Therapy for Auditory Processing Impairment in Aphasia:

An evaluation of two approaches

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Abstract

Purpose: This study evaluated two forms of discrimination therapy for auditory processing impairment in aphasia. It aimed to determine whether therapy can improve speech perception and/or help participants use semantic information to compensate for their impairment. Changes in listening were also explored by recording the level of facilitation needed during therapy tasks. Finally the study examined the effect of therapy on an everyday listening activity: a telephone message task.

Method: The study employed a repeated measures design. Eight participants received 12 sessions each of phonological and semantic-phonological therapy. Both programmes used minimal pair judgement tasks, but the latter embedded such tasks within a meaningful context, so encouraged the strategic use of semantic information (semantic bootstrapping). Experimental measures of auditory discrimination and comprehension were administered twice before therapy, once after each programme, and again six weeks later. The telephone message task was also administered at each time point. Test data were subjected to both group and individual analyses. Records of progress during therapy (i.e changes in support needed to carry out therapy tasks) were completed during treatment and analysed across the group.

Results: Group analyses showed no significant changes in tests of word and nonword discrimination as a result of therapy. One comprehension task improved following therapy, but two did not. There was also no indication that therapy improved the discrimination of treated words, as assessed by a priming task. The facilitation scores indicated that participants needed less support during tasks as therapy progressed, possibly as a result of improved listening. There was a significant effect of time on the telephone message task. Across all tasks there were few individual gains.

Conclusions: The results offer little evidence that therapy improved participants' discrimination or semantic bootstrapping skills. Some changes in listening may have occurred, as indicated by the facilitation scores. Reasons for the null findings are discussed.

Introduction

Impaired comprehension of speech is one of the very devastating consequences of aphasia. It isolates the person from conversation, employment and leisure activities, with likely effects for confidence and self-esteem (Davidson, Howe, Worrall, Hickson, & Togher, 2008; Le Dorze, Brassard, Larfeuil & Allaire, 1996; Pound, Parr, Lindsay & Woolf, 2000).

Lexical models (see Whitworth, Webster & Howard, 2014) suggest that speech comprehension involves a number of processing stages. The phonemic content of the word is determined by auditory analysis; word recognition occurs when the lexicon is accessed and understanding is accomplished when the word form is linked to the semantic representation.

There is evidence that each stage of the comprehension process can be subject to aphasic impairments (Franklin, 1989). In a number of cases auditory analysis is impaired, resulting in an inability to discriminate speech sounds. This disorder is typically referred to as word sound deafness (e.g. Best & Howard, 1994). The problem can be one of a complex of aphasic symptoms or occur in isolation, in which case it is termed pure word deafness (e.g. Stefanatos, Gershkoff & Madigan, 2005). People with word sound deafness are typically impaired on all spoken input tests, such as synonym judgment, word to picture matching, lexical decision and repetition, since all require accurate phonemic perception. Minimal pair tasks, which involve the discrimination of words or nonwords that differ by one phoneme, are particularly diagnostic. These tasks are failed by people with word sound deafness, but not other comprehension disorders (Franklin, 1989). Problems with minimal pairs may be general, or confined to specific contrasts, such as voicing or place of articulation (Blumstein, 1991; Caplan & Utman, 1994).

There are varying estimates of the prevalence of word sound deafness. For example, Varney (1984) suggests that 18% of people with aphasia have impaired speech sound discrimination, while others identify problems in phoneme discrimination or recognition in at least 70% of cases (Basso, Casati & Vignolo, 1977; Blumstein, 1991, 1994). Under-identification of all aphasic comprehension impairments (i.e. not just word sound deafness) can occur in the clinical context, given that these impairments are less evident than disorders of speech production. Indeed, McClenahan, Johnston and Densham (1990) showed that family members and many health professionals underestimate comprehension deficits which are revealed by language testing.

