk stɪk'	stick
stamp	d̥æmp d̥æmp	d̥æmp d̥æmp	dæmp dæmp	d̥æmp	stamp
stairs	deəʋ deəʋ	deə steə	deəʋ deəʋ	-	-

TABLE 13: Nonword output tests for st/d

Nonword Stimulus	NWRAV	NW reading	NW spelling
/dɔɪ/	dɔɪ dɔɪ	bɔɪ dɔɪ	-
/deg/	deg deg	-	-
/dɜ:k/	dɜ:k dɜ:k	-	-
/dɑ:p/	dɑ:p dɑ:p	-	-
/staʊ/	daʊ daʊ	-	-
/sti:k/	di:k i:k	_	_
/stɪmp/	dɪmp dɪmp	stɪmp	stimp
/staʊz/	daʊ daʊw	-	-
/stɔɪ/	-	stɔɪ	stoy
/dɑ:/	-	bɹæ dɑ:*	dure
/dɪmp/	-	də dɪmp	dimpe
/steg/	-	deg	steg

In NW reading, where two responses are given, MC corrected himself.

During computer tests from the Rees Coleman Procedure MC realised /st/ correctly twice, both times in the RWRAV task. He produced it a further three times in the reading tasks; twice in NWreading and once in RWreading.

Table 14: Summary of MC's realisations of /st/ and /d/

	/d/ realised correctly	/st/ realised correctly	Alternative realisations of /st/	
			st→d	st→ d̥
RWRA	8/8	2/8	1/8	5/8
RWRAV	8/8	0/8	5/8	3/8
Naming	8/8	0/8	4/8	4/8
NWRAV	8/8	0/8	8/8	0/8
RWreading	3/3	1/3	1/3	2/3
NWreading	3/3	2/3	1/3	2/3

In real- and nonword spelling MC spelled the words beginning with the correct letter/letters though some of the spellings were incorrect, e.g. 'star' → <sture>.

s/d

TABLE 15: Scores of all input tests for s/d.

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA	8/8	7/8	15/16	.001*
PYNJAV	8/8	8/8	16/16	.001*
RWDAA	8/8	8/8	16/16	.001*
RWDAV	8/8	8/8	16/16	.001*
NWDAA	8/8	8/8	16/16	.001*
NWDAV	7/8	8/8	15/16	.001*

* significant at the 0.001 level.

MC scored significantly above chance for all input tests for s/d with no difference between audio and audiovisual tasks. The distractors /bi:/ and /bɒk/ were rejected in PYNJ tasks.

TABLE 16: Real word output tests for s/d

Word Stimulus	Naming	RWRAV	RWRAA	RWreading	RW spelling
duck	dʌk dʌk	dʌk dʌk	dʌk dʌk	dʌk	duak
dog	dɒg dɒg	dɒg dɒg	dɒg dɒg	dɒg	dog
d	di: di:	di: di:	di: di:	-	-

door	dɔ: dɔ:	dɔ: dɔ:	dɔ: dɔ:	dɔ:	door
sea	di: di:	di: di:	di: di:	di:	see
sun	dʌn dʌn	dʌn dʌn	dʌn dʌn	-	-
saw	dɔ: dɔ:	dɔ: dɔ:	dɔ: dɔ:	dɔ:	saw
sock	dɒk dɒk	dɒk dɒk	dɒk dɒk	dɒk	soike

TABLE 17: Nonword output tests for s/d

Nonword Stimulus	NWRAV	NW reading	NW spelling
/dæk/	dæk dæk	-	-
/deg/	deg deg	deg	-
/dɜ:/	dɜ: dɜ:	-	-
/dɑ:/	dɑ: dɑ:	bɹæ dɑ:*	dure
/sɑ:/	dɑ: dɑ:	dɑ:	-
/sɒn/	dɒn dɒn	dɒn	son
/sek/	dek dek	dek	sek
/dɔɪ/	-	bɔɪ dɔɪ	-
/dɒn/	-	bɒn dɒn	donn

* In NW reading, where two responses are given, MC corrected himself.

In all output tasks, including real- and nonword reading, MC realised /s/ and /d/ as [d]. There was no difference between his realisations of /s/ and /d/ in the real and nonword tasks. In both the real- and nonword writing tasks MC spelled all words beginning with the correct letter though some spellings were incorrect (see discussion.)

ʃ/tʃ

TABLE 18: Scores of all input tests for ʃ/tʃ .

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA: ʃ/tʃ:ʃ PYNJAA: ʃ/tʃ:tʃ	8/8 8/8	0/8 3/8	8/16 11/16	.598 .105
RWDAV	8/8	3/8	11/16	.105
NWDAV	7/8	2/8	9/16	.402

In the PYNJAA task MC accepted all of the correct realisations as being correct for both ʃ/tʃ:ʃ and ʃ/tʃ:tʃ. However for ʃ/tʃ:ʃ he also accepted all incorrect realisations and for ʃ/tʃ:tʃ he accepted 5/8 incorrect realisations. The distractors /beə/, /bɪp/, /bɒp/ and /bu:/ were rejected in the PYNJ tasks. In the RWDAV and NWDAV tasks he correctly identified 8/8 and 7/8 pairs of same words but also identified 5/8 and 6/8 pairs of different words as being the same. The probability of him obtaining any of these results by chance was not significant.

There was little difference between real and nonwords. Due to time constraints the difference between A and A/V was not tested.

TABLE 19: Output tests for ʃ/tʃ

Word Stimulus	Naming	RWRAV	RW reading	RW spelling	Nonword Stimulus	NWRAV
cheese	di: di:	di: di:z	di:	ches	/tʃɜ:z/	dɜ:z dɜ:z
chair	deə deə	deə deə	ʃeə	cher	/tʃɔɪjə/	dɔɪjə dɔɪjə
church	dɜ: dɜ:	dɜ: dɜ:	tɜ:t	chach	/tʃi:tʃ/	ti:s ti:?
chip	dɪps dɪps	dɪp dɪp	-	-	/tʃʌp/	ʃʌp dʌp
shirt	tɜ:t ʃɜ:t	dɜ:t dɜ:t	-	-	/ʃeət/	seət ʃeət
shop	çɒp dɒp	dɒp dɒp	stɒp	shop	/ʃep/	ʃep dep

ship	dɪp dɪp	dɪp dɪp	ʃɪp	ship	**/ʃʌp/**	dʌp ʃʌp
shoe	du: du:	du: du:	su:	showe	**/ʃɜ:/**	dɜ: dɜ:

MC did not produce [tʃ] in any tests. In Naming and RWR /tʃ/ → [d] 8/8 times in each test and 5/8 times in NWR. In NWR /tʃ/ → [t] twice and [ʃ] once. /ʃ/ was realised correctly 4/24 times, once in Naming and three times in NWR. /ʃ/ → [d] 17/24 times, see table below for details. The difference between audio and audiovisual stimuli was not tested due to time constraints. In RW reading MC realised /ʃ/ and /tʃ/ differently on each attempt. In RW spelling /ʃ/ → <sh> and /tʃ/ → <ch>.

Table 20: Summary of MC's realisations of /tʃ/

	/tʃ / realised correctly	**Alternative realisations of /tʃ/**		
		tʃ →d	**tʃ→t**	**tʃ→ʃ**
RWRAV	0/8	8/8	0/8	0/8
Naming	0/8	8/8	0/8	0/8
NWRAV	0/8	5/8	2/8	1/8
RWreading	0/3	1/3	1/3	1/3

Table 21: Summary of MC's realisations of /ʃ/

	/ʃ/realised correctly	**Alternative realisations of /ʃ/**				
		ʃ→d	**ʃ→s**	**ʃ→t**	**ʃ→ç**	**ʃ→st**
RWRAV	0/8	8/8	0/8	0/8	0/8	0/8
Naming	1/8	5/8	0/8	1/8	1/8	0/8
NWRAV	3/8	4/8	1/8	0/8	0/8	0/8
RWreading	1/3	0/3	1/3	0/3	0/3	1/3

If the realisations are compared within a test the following results are obtained.

- RWRAV - /tʃ/ and /ʃ/ → [d] 16/16 times so the contrast was never marked.

- Naming - /ʧ/ → [d] in 8/8 tests, /ʃ/→[d] in 5/8 tests therefore contrast was marked in 3/8 cases in this test.
- NWRAV – see tables 20,21 above for different realisations. The contrast was marked 1/8 times.

sp/b

Due to time constraints PYNJAA and AV were the only input tests carried out for this contrast.

TABLE 22: Scores of all input tests for sp/b.

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA:	8/8	8/8	16/16	.001*
PYNJAV	8/8	7/8	15/16	.001*

* significant at 0.01 level

MC scored 16/16 for the AA task and 15/16 for the AV task, both scores significantly above chance. The distractors /lu:n/ and /leɪd/ were both rejected.

TABLE 23 MC's realisations of sp/b in the naming task.

Word Stimulus	Naming
bell	bel bel
bath	bɑ:f bɑ:
bus	bʌç bʌθ
big	bɪg bɪk
spell	bel bel
spade	beɪd beɪd
spider	baɪdə baɪdə
spoon	bu:n bu:n

/p/ and /b/ were both realised as [b] in 100% of targets therefore the contrast was not marked at all.

m/b

PYNJAA was the only input test carried out for this contrast. MC scored 100% and rejected both distractors (/læt/ and /laʊs/).

TABLE 24: Scores of all input tests for m/b.

TEST	SCORE S/R	SCORE D/W	TOTAL SCORE	Probability score occurred by chance.
PYNJAA:	8/8	8/8	16/16	.001*

* significant at 0.01 level.

Naming was the only output test carried out. MC realised both /m/ and /b/ correctly in these tasks.

TABLE 25: MC's realisations of m/b in the naming task.

Word Stimulus	Naming
microphone	maɪkəfəʊn maɪkəfəʊn
man	mæn mæn
mouse	maʊθ maʊs
mat	mæt mæt
ball	bɔ:l bɔ:l
bath	bɑ:f bɑ:f
bat	bæt bæt
bike	baɪk baɪk

TABLE 26: SUMMARY OF ALL INPUT RESULTS FOR EACH CONTRAST TESTED.

INPUT	p/b	m/b	sm/m	st/d	s/d	sp/b	ʃ/tʃ:ʃ	ʃ/tʃ:tʃ
PYNJAV	16/16	-	16/16	16/16	16/16	15/16	-	-
PYNJAA	16/16	16/16	16/16	15/16	15/16	16/16	8/16	11/16
RWDAV	16/16	-	16/16	16/16	16/16	-	11/16	
RWDAA	16/16	-	16/16	16/16	16/16	-	-	
NWDAV	16/16	-	16/16	15/16	15/16	-	9/16	
NWDAA	-	-	16/16	15/16	16/16	-	-	

TABLE 27: SUMMARY OF ALL OUTPUT TESTS FOR EACH CONTRAST TESTED – SHOWING THE NUMBER OF TIMES EACH TARGET CONSONANT WAS PRODUCED CORRECTLY.

	p	m	sm	st	s	sp	ʃ	tʃ
NAMING	8/8	8/8	0/8	0/8	0/8	0/8	1/8	0/8
RWRAV	8/8	-	0/8	0/8	0/8	-	0/8	0/8
RWRAA	8/8	-	0/8	2/8	0/8	-	-	-
NWRAV	8/8	-	0/8	0/8	0/8	-	3/8	0/8
NWRAA	-	-	-	-	-	-	-	-
RWreading	-	-	0/3	1/3	0/3	-	1/3	0/3
NWreading	-	-	0/3	2/3	0/3	-	-	-

DISCUSSION

MC's performance in the Rees-Coleman tests and subsequent tests of reading and writing can be related to Stackhouse and Wells' speech processing model (1997). Each contrast will be discussed separately before a comparison of all results to establish if there are different loci of breakdown.

p/b

Results of the psycholinguistic tests indicate that MC's input skills for words beginning with these phonemes are accurate (therefore indicating good auditory discrimination and accurate phonological representations) as are his output skills (indicating accurate motor programs and motor programming skills.)

m/b

The two tests carried out from the Rees-Coleman Procedure suggest the same as for p/b; that MC's input and output skills for words beginning with these phonemes are accurate.

sm/m

MC scored 8/8 for all input tests completed. This indicates that he can hear a difference between /sm/ and /m/ at the beginning of words and that his phonological representations are accurate enough for him to reject words beginning with [m] for target words beginning with /sm/, e.g. rejecting [məʊk] as a label for /sməʊk/. However as MC only marks the contrast 50% of the time in his output and since he produces /sm/ inaccurately as [m̥], this suggests that although he may perceive some auditory information (i.e. some friction) before /m/, he may not hear the contrast as a normal hearing child would. If this is the case it can be hypothesised that his phonological representations are not fully accurate and he would not reject his own incorrect realisation of [m̥] for /sm/ at the beginning of words in a PYNJ task.

The fact that MC was only heard to mark the contrast between these phonemes 50% of the time across output tests is unlikely to be fully explained by input difficulties as he can hear a contrast between words beginning with [sm] and [m] at all times. It is also unlikely to be due to poor motor programming skills as there is no evidence of this in other tests. It is possible that his marking of the contrast was so subtle that the tester did not always hear it. Another more likely explanation could be that MC is in the process of updating his motor programs for these words. The fact that he only marked the contrast 5/8 times in the NWRAV task could also be explained by this as although he would have no stored motor programs for nonwords in the NWR task, it is possible that his performance in this task is affected by fuzzy representations of words that sound similar.