Despite the impact and likely prevalence of speech perception disorders, little attention has been paid to this area in aphasia therapy. A small number of single case studies have aimed to retrain auditory analysis via structured practice in distinguishing similar sounding words (Grayson, Franklin & Hilton, 1997; Hessler & Stadie, 2008; Maneta, Marshall & Lindsay, 2001; Morris, Franklin, Turner & Bailey, 1996; Tessier, Weill-Chounlamountry, Michelot & Pradat-Diehl, 2007)[1]. Although different, all the programmes were hierarchical; i.e. discrimination targets became more similar over time and/or listening conditions became more demanding. They also exploited a range of systematic facilitation techniques, including the repetition of targets, the use of meaning based cues, and visual supports such as lip reading. Such cues were introduced or withdrawn in response to success levels in therapy. One of the studies (Tessier et al, 2007) additionally used an errorless format in the hope that this would consolidate listening skills. The participant in this study also varied from the others in that he had general auditory agnosia, but not aphasia.

[1] Naeser, Haas, Mazurski & Laughlin (1986) also used discrimination tasks in therapy. However, they were not aiming to retrain auditory analysis. Rather they were taking advantage of *retained* phoneme discrimination abilities to facilitate sentence level auditory comprehension.

These studies produced some evidence that therapy can improve discrimination skills, with four reporting gains on minimal pair tasks (Hessler & Stadie, 2008; Morris et al, 1996; Tessier et al, 2007; Grayson et al, 1997). However, in two of the studies associated gains in auditory comprehension were either not reported (Hessler & Stadie, 2008) or absent (Morris et al, 1996). One of the participants showed no gains at all (Maneta et al, 2001).

Looking at the results in more detail, a further question is whether therapy particularly benefited the discrimination of treated words. Such a gain might be anticipated because treated words can benefit from two potential mechanisms of change. One is a general improvement in phonemic discrimination. The other is an item specific priming effect, whereby repeated exposure to a stimulus reduces its activation threshold, making it more readily available for subsequent processing. One study explored this question (Hessler and Stadie, 2008). This showed that all assessments improved with treated words, while 5 (out of 7) improved with untreated words. Therefore the greatest gains occurred with treated words, perhaps reflecting an item specific priming effect. However, the fact that there was generalisation across most tasks pointed, additionally, to improvements in phonemic discrimination that were not item specific. In line with this, the other positive studies showed gains on assessments with untreated words (e.g. Morris et al,1996; Tessier et al, 2007).

Although promising, the literature to date reports results from a very small number of participants, and only two indicate that discrimination therapy can improve the understanding of speech. The current study adds to the evidence by evaluating the effects of discrimination therapy with 8 participants using a range of discrimination and comprehension tasks.

This study will also explore whether discrimination skills improve in both ideal and non ideal listening conditions as a result of therapy. There is evidence that the comprehension of people with aphasia is particularly vulnerable in sub-optimal conditions, e.g. when the speech signal is distorted (Moineau, Dronkers & Bates, 2005); and many personal accounts of aphasia stress the negative impact of background noise on speech comprehension (Ireland and Black1992; Liechty, 2012). Therapy gains that extend to non-ideal listening conditions would, therefore, be particularly desirable. This was tested in the current study by administering discrimination tasks in both noise and quiet.

An alternative therapy approach aims to develop strategies that support speech comprehension, despite the discrimination impairment. For example, following their participant's poor response to discrimination therapy, Maneta et al (2001) trained his wife to employ a range of strategies alongside speech, such as writing. As a result, exchanges with her husband became far more efficient and effective.

Whether or not therapy can develop compensatory strategies on the part of the affected individual has barely been explored. There is evidence that some people with word sound deafness can exploit lip reading (Gieliewski, 1989, Hessler, Jonkers & Bastiaanse, 2010; Morris et al, 1996; Shindo, Kaga & Tanaka, 1991). An additional strategy involves semantic bootstrapping, whereby the person uses the semantic context to support their interpretation of speech (Saffran, Marin & Yeni-Komshian 1976). Woolf (2004) compared the discrimination of speech sounds in three different contexts: nonwords, words, and words accompanied by pictures. Unlike controls, listeners with word sound deafness were strongly influenced by context; i.e. they showed a lexical effect (words > non words) and were assisted by picture contexts in lexical selection. This was particularly the case for phonetic contrasts that they had difficulty encoding. Woolf concluded that these participants were using meaning to compensate for their impaired speech perception. Rather similar findings are reported by Robson and colleagues (Robson, Davies, Lambon-Ralph & Sage, 2012). Their participant with word deafness was asked to repeat words either in isolation, or when presented alongside pictures or written words. Repetition was poor when conducted without facilitation, but improved significantly when supported by a picture or written version of the target. Non target pictures and words either had no effect, or, in the case of rhymes significantly disrupted repetition.