In the informal real- and nonword reading tests MC marked the contrast 100% of the time (though still not accurately) suggesting that the orthographic form <s> reminds him of the presence of the first consonant (or at least of some friction). It is possible that he then assembles a new motor program for this phoneme, different from the one he uses in spontaneous speech. It is known that children develop representations for single phonemes when learning to read so they can match them to graphemes. (This concept of motor programs for individual phonemes is not included in the Stackhouse and Wells' speech processing model (1997) as it is a single word model.)

st/d

MC scored 7/8 or 8/8 for all input tests for this contrast. See sm/m for discussion and hypothesised explanation of these results.

The tester heard MC mark the contrast a total of 14/32 times in the Rees-Coleman Procedure tests. He was perceived as realising /st/ as [d], [d̥] and [st] in the output tests although he was only heard to produce the latter twice, in RWRAV. There is such a subtle difference between these phonemes (the difference between [dæmp] and [d̥æmp] being a matter of milliseconds in the difference in the onset of voicing) that it is possible that the tester did not always pick up on it and with only one tester transcribing the results there was no inter-tester reliability.

As MC does occasionally realise /st/ correctly this suggests that he can hear the exact difference between /st/ and /d/ at the beginning of words but that he has not yet updated his motor programs for the contrasts. In the real and nonword reading tasks MC was heard to mark the contrast 2/3 times in each case, although it was only realised correctly once in the real-word test and twice in the nonword test. As with sm/m this suggests that the orthographic form <s> sometimes prompts him to mark the contrast and bypass his stored motor program for this phoneme at the beginning of words.

s/d

MC scored 7/8 or 8/8 for all input tests carried out. As he realises /s/ as [d] in 100% of the output tests these results show that he knows that his realisations of /s/ are incorrect, indicating that current poor input skills are not the sole underlying reason for his poor output.

MC did not mark the contrast between words beginning with /s/ and /d/ at all in the spoken output tests. It is known that he can hear the contrast and that he distinguishes between the two phonemes when spelling them at the beginning of real- and nonwords therefore showing that he recognises that they are separate phonemes. It could therefore be hypothesised that MC has not yet updated his motor programs for words beginning with these phonemes and that he previously had inaccurate phonological representations due to poor auditory discrimination skills. MC continued to produce [d] for /s/ in the real- and nonword repetition tasks which as discussed for sm/m could be explained by the fact that his output is influenced by other inaccurate motor programs for similar words or a possible more subtle deficit in lower level input skills.

MC does not mark the contrast at all when reading real- and nonwords beginning with /s/ and /d/ unlike the results for st/d or sm/m when the graphemic form seemed to prompt him to bypass his stored motor program. It seems that MC's motor programs for /s/ plus a vowel are weaker than those for words beginning with /sm/ and /st/ as when reading these two latter sounds the grapheme "s" reminds MC to use a practised temporary motor program, (even though this is not fully accurate.) This does not happen when he sees "s" followed by a vowel. This again suggests single phoneme processing as well as whole word processing as presented by Stackhouse and Wells, (1997).

sp/b

Only two input tests and the naming test were carried out for this contrast but results follow the pattern for s/d above. No reading or writing tests were administered.

ʃ/tʃ

This is the only contrast tested revealing difficulties in input. Results of the RWDAV and NWDAV tests show that MC is unable to hear the difference between most pairs of words beginning with /ʃ/ and /tʃ/ therefore suggesting poor auditory discrimination skills for these words. Due to these difficulties MC accepts most incorrect realisations as being correct in the PYNJAA task indicating that he has inaccurate phonological representations. As MC's realisation of the phonemes is so inconsistent (he produces /s/, /d/, /t/ etc) further input tests could be carried out contrasting these phonemes with /ʃ/ and /tʃ/ to see if he can hear the difference between these.

MC's poor input skills for this contrast can provide an explanation for his inaccurate output of both /ʃ/ and /tʃ/. With poor auditory discrimination and imprecise phonological representations it would be difficult for him to form accurate motor programs. MC did not produce [tʃ] at all in the Rees-Coleman Procedure and realised it as [d] 22/27 times. He also produced /ʃ/ as [d] 17/27 times across the tests therefore not marking the contrast. His other realisations of the two phonemes were also variable and similar to each other. (See results.)

In the real word reading test MC produced different variations of /ʃ/ and /tʃ/ at the beginning of each word. /tʃ/ was never realised correctly but /ʃ/ was once. Only three stimuli were presented for each contrast however and it seems that his marking of the contrast is just as inconsistent as in the other tasks and spontaneous speech.

Comparison of Results Across Contrasts

Each contrast tested can be fitted into one of four general psycholinguistic profiles (based on Stackhouse and Wells' 1997 model). The first profile includes words beginning with the two contrasts p/b and m/b for which no breakdown was identified indicating intact processing at all levels tested. The second group consists of words beginning with the contrasts st/d and sm/m. Tests carried out do not reveal any breakdown at the input level but due to his inconsistent output it is hypothesised that further tests may uncover more subtle deficits. His output for words beginning with these contrasts is variable, therefore suggesting inaccurate motor programs for words beginning with /st/ and /sm/, where these first two phonemes are not well specified. The third profile pattern identified includes words beginning with the contrasts s/d and sp/b. It is similar to the second but in this case MC does not mark the contrast at all in his output suggesting that his processing skills for these contrasts are slightly behind those in the second group. The final group consists of words beginning with /ʃ/ and /tʃ/. Results indicate that MC has poor input skills for this contrast and therefore also variable output. There were no significant differences between the audio and audio-visual conditions in any of the tests indicating that lipreading did not help MC to distinguish between contrasts.

Discussion of MC's reading and spelling errors

Psycholinguistic analysis of spelling results

In the tests carried out MC spelt all real- and nonwords beginning with the correct letters. This indicates that even though he does not always distinguish between some phonemes in his speech, he knows that they are represented by different graphemes in writing. For example when repeating /stɪmp/ MC produced [dɪmp] therefore not marking the st/d contrast but when writing it he represented /st/ with <st>.

General analysis of spelling errors

A number of phonological spelling errors were identified (when MC appeared to spell some words as he heard them), providing evidence that he is using some phonological coding in his spelling, e.g. 'smile' → <smiyall> (the only example from test results), 'once upon' (a time) → <wunapoll> (from schoolwork). These results contrast with those found by researchers such as Harris and Moreno (2004) who found few such errors. However their study looked at children with severe hearing impairments and MC has effective residual hearing with his hearing aids, (supported by results of input tests which indicate that ʃ/tʃ was the only contrast that MC had difficulty with). This, along with the fact that MC's realisation of all vowels in the Rees-Coleman Procedure tests was accurate, suggests that MC has access to phonology auditorialy.