Given that some people with word sound deafness seem to be strategic listeners, this may be a productive avenue for therapy. For example, further gains may be achieved by encouraging these individuals to attend carefully to the semantic context when they are attempting to interpret speech. The current study explored this question by evaluating two therapy approaches. One therapy (Phonological Therapy) involved discrimination tasks focusing on differences in phonological input. The other (Semantic-Phonological Therapy) embedded such tasks within semantic contexts, with the hypothesis that the latter might encourage semantic bootstrapping. Both approaches incorporated tasks that have been reported elsewhere. For example, previous studies have included discrimination and semantic tasks (Morris et al., 1996; Maneta et al., 2001; Grayson et al,1995). However, the differential effects of these tasks have not been fully explored. Our study therefore examined these approaches separately.

Therapy might also bring about more general changes in listening. This was explored in the current study by examining the type of facilitation needed in the therapy tasks and whether this changed over time. Evidence that tasks could be accomplished with less facilitation from the therapist might point to improved listening, and perhaps better use of acoustic and visual cues to phoneme identity.

A final question is whether therapy can affect the understanding of speech in everyday contexts. Most previous studies of comprehension therapy confined their evaluations to clinical tests, so neglected this question (see Grayson et al, 1997; Morris et al, 1996; Francis, Riddoch & Humphreys, 2001). Tessier et al (2007) administered a communication abilities rating measure, with the finding that this improved post therapy. The current study employed a novel telephone message task that attempted to evaluate word discrimination in a simulated ‘real life’ context.

In summary, this study aimed to build upon the findings of previous research by exploring therapy outcomes with eight participants who had speech discrimination and comprehension impairments. It compared the effects of speech discrimination training (phonological therapy) with a training that embedded discrimination targets within a semantic context (semantic-phonological therapy). A range of experimental measures were used to capture changes in speech discrimination and comprehension. Participants' need for facilitation during therapy was systematically recorded, so that changes could be tracked. Finally, effects on an authentic everyday listening task were explored.

There were five hypotheses:

i) Phonological and/or semantic-phonological therapy will improve participants' speech discrimination, or the ability to distinguish between phonemes. Also of interest was whether changes in discrimination would be evident both in ideal listening conditions (quiet) and non-ideal conditions (noise).

ii) Therapy, and particularly semantic-phonological therapy, will develop semantic bootstrapping skills, or the ability to recruit meaning to compensate for impaired discrimination. This would be evident in comprehension tasks and when discrimination was tested in the context of semantic primes.

iii) Therapy will particularly improve discrimination of treated words, with possible generalisations to untreated words. Of interest was whether generalisation patterns would differ between phonological and semantic-phonological approaches.

iv) Therapy will reduce the need for listening support and enable participants to make better use of acoustic and visual cues to phoneme identity.

v) Therapy will improve performance on an everyday listening task: listening to telephone messages.

Method

Ethical Approval was granted by Bedfordshire Local Research Ethics Committee (05/Q0202/75). All participants gave informed consent using an aphasia-friendly consent process prior to their involvement.

Participants

All participants had aphasia following a stroke that occurred at least six months prior to the study. They were identified as having impaired speech comprehension by referring therapists or family members. They were native users of English and at least 18 years old. They had no hearing loss above 40 dB HL in their better ear (established with pure tone audiometry carried out at 1, 2 and 4 kHz).

Initial assessment focused on screening and background tests of direct relevance to the therapies and experimental outcome measures. Although a standard aphasia battery may have yielded further useful information, one was not administered due to the already high burden of assessment in the study. All participants had impaired spoken word comprehension, scoring more than 1SD below the control mean in the PALPA Spoken Synonym Judgement test (Kay, Lesser & Coltheart, 1992). Phoneme discrimination impairment was established via a non word discrimination test. All participants first demonstrated that they could distinguish maximal pairs (such as *nurg* and *thip*) with at least 75% success rate. This showed compliance with the task. For most participants, maximal pairs were tested live, although HH and JY, who were given an early and more extensive version of the test, were assessed on a computer. Non word minimal pairs were then tested via computer presentation. 32 pairs were the same (e.g. *dak* and *dak*) and 32 were minimally different (e.g. *wug* and *wuk*). To be included in the study participants had to score no more than 75% with the minimal pairs, indicating impaired perception of phonemic distinctions. Twenty controls scored mean 95% on this task (SD: 0.51 - see details on controls below).