Some of MC's other spelling errors can be classified as visual errors, e.g. 'mouse' → <moseu>, 'duck' → <duak> as MC appears to confuse either the position of letters in words or letters which look similar. Aaron et al., (1998) believe that in children with a severe hearing impairment this is a sign that they are relying on visual processing rather than phonological processing, possibly due to poor phonological awareness. Other errors in MC's real- and nonword spelling indicate poor phoneme-grapheme conversion for vowels, especially when they should be represented by a digraph, e.g. 'cheese' → <ches>, 'chair' → <cher>, 'smern' → <smun>, /dɑ:/ → <dure>. In fact from the sample obtained of MC's spelling it can be hypothesised that MC only spells vowels correctly when there is a link between a simple monophthong and a single written vowel. The only digraph which he produced correctly was /ɔɪ/ to <oy> in the nonword "stoy", possibly as he makes the connection in the frequent word "boy."

Psycholinguistic Analysis of Reading Results

Results of MC's real- and nonword reading were discussed above. For the contrasts sm/m and st/d, it appears that seeing the grapheme <s> at the beginning of words prompts MC to build a temporary motor program for this first phoneme which overrides his stored knowledge of how to produce the sound. This results in him marking the contrast more than in the other tests or in spontaneous speech. When reading words beginning with <s> plus a vowel however, MC did not mark the contrast with /d/ suggesting that his motor program for the /s/ phoneme in isolation is unstable.

MC also produces many vowels incorrectly when reading nonwords. As with spelling, most of the errors occur when MC reads digraphs – he sometimes realises just one of the written vowels, e.g. /moik/ → [mɒk] but on other occasions says it correctly, e.g. /stɔɪ/ → [stɔɪ]. Normally developing children should be able to do this by year 2 of the National Curriculum (ages 6- 7 yrs) according to the DfES. (DfES Standards Website.)

<u>Conclusions about MC's Reading and Spelling</u>

Only two of MC's reading and spelling error types can be explained by processing deficits which are probably due to his hearing impairment. The first is his often incorrect realisation of /s/ when reading many words and nonwords beginning with "s" due to faulty motor programs for these words in speech, (see above explanation for output tests). Secondly, some of MC's phonological errors can be explained by his faulty processing skills as it appears that his misspellings correspond with how he hears the words.

Most of MC's literacy difficulties are likely to be caused by deficits other than deafness. His incorrect realisation of vowels in real- and nonword reading are unlikely to be due to auditory processing difficulties as given his degree of hearing loss and relatively good ability to discriminate between consonant pairs, vowel minimal pairs are likely to be easy for him to discriminate. Also, his results for input tests carried out were generally good (except for ʃ/tʃ) indicating that he has access to phonology auditorialy. This indicates that MC's reading and writing difficulties are likely to be due to either difficulty linking phonemes with graphemes and/or to phonological awareness difficulties.

No tests of phonological awareness, e.g. rhyme, sound blending, etc. were carried out for this study due to time constraints but if MC is not aware of the internal structure of phonological representations this would impact on his ability to read and write. Many studies have shown that phonological awareness skills are a good predictor of literacy in all children, including those with a hearing impairment (Harris et al, 2004) and children with poor phonological awareness skills have difficulty progressing to the alphabetic stage of literacy development in Frith's 1985 model (Stackhouse, 1997). It is unlikely that MC's hearing impairment is the sole cause of any phonological awareness difficulties which he may have. Trezek and Malmgren, (2005) successfully introduced a phonics and phonological awareness skills treatment package to deaf children indicating that these skills are not dependent on being able to hear the speech signal and suggesting that they can be taught to at least some deaf children. MC has had much help with his literacy but is still making slow progress despite this and his relatively good levels of auditory discrimination.

It is also likely that MC has difficulty in linking and remembering how some phonemes are represented in the visual form. This is supported by the fact that he makes so many phonological and visual errors (or more likely phonological-visual errors in linking phonemes and graphemes). MC confused /b/ and /d/ on several occasions during different tests. In the letter naming and sounding out test he named /d/ as [bi] and pronounced it as /bə/ and in nonword reading he initially read /d/ as [b] 3/4 times before self-correcting. His class teacher confirmed that this is something which MC does frequently. This could be due to auditory discrimination difficulties between /b/ and /d/ but in MC's case this is unlikely. This, along with his large number or visual errors when spelling words, is an indication that MC may have visual dyslexia. (Smith, 1991) identified other possible signs of this as a limited sight vocabulary, the omission of letters and words which children have not noticed and difficulty learning irregular words. Difficulties with this or phonological awareness would support a diagnosis of dyslexia, as suggested by his reports.

CONCLUSION

This study had three main aims; 1.) to see if psycholinguistic profiling could determine the levels of breakdown in MC's processing, 2.) to see if there were different levels of breakdown across the contrasts tested and 3.) to identify whether any deficits uncovered could account for MC's literacy difficulties.

The Rees-Coleman Procedure has succeeded in indicating several levels of breakdown in MC's speech processing and, as explained above, contrasts can be divided into four identified profile patterns. This supports the first pre-test hypothesis that different levels of breakdown would be identified for different contrasts and means that the first two aims of the study have been met. It had been hypothesised that MC would only have accurate input skills for the contrasts which he marked in his speech before testing began, (p/b and m/b). Although this is true for these two contrasts, no breakdown in input skills was found for any of the other contrasts except for ʃ/tʃ. It was found however that MC has not yet updated his motor programs for words beginning with the contrasts which he does not mark, even if his input skills are now adequate. He has begun to update his motor programs for the two contrasts which he has begun to mark some of the time (sm/m and st/d). Additional difficulties in reading (especially nonwords) suggest inaccurate motor programs for the individual phonemes at the beginning of words (see above).

Tests to identify any deficits possibly causing MC's literacy difficulties were partly successful. In hypothesis 4 it was predicted that some of these difficulties would be due to poor input skills but this is only true of ʃ/tʃ. However, links have been made with MC's faulty motor programs and it is likely that these are due to earlier auditory discrimination problems (therefore this hypothesis can only be partially rejected). The additional literacy difficulties identified support hypothesis 5 as they are unlikely to be explained by the uncovered speech processing deficits and are possibly due to deficits in phonological awareness and/or MC's ability to make links between phonemes and graphemes.

In this study as many tests as possible were carried out to enable a detailed comparison of results both within a contrast and with other contrasts. Stimuli were also closely matched to ensure accurate comparisons. The value of this can be seen in the nonword repetition test for example, which if carried out in isolation for st/d and s/d, may have suggested that MC does not realise these phonemes correctly due to poor input skills (which is not the case.) However, due to time constraints it was not always possible to carry out every test for each contrast – e.g. both the audio and audiovisual test. In MC's case as there was virtually no difference between these two conditions no information was lost and this actually spared MC from undergoing any unnecessary testing. Although no more than two contrasts were tested per session and tests were followed by a reward sequence on the computer, MC did appear to lose concentration towards the end of the testing sessions and started to predict which stimulus was coming next without waiting. Unfortunately it was not possible to conduct shorter sessions.

If this study were to be carried out again it would be useful to test MC's input skills further using his own incorrect realisations, to see if this is what he actually hears, e.g. for sm/m a PYNJ task could be carried out contrasting /m̥/ with /s/ and /sm/. Also, in order to confirm the hypotheses about MC's reading and writing, further tests would need to be carried out as these were only tested informally with three items per contrast. Results were only transcribed by one person and this was from a video recording. This means that transcriptions may not always have been fully accurate and there was no inter-tester reliability.

The Rees-Coleman Procedure has identified several points of breakdown across the contrasts which would not have been revealed in more traditional descriptive methods of testing, such as the PETAL, (Parker, 1999). This highlights the value of psycholinguistic profiling in hearing impaired children and adds to the evidence showing the importance of testing different contrasts and comparing the results. It would have been interesting to do this as a longitudinal study to see how MC's psycholinguistic profile had changed before this point (perhaps explaining some of his current deficits) and also to see how quickly he updates his motor programs now that he has updated his phonological representations for most phonemes. Future studies with hearing impaired children may choose to take this perspective. Also MC was selected for this study as he had already been identified as having additional difficulties. It would be interesting to carry out psycholinguistic testing with hearing impaired children who have no additional speech or language diagnosis to see if any hidden deficits may be discovered. This study has also shown the benefit of using psycholinguistic profiling to examine literacy difficulties in deaf children. This could be expanded upon in the future either in order to find out more about individual speech processing deficits or to help explain theories of literacy development in hearing impaired children.

The psycholinguistic profile put together for MC can be compared with that of TG (Ebbels, 2000) to see if any patterns appear to be emerging which could be typical of hearing impaired children. Both studies identified multiple levels of breakdown and different profiles for different contrasts tested. They also both found that all errors could be accounted for by deficits in the early stages of processing rather than output difficulties. Results of Ebbel's (2000) study revealed that TG does not always give phonological significance to differences which she can hear (she has faulty phonological representations and therefore motor programs for these contrasts), MC however does seem to have accurate phonological representations in general (except for words beginning with ʃ/ and tʃ) but does not always give phonological significance in his output (due to faulty motor programs).

The above comparison shows that there are some similarities between the results of the two studies but it must be remembered that both children have been identified as having different additional difficulties on top of their hearing impairment.

So far few studies have focussed on the effect of psycholinguistic profiling on the therapy approach selected for hearing impaired children or on the success of these approaches. As stated by Waters (2001), therapy should be targeted at children's strengths as well as their weaknesses. In MC's case this might mean initially addressing the contrasts which he is already beginning to mark, i.e. sm/m and st/d, before those which he is not heard to distinguish between (sp/b and s/d) and also using his strong input skills in order to teach him to mark contrasts in his speech. For the contrast ʃ/tʃ for which MC has poor input skills, therapy may be more successful if it addresses input and output simultaneously. Studies addressing psycholinguistic profiling and therapy could help to improve assessments and therapy programs devised in the future.

WORD COUNT: 9895

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REFERENCES

Aaron, P., Keetay, V., Boyd, M., Palmatier, S. & Wacks, J. (1998). Spelling without phonology: A study of deaf and hearing children. *Reading and Writing: An Interdisciplinary Journal.* (10). pp.1-22.

Abraham, S. (1989). Using a phonological framework to describe speech errors of orally trained hearing-impaired school-agers. *Journal of Speech and Hearing Disorders,* 54. pp. 600-609.

Baker, E., Croot, L., McLeod, S. & Paul, R. (2001). Psycholinguistic Models of speech development and their application to clinical practice. *Journal of Speech, Language and Hearing Research,* 44, pp. 685-702.

Chalifoux, L. (1991). The implications of congenital deafness for working memory. *American Annals of the Deaf* 136. pp. 292-299.

Christiansen, M. & Chater, N. (1999). Connectionist Natural Language Processing: The state of the Art. *Cognitive Science,* 23 (4), pp. 417-437.

Conrad, R. (1979). *The deaf school child: Language and cognitive function.* London: Harper & Row.

Constable, A., Stackhouse, J., & Wells, B. (1997) Developmental word finding difficulties and phonological processing: the case of the missing handcuffs. *Applied Psycholinguistics,* 18. pp.507-536.

Cornett, O. (1967) Cued Speech. *American Annals of the Deaf,* 112. pp. 3-13.

Dent, H, (2001). Electropalatography: A tool for psycholinguistic therapy. In Stackhouse, J. & Wells, B. (Eds) *Children's Speech and Literacy Difficulties 2: Identification and Intervention.* London: Whurr.

Department for Education and Skills. The Standards Site: The National Literacy Strategy. Available from: <http://www.standards.dfes.gov.uk/literacy/teaching_resources/nls_framework/year2/term1/> [Accessed August 12 2005].

Dodd, B. (1976). The phonological systems of deaf children. *Journal of Speech and Hearing Disorders,* 41. pp. 185-198

Dodd, B. (1995). Children with speech disorder: Defining the problem. In B. Dodd (Ed.) *The differential diagnosis and treatment of children with speech disorder.* London: Whurr.

Dodd, B., & Murphy, J. (1995). Hearing impairment. In B. Dodd (Ed.) *The differential diagnosis and treatment of children with speech disorder.*_London: Whurr.

Dunn, L.M. & Dunn, L. (1997). *British Picture Vocabulary Scales* 2nd Edition. Windsor: NFER-Nelson.

Ebbels, S. (2000) Psycholinguistic profiling of a hearing impaired child. *Child Language Teaching and Therapy,* 16 (1), pp3-22.

Ellis, A. & Young, A. (1996). *Human cognitive neuropsychology: a textbook with readings.*_London: Psychology Press.

Fredrickson, N. (Ed). (1995). *PhAB : Phonological Asessment Battery* London : Educational Psychology Publishing, University College London

Frith, U. (1985). Beneath the surface of developmental dyslexia. In Patterson, K., Marshall, J., Coltheart, M. (Eds) *Surface Dyslexia* pp. 301-330. London: Routledge and Kegan Paul.

Harris, M. & Moreno, C. (2004). Deaf children's use of phonological coding: evidence from reading, spelling, and working memory. *Journal of Deaf Studies and Deaf Education* 9 (3) pp. 253-268.