A number of the assessment and therapy tasks involved matching spoken words with pictures or with written words. Participants therefore had to score at least 35/40 on the PALPA Written Word to Picture Matching Test (Kay et al, 1992) and at least 28/32 on the Birmingham Object Recognition Battery Easy Object Decision Test (Riddoch & Humphreys, 1993). In both cases these scores fell within the normal range, as reported by the test authors. Three additional background tests were carried out to provide further information about individual profiles, e.g. with respect to semantic processing. These were the PALPA Written and Spoken Synonym Judgement (Kay et al. 1992) and the Pyramids & Palm Trees three-picture version (Howard & Patterson, 1992). At least one previous individual has responded positively to discrimination therapy despite performing poorly on these latter tests (Morris et al, 1996). Failure was not, therefore, a reason for exclusion from the current study.

Thirty four participants were screened, but only 11 met the criteria. A common reason for exclusion (8 participants) was hearing impairment. Others scored outside the required range on our screening tests. One participant displayed an unstable baseline performance, so did not progress to therapy and two failed to complete the final assessments for health reasons. Data are therefore reported on eight participants. Their details and screening test results are reported in Table 1, with hearing thresholds reported in Table 2.

There was considerable heterogeneity within the group, making this a non ideal sample (we return to this issue in the discussion). All had impaired phoneme discrimination as one of their aphasic symptoms. Severity of the auditory deficit ranged from severe to moderate (nonword minimal pair discrimination scores at screening ranged from 58-75% mean 66%). All participants had impaired auditory comprehension, as tested by synonym judgement. Seven participants were either unimpaired in reading comprehension (WS, JY and JP) or had significantly better reading than auditory comprehension (HH, JC, SL, JG). AA was impaired across modalities. With the possible exception of AA, all participants could be described as having word sound deafness as a feature of their aphasia, but certainly not in its pure form. AA showed evidence of a central semantic processing deficit (see Pyramids and Palm Trees score) accounting for her more generalised comprehension difficulties. In this respect, she resembled JS who was treated successfully by Morris et al (1996). Participants and their family members all reported everyday difficulties with the comprehension of speech. For example, they needed information to be repeated or written down and had difficulties understanding the television, radio and telephone.

(insert Tables 1 and 2 about here)

Therapy

Each participant received two programmes of therapy aiming to improve their speech discrimination and thereby auditory comprehension. One programme consisted of phonological therapy and the other semantic-phonological therapy. Programmes comprised a total of 12 one hour domiciliary sessions delivered twice a week over 6 weeks. Therapy in both programmes was standard across participants and prescribed in a manual. It was delivered by authors CW and AP, both experienced Speech and Language Therapists.

Both programmes involved a range of tasks that required the discrimination of words differing by one phoneme (Morris et al, 1996; Grayson et al, 1997; Maneta et al, 2001). The same hierarchy of phonemic contrasts was used in both programmes. This progressed from place contrasts to voice contrasts, since more lipreading information is available for the former. Initial place contrasts (e.g. cub/pub), were worked on before final place (e.g.cog/cod), and final voice contrasts (e.g.mop/mob) before initial voice (e.g. gut/cut). This order was informed by the typical success rates of people with word sound deafness (e.g. Woolf, 2004).

Each programme had a dedicated and different set of twenty minimal pairs that were included in all tasks. These items were collectively presented 1000 times within each programme. This intensive exposure permitted exploration of change on treated words, and comparison with matched sets of untreated words, through inclusion in an experimental priming task (described below). To encourage the generalisation of skills and maintain participant interest, treatment stimuli were not confined to these words. In total, 1053 different words were included in therapy.

The programmes differed in the degree of meaning engaged by the tasks. Judgements in the phonological therapy were based primarily on word form. Judgements in semantic-phonological therapy were based primarily on meaning, but also required processing of form, e.g. because of the presence of phonological distracters. Thus the semantic-phonological therapy aimed to recruit semantic skills to help participants overcome their difficulties with speech discrimination. Therapy tasks and examples are provided in Appendix 1.