Leybaert, J. (2000). Phonology acquired through the eyes and spelling in deaf children. *Journal of Experimental Child Psychology.*_75. pp. 291-318.

Leybaert, J. & Alegria, J. (1995). Spelling development in deaf and hearing children: Evidence for use of morphophonological regularities in French. *Reading and Writing: An Interdisciplinary Journal* 7 pp. 89-109.

Musselman, C. (2000). How do children who can't hear learn to read an alphabetic script? A review of the literature on reading and deafness. *Journal of Deaf Studies and Deaf Education,* 5 (1) pp. 9-31.

Parker, A. (1999)._*Phonological Evaluation and Transcription of Audio-Visual Language.* Bicester: Winslow Press.

Perfetti, C. & Sandak, R. (2000) Reading optimally builds on spoken language: implications for deaf readers. *Journal of Deaf Studies and Deaf Education* 5 (1). pp. 32-50.

Popple, J., & Wellington, W. (1996). Collaborative working within a psycholinguistic framework. *Child Language Teaching and Therapy,*_12 (1) pp60-70

Raven, J & Court, J. (1991). *Manual for Raven's progressive matrices and vocabulary scales* London: H.K.Lewis & Co. Ltd.

Renfrew, C. (1997). *Action Picture Test* 4th Edition. Bicester : Winslow.

Renfrew, C. (1997). *Bus Story Test : a test of narrative speech* 4th Edition. Bicester: Winslow

Siegel, S. & Castellan, N. J. (1988).*Nonparametric Statistics for the Behavioural Sciences* New York: McGraw-Hill.

Stackhouse, J. (1997). Phonological awareness: Connecting speech and literacy problems. In Hodson, B.& Edwards, M. (Eds). *Perspectives in Applied Phonology.*_pp. 157-196. Gaithensburg, Maryland, MD: Aspen Publishers.

Stackhouse, J. & Wells, B. (1997). *Children's Speech and Literacy Difficulties: A Psycholinguistic Framework.*_London: Whurr.

Stackhouse, J. & Wells, B. (2001). *Children's Speech and Literacy Difficulties 2: Identification and intervention.* London: Whurr.

Transler, C., Gombert, J. & Leybaert, J. (2001). Phonological decoding in severely and profoundly deaf children: Similarity judgment between written pseudowords. *Applied Psycholinguistics* 22. pp. 61-82.

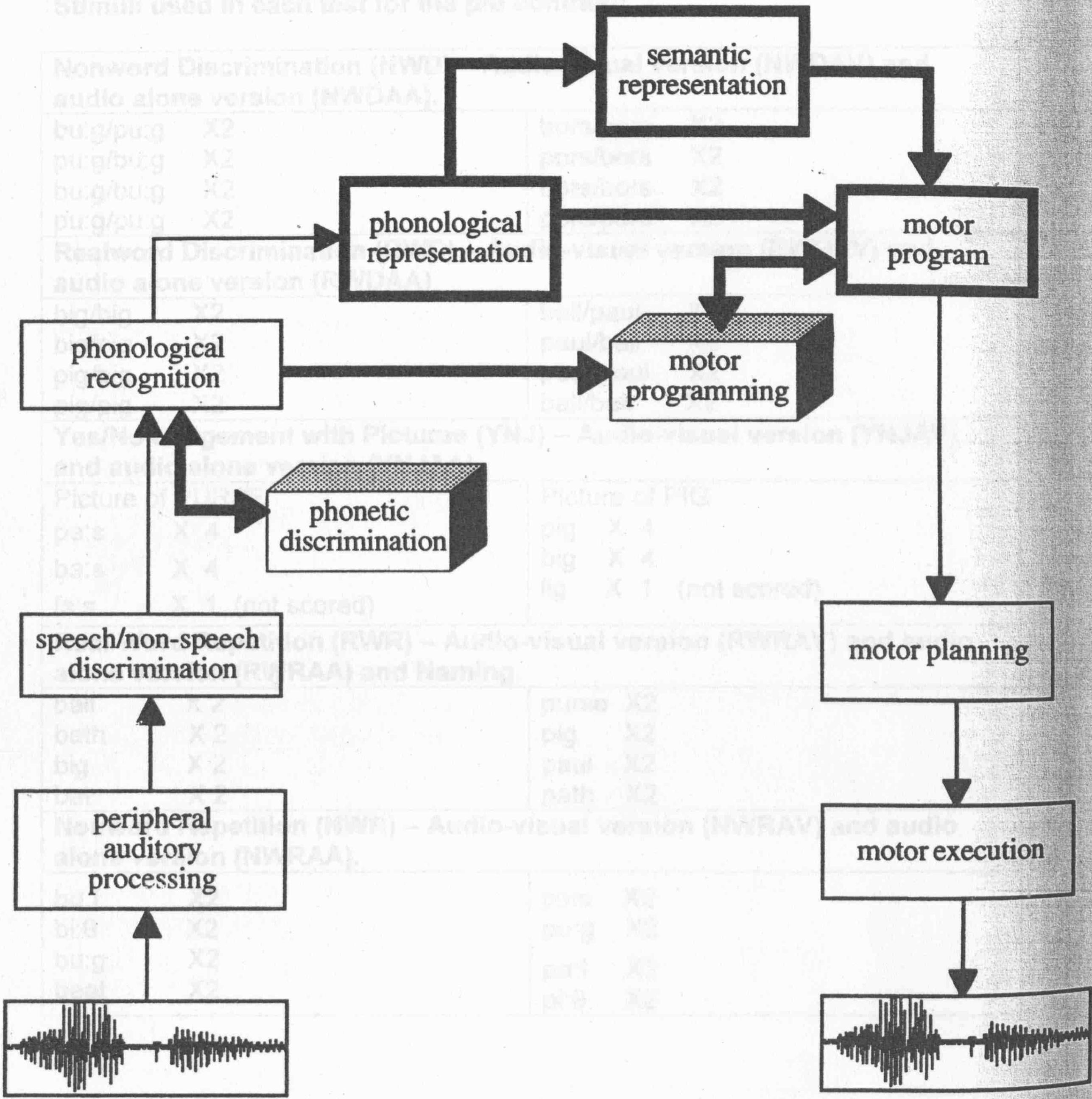
Trezek, B. & Malmgren, K. (2005) The efficacy of utilizing a phonics treatment package with middle school deaf and hard-of-hearing students. *Journal of Deaf Studies and Deaf Education*_ 10 (3) pp. 256-271.

Waters, D, (2001). Using input processing strengths to overcome speech output difficulties. In Stackhouse, J. & Wells, B. (Eds) *Children's Speech and Literacy Difficulties 2: Identification and Intervention.* London: Whurr.

Wiig, E., Secord, W. & Semel, E. (2000). *Clinical Evaluation of Language Fundamentals – preschool UK.* London: The Psychological Corporation.

STACKHOUSE AND WELLS' 1997

SPEECH PROCESSING MODEL



APPENDIX 2

Stimuli used in each test for the p/b contrast:

Nonword Discrimination (NWD) – Audio-visual version (NWDAV) and audio alone version (NWDAA).	
bu:g/pu:g X2 pu:g/bu:g X2 bu:g/bu:g X2 pu:g/pu:g X2	bors/pors X2 pors/bors X2 bors/bors X2 pors/pors X2
Realword Discrimination (RWD) – Audio-visual version (RWDAV) and audio alone version (RWDAA)	
big/big X2 big/pig X2 pig/big X2 pig/pig X2	ball/paul X2 paul/ball X2 paul/paul X2 ball/ball X2
Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).	
Picture of PURSE pɜ:s X 4 bɜ:s X 4 lɜ:s X 1 (not scored)	Picture of PIG pig X 4 big X 4 lig X 1 (not scored)
Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.	
ball X 2 bath X 2 big X 2 bat X 2	purse X2 pig X2 paul X2 path X2
Nonword Repetition (NWR) – Audio-visual version (NWRAV) and audio alone version (NWRAA).	
bɑ:l X2 bi:θ X2 bu:g X2 beət X2	pɔ:s X2 pu:g X2 pɑ:l X2 pi:θ X2

Stimuli used in each test for the sm/m contrast:

Nonword Discrimination (NWD) – Audio-visual version (NWDAV) and audio alone version (NWDAA).	
smɒl/ smɒl X 2 mɒl/smɒl X 2 smɒl/mɒl X 2 mɒl/mɒl X 2	mɔɪk/mɔɪk X 2 smɔɪk/smɔɪk X 2 mɔɪk/smɔɪk X 2 smɔɪk/mɔɪk X 2
Realword Discrimination (RWD) – Audio-visual version (RWDAV) and audio alone version (RWDAA)	
mile/mile X 2 mile/smile X 2 smile/smile X 2 smile/mile X 2	mall/mall X 2 mall/small X 2 small/small X 2 small/mall X 2
Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).	
Picture of SMILE maɪl X 4 smaɪl X 4 laɪl X 1 (not scored)	Picture of SMOKE məʊk X 4 sməʊk X 4 ləʊk X 1 (not scored)
Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.	
small X 2 smile X 2 smoke X 2 smell X 2	mouse X 2 match X 2 mat X 2 moon X 2
Nonword Repetition (NWR) – Audio-visual version (NWRAV) and audio alone version (NWRAA).	
smɔɪk X 2 smu:l X2 smɒl X2 smɑ:l X2	məʊs X 2 mel X 2 mɒtʃ X 2 mɜ:n X2

Stimuli used in each test for the s/d contrast:

<table>
<tr><td colspan="2">Nonword Discrimination (NWD) – Audio-visual version (NWDAV) and audio alone version (NWDAA).</td></tr>
<tr><td>sɑ:/ sɑ: X 2
sɑ:/dɑ: X 2
dɑ:/sɑ: X 2
dɑ:/ dɑ: X 2</td><td>saʊk/saʊk X 2
saʊk/daʊk X 2
daʊk/saʊk X 2
daʊk/daʊk X 2</td></tr>
<tr><td colspan="2">Realword Discrimination (RWD) – Audio-visual version (RWDAV) and audio alone version (RWDAA)</td></tr>
<tr><td>d/d X 2
d/sea X 2
sea/sea X 2
sea/d X 2</td><td>duck/duck X 2
duck/suck X 2
suck/duck X 2
suck/suck X 2</td></tr>
<tr><td colspan="2">Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).</td></tr>
<tr><td>Picture of SEA
si: X 4
di: X 4
bi: X 1 (not scored)</td><td>Picture of SOCK
sɒk X 4
dɒk X 4
bɒk X 1 (not scored)</td></tr>
<tr><td colspan="2">Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.</td></tr>
<tr><td>sea X 2
sun X 2
sock X 2
saw X 2</td><td>duck X 2
d X 2
dog X 2
door X 2</td></tr>
<tr><td colspan="2">Nonword Repetition (NWR) – Audio-visual version (NWRAV) and audio alone version (NWRAA).</td></tr>
<tr><td>sɑ: X 2
sɒn X 2
sek X 2</td><td>dæk X 2
dɜ: X 2
deg X 2
dɑ: X 2</td></tr>
</table>

Stimuli used in each test for the st/d contrast:

Nonword Discrimination (NWD) – Audio-visual version (NWDAV) and audio alone version (NWDAA).	
staʊ/staʊ X 2 staʊ/daʊ X 2 daʊ/staʊ X 2 daʊ/daʊ X 2	stɪmp/ stɪmp X 2 stɪmp/dɪmp X 2 dɪmp/stɪmp X 2 dɪmp/dɪmp X 2
Realword Discrimination (RWD) – Audio-visual version (RWDAV) and audio alone version (RWDAA)	
steep/steep X 2 steep/deep X 2 deep/deep X 2 deep/steep X 2	store/store X 2 store/door X 2 door/door X 2 door/store X 2
Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).	
Picture of STAR stɑ X 4 dɑ X 4 bɑ X 1 (not scored)	Picture of STAMP stæmp X 4 dæmp X 4 bæmp X 1 (not scored)
Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.	
dog X 2 door X 2 deep X 2 duck X 2	star X 2 stick X 2 stairs X 2 stamp X 2
Nonword Repetition (NWR) – Audio-visual version (NWRAV) and audio alone version (NWRAA).	
dɑ:p X 2 dɔɪ X 2 dɜ:k X 2 deg X 2	sti:k X 2 staʊ X 2 stɪmp X 2 staʊz X 2

Stimuli used in each test for the ʃ/tʃ contrast:

Nonword Discrimination (NWD) – Audio-visual version (NWDAV) and audio alone version (NWDAA).	
tʃɜ:/ʃɜ: X 2 tʃɜ:/ tʃɜ: X 2 ʃɜ:/tʃɜ: X 2 ʃɜ:/ʃɜ: X 2	tʃʌp/ʃʌp X 2 tʃʌp/tʃʌp X 2 ʃʌp/tʃʌp X 2 ʃʌp/ʃʌp X 2
Realword Discrimination (RWD) – Audio-visual version (RWDAV) and audio alone version (RWDAA)	
chair/chair X 2 chair/share X 2 share/share X 2 share/chair X 2	chop/chop X 2 chop/shop X 2 shop/shop X 2 shop/chop X 2
Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).	
ʃ Picture of SHOE ʃu: X 4 tʃu: X 4 bu: X 1 (not scored)	ʃ Picture of SHOP ʃɒp X 4 tʃɒp X 4 bɒp X 1 (not scored)
tʃ Picture of CHAIR tʃeə X 4 ʃeə X 4 beə X 1 (not scored)	tʃ Picture if CHIP tʃɪp X 4 ʃɪp X 4 bɪp X 1 (not scored).
Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.	
cheese X 2 chair X 2 chip X 2 church X 2	shirt X 2 shop X 2 ship X 2 shoe X 2
Nonword Repetition (NWR) – Audio-visual version (NWRAV) and audio alone version (NWRAA).	
tʃɜ:z X 2 tʃɔɪjə X 2 tʃi:tʃ X 2 tʃʌp X 2	ʃeət X 2 ʃep X 2 ʃʌp X 2 ʃɜ: X 2