All tasks were completed in each session. Levels of facilitation were provided in a consistent manner across the therapies (see Table 3). Items were initially presented live by the therapist with her face visible (‘Free Voice’, level 4). If a participant succeeded on 10 sequential items presented in the free voice condition, support was systematically reduced. So stimuli were subsequently presented with the therapist’s mouth covered (level 5) and then in background noise (level 6). If the participant failed to give a correct response, facilitation cues were provided in a consistent order, e.g. through levels 3 to 1. In phonological discrimination therapy, facilitation provided increasing phonological and phonetic information about the target word. In semantic-phonological therapy, facilitation provided additional information about its meaning. In both therapies the final level of facilitation was to write the target in order to elicit a correct response (level 0).

Levels of facilitation were informed by findings in the literature. The most challenging condition was background noise, in line with personal testimonies and research findings (Ireland and Black,1992; Woolf, 2004). The presence, absence and exaggeration of lip information were manipulated in line with evidence that lip reading is facilitatory (Shindo et al, 1991). Repetition, articulograms and written cues have all been employed in previous treatment studies, with the hypothesis that these support understanding (Morris et al, 1996; Maneta et al, 2001). The order of cues was also influenced by these studies. For example, Morris et al (1996) provided repetition ahead of other cues to phoneme identity (in their case cued speech), and increased difficulty first by removing lip-reading information and then delivering stimuli on tape.

The level of facilitation used for each item of each task was recorded and data were analysed to explore whether there was any change in listening support needed during therapy. Facilitation records were also used to provide feedback to participants, e.g. about the strategies that were most helpful within therapy. For example, if a participant responded mainly at level 3, feedback would indicate that he needed to look at the speaker's mouth and often benefited from words being repeated before he could interpret speech.

Insert Table 3 about here

The Design

The study employed a repeated measures design. Participants underwent repeated baseline testing separated by six weeks (time points 1 and 2). They then entered the two programmes of therapy, each lasting six weeks. Testing occurred after each programme (time points 3 and 4) and again after 6 weeks (time point 5). No therapy was received between time points 4 and 5, so that the maintenance of any gains could be assessed during this wash-out period. Treatment order was randomly assigned so that half the participants received the phonological therapy first, and half received the semantic-phonological therapy first.

Test data were subjected to both group and individual analyses. The former used ANOVA to determine whether there was an overall treatment effect on each measure. This would be marked by a main effect of time, with post therapy scores (time points 4 and 5) being higher than pre therapy scores (time points 1 and 2). Given the small participant numbers this analysis could not compare treatment groups (i.e. those receiving phonological therapy first vs those receiving semantic-phonological therapy first). Individual analyses explored gains arising from each programme of therapy. Here pre and post therapy scores on each measure were compared using the McNemar Chi Square statistic.

The Outcome Measures

There were six experimental outcome measures, and all bar one (the Priming Task) was administered at each time point. In order to standardise test presentation and eliminate researcher bias, tests were administered and responses recorded on a computer. Items were presented via the computer loud speaker in random order determined by a random number generator using Super Lab 2.0™ (Cedrus Corporation). Responses were made via a two choice button box or, in the case of written word selections, via a touch screen. Where tests included a background noise condition this consisted of 20-talker babble. Signal to noise ratios varied across tasks, but were within the range of 12.5db - 17.75db. They were set so that unimpaired control participants achieved between 80 and 89% success levels in the noise condition.

Data from healthy controls were collected on all measures. The number of controls tested on each measure is outlined below. Screening of controls for neurological and hearing impairments would have been desirable, but was unfortunately not feasible. This was, therefore, only checked through personal report. Controls' mean age was 52.65, range 34-72.

The measures used in the study aimed to explore the five hypotheses. The first hypothesis stated that therapy would improve speech discrimination, or the ability to distinguish between phonemes. This hypothesis was tested with tasks that required discrimination skills, and which could be accomplished with minimal or (in the case of non words) no input from semantics. They are described below. These tasks also aimed to explore whether changes in discrimination in ideal quiet conditions would extend to non-ideal noise conditions. The noise condition allowed further scope for showing change, for instance if a participant were at ceiling in the quiet condition following the first phase of therapy.

Word discrimination (adapted from Woolf, 2004).

Participants heard two spoken CVC words (n=128) and had to judge whether they sounded the same or different. Different pairs shared all but one phoneme, which differed by either voicing or place of articulation e.g. ‘cat’ and ‘cap’. Half the items were presented in quiet and half with background noise. Twenty controls scored 94.4% (SD: 0.42) correct in quiet, and 83.82% (SD: 1.42) correct in noise.

Nonword discrimination (adapted from Woolf, 2004).

Participants heard two spoken CVC nonwords (n=128) and had to judge whether they sounded the same or different. As in the word task, different pairs shared all but one phoneme, which differed by either voicing e.g. *kofe-gofe,* or place of articulation e.g. *pib-tib*. Half the items were presented in quiet and half with background noise. Twenty controls scored 95.04% (SD: 0.51) correct in quiet, and 87.77% (SD: 0.81) correct in noise.

The second hypothesis stated that therapy, and particularly semantic-phonological therapy, would develop semantic bootstrapping skills, or the ability to recruit meaning to compensate for impaired discrimination. This hypothesis was tested with tasks that engaged meaning in addition to speech discrimination. Three such tasks were used. The first two allowed explicit reflection on meaning (picture word verification and synonym judgement). The third was a priming task. Here a very brief written prime cued or miscued discrimination. This therefore explored the online, and possibly subconscious, application of semantic information. If semantic-bootstrapping increased after therapy this should produce differential effects under the different priming conditions, e.g. with fewer errors on primed words. In addition, this task employed words that had been treated in therapy, so allowed the exploration of whether therapy improved discrimination of treated words and whether gains extended to untreated words (hypothesis three). The three tasks are described below.

Picture-word verification (Woolf, 2004).

Participants saw a picture and heard a spoken word, which they had to accept or reject as the picture name (n=128). Non-matching names differed by one phoneme from the target (such as 'coat' for a picture of a goat). Words were the same items used in the word discrimination test. Half the items were presented in quiet and half with background noise. Success required the ability to discriminate speech sounds in the context of a semantic cue provided by the picture. Twenty controls scored 94.67% (SD: 0.41) correct in quiet and 88.6% (SD: .93) correct in noise.

Spoken Synonym Judgements (Kay et al,1992).

This was the same task as was used in screening. Participants heard two spoken words (n=60) and had to decide whether they were related in meaning. Half of the items were close in meaning (*wedding-marriage*), and the other half were unrelated (*cash-fight*). Control mean accuracy was 97% (SD:1.4)[2]. This was a challenging task, requiring participants to access and compare the meaning of two spoken words.

Priming Task

In this task participants briefly saw a written prime and then heard a spoken word. They then saw three written words on a touchscreen computer display and were asked to select the word they had heard. The written choices comprised the target and two similar sounding alternatives. Targets were presented under three conditions: primed, misprimed and neutral. In the primed condition the target was preceded by a semantically related word.

[2] Unpublished normative data from a group of seven controls aged 66-80 (mean age 73 years) was provided by Dr Karen Sage of the University of Manchester (personal communication 25th February 2005).

In the misprimed condition it was preceded by a word related to one of the distractors. In the neutral condition there was no preceding prime; instead the target was preceded by the orthographic form XXXX in order to maintain consistency of stimulus presentation across the three conditions (see Table 4).

The stimuli for the priming task were 40 words that were included in therapy and 40 untreated words. Treated and untreated items were matched for frequency,imageability, contrast type (place/voice) and position (initial/final). Each word was presented in the three priming conditions. Thus the total number of items in the test was 240. Random presentation of the stimuli was achieved by superlab, but with blocked items (to ensure that the three presentations of each item were distributed across the test). Two sets of stimuli were developed, one to test the phonological therapy and one to test the semantic-phonological therapy. Different sets were used so that words treated in the second phase would not have an advantage through being treated twice, and to avoid possible ceiling effects after the first phase of therapy. As this task was specific to each programme of therapy it was administered outside the main assessment regime. The stimuli were presented once immediately before and twice after each programme of therapy, with the post therapy testing separated by at least a four week gap.