Stimuli used in each test for the m/b contrast:

Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).	
Picture of MAT	Picture of MOUSE
bæt X 4	maʊs X 4
mæt X 4	baʊs X 4
læt X 1 (not scored)	laʊs X 1 (not scored)
Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.	
ball X 2	man X 2
bat X 2	mat X 2
bath X 2	mike X 2
bike X 2	mouse X 2

Stimuli used in each test for the sp/b contrast:

Yes/No Judgement with Pictures (YNJ) – Audio-visual version (YNJAV) and audio alone version (YNJAA).	
Picture of SPADE	Picture of SPOON
speɪd X 4	spu:n X 4
beɪd X 4	bu:n X 4
leɪd X 4 (not scored).	lu:n X 4 (not scored).
Real Word Repetition (RWR) – Audio-visual version (RWRAV) and audio alone version (RWRAA) and Naming.	
bell X 2	spoon X 2
bath X 2	spell X 2
bus X 2	spade X 2
big X 2	spider X 2

APPENDIX 3

Real Word Reading and Spelling Stimuli

CONTRAST	STIMULUS
sm/m	smile
	smoke
	smell
	mouse
	mat
	moon
st/d	star
	stick
	stamp
	door
	dog
	duck
s/d	sea
	sock
	saw
ʃ/tʃ	cheese
	chair
	church
	shop
	ship
	shoe

APPENDIX 4

Nonword Reading and Spelling Stimuli

CONTRAST	STIMULUS
sm/m	smern*
	smoik*
	Smarl*
	mern*
	moik
	marl
st/d	stimp*
	steg*
	stoy*
	dar*
	dimp*
	doy
s/d	sar
	seck*
	son*
	deg
	dar*
	don*

* = stimuli also used in nonword spelling task

APPENDIX 5

ADMINISTERING THE REES-COLEMAN PROCEDURE TESTS

STARTING THE PROGRAM:

1.) To access the computer programme, go to my computer and select 'c' drive.
2.) Click on the 'PIDS' icon from the screen and this will bring up a number of choices.
3.) To begin testing, click on the 'contrast.exe' icon and this will bring up the main menu screen (see below.)

Contrast	Task	Media
m/b	Familiarisation	Audio-visual
p/b	Picture Naming	Audio-alone
s/d	Real Word Repetition	Visual
ʃ/tʃ	Non-word Repetition	
sw/w	Lexical Decision	
sp/b	Real-word Same-Different	
st/d	Non-word Same-Different	
sk/g		
sm/m	Enter Child's Name: ____________	
sn/n		
	Exit Programme	Done Selecting

4.) The screen will automatically appear with the name of the last child who was tested but none of the tests will be selected.
5.) To create a new directory for a child, enter the child's name and this will be done automatically.
6.) To practise using the programme, enter "demo" under child's name.

SELECTING A TEST:

1.) Using the main menu shown above, enter the child's name first.
2.) Then enter the contrast you wish to use.
3.) Then select the test you wish to use.
4.) Finally select the media option you wish to use.

5.) Then click "done selecting" this will automatically bring up the test you have requested.

6.) For each test you need to click on the 'start' on the small menu on the screen to begin the test when the child is ready.

7.) See the following section, administering each test, for how each test works.

ADMINISTERING EACH TEST:

General Introduction: "We're going to do some tasks on the computer. They don't take very long and I'll show you how each one works before you do it."

Familiarisation: "We're going to look at some pictures that you'll see in the tasks we'll be doing. I'd like you to tell me what the pictures are."

If the child is unable to name the picture, prompt them and then go over the ones they needed prompting on at the end.

Picture Naming: "On the computer you're going to see some of the pictures we've already seen. I'd like you to tell me what the pictures are as they come up."

Repetition:

AV

"In this task you'll see a lady's face on the screen. Her name is Rachel. She says lots of different words. These words are real words / not real words. After each word she says, I'd like you to say it too."

AA

"This time Rachel is going to say some more real words / words that aren't real. This time you won't be able to see her face, so you'll have to listen very carefully. After each word she says, I'd like you to say it too."

Same-Different:

AV

"In this task, you'll see Rachel's face again. This time she will say two words in a row. You need to listen carefully and decide if these two words are the same as each other or different. Some of them will be the same and some of them will be different. These are real words / are not real words. If you think they are the same, you need to tell the computer by pressing the "Z" key (marked with a gold tick). If you think the two words sound different, you must tell the computer by pressing the "M" button (marked with a silver cross)."

Show which keys to press.

AA

In this task, you won't be able to see Rachel's face so you need to listen carefully ... (See explanation for AV task.)

Lexical Decision

AV

"This time, there will be a picture on the screen and next to it you will see Rachel's face. She is going to say the name of the picture. Sometimes she will say the name correctly and sometimes she will say it wrong. If you think that Rachel has said the name correctly, you need to press the "Z" button but if you think she has said the name wrong, you need to press the "M" button.

AA

"In this task, you will just see the picture and hear Rachel's voice so you need to listen very carefully. (See explanation for AV task.)

INPUT TESTS

1.) The child records the answer by pressing either "Z" or "M".
2.) The computer automatically records the latency for these tests.
3.) After the child has entered their answer, the tester needs to press "next" on the small menu on the screen to generate the next item.

4.) When the last item on the test has been completed, a reward sequence will automatically take place.
5.) To exit the test, click on the right hand button on the mouse and this will bring up the popup menu and select exit (at the bottom). The computer will automatically save the data on the child's file.

OUTPUT TESTS

1.) Once the computer has presented the item, click on the small menu on the screen, this will record the latency.
2.) The child will respond to the stimuli with a verbal response.
3.) The tester marks this as either:
    - Correct '/' if the child's response is the same as the adult form (no phonetic differences) or the contrast could not be recognised as anything else.
    - Incorrect '\' if the child's response was missed by the tester or they were not sure how to score it.
    - Unsure '?' if the child's response was missed by the tester or they were not sure how to score it.
4.) The tester then needs to click 'next' on the small menu on the screen to generate the next item.
5.) To exit the test, see instructions for input tests.