(insert Table 4 about here)

The priming task was piloted with 12 healthy controls. For the controls, stimuli were presented in multi-speaker babble noise to induce a 20% error rate[3]. This enabled us to explore the effects of priming condition. Controls responded more accurately to primed

[3] Measurement of reaction times (RTs) was counter-indicated by the format of the task. Touchscreen responses would elicit long RTs; and differences between conditions could be masked by varying travel times between the resting position of the hand and the location of target words on the screen.

words than words presented in both the neutral and misprimed condition (primed mean: 85%; neutral mean: 79%; misprimed mean: 75%).

The fourth hypothesis stated that treatment might reduce need for listening support and enable participants to make better use of acoustic and visual cues to phoneme identity; i.e. participants might pay more attention to the speaker and exploit cues such as lip patterns. The experimental measures offered little opportunity to benefit from changed listening behaviours as stimuli were recorded and presented on a computer. This hypothesis was therefore tested by noting the level of support needed for each item in each therapy task. Improved listening would be signalled by a reduced need for facilitation during the course of therapy.

The final hypothesis stated that therapy might improve performance on an everyday listening task. This was tested by the following measure:

Telephone Message Task

In this task, participants heard 20 recorded messages and after each one had to select the final word from a written choice of three on a touchscreen display. Choices comprised the target and two phonologically related and plausible alternatives. In ten items the target was a proper noun e.g.

> Message: *Sid just told me a piece of good news. The lottery jackpot was won by Gary*.
> Choices: *Gary, Barry, Carrie*

In the remaining ten items the target was a common noun e.g.

> Message: *The builder has given me a ridiculous quote. It's for putting in the new path*.
> Choices: *bath, hearth, path*

Neither proper nor common noun targets could be predicted from the context.

To prevent learning effects five different sets of 20 messages were used across the test points, with messages within each set presented in random order. Ratings of message plausibility were obtained from eleven controls, and messages distributed across the five stimulus sets to balance for plausibility. Accuracy data was then collected from a further 20 controls, who performed at ceiling.

Results

Mean scores for the participants with aphasia on the 6 experimental measures are presented in tables 5 and 6.

(Insert tables 5 and 6 about here)

The first therapy hypothesis stated that therapy would improve participants' discrimination skills. To explore this hypothesis the word and nonword discrimination scores were analysed by two factor within subject analyses of variance (ANOVA). Factors were time (5 levels: time points 1-5) and condition (2 levels: noise and quiet). In both analyses the only significant main effect was condition (words $F(1,7) = 83.54$, $p<.001$; non words: $F(1,7) = 55.482$, $p<.001$) indicating that participants scored more highly in the quiet condition. There was no main effect of time and no interaction between time and condition.

The ANOVA suggested that therapy did not improve discrimination skills, given that there was no main effect of time. However, this may have masked therapy specific or individual benefits. Therefore pre and post therapy individual scores were compared for each programme of therapy. For the initial programme, the analysis compared the highest baseline score with the score at time 3. For the second programme, scores at time 4 and time 3 were compared. This procedure is followed in all subsequent individual analyses. Gain scores are presented in figures 1 and 2. In both figures (and in all subsequent figures), the first four participants (HH, JC, SL & WS) received phonological therapy first and the final four participants (JY, JP, AA & JG) received semantic-phonological therapy first. In all figures the absence of a bar indicates a gain score of nil.

These figures suggest that neither programme of therapy consistently improved the participants' discrimination skills, given that there are almost as many negative as positive changes. Significant gains are rare, and all failed to maintain at time 5. JG appeared to benefit from phonological therapy. However, this was partly because his scores declined after the first programme (semantic-phonological). His scores at time 5 also fell back to baseline levels. Therefore both the group and individual analyses offered no support for the first hypothesis.

Insert Figures 1 & 2 about here

The second hypothesis stated that therapy, and particularly semantic-phonological therapy would develop semantic bootstrapping skills. This would be marked by an improvement on tasks that engage meaning as well as discrimination, i.e. picture word verification, synonym judgement and priming. The picture word verification scores were analysed by a two factor within subject ANOVA. This yielded a main effect of condition ($F_{(1,7)} = 16.792$, $p < .005$), with scores being highest in the quiet condition. There was also a main effect of time ($F_{(4, 28)} = 3.538$, $p < .05$). Planned comparisons showed that the two post therapy scores (4 & 5) were significantly higher than the two pre therapy scores (1 & 2) ($F_{(1,28)} = 10.54$, $p < .01$). There was no difference between the two baseline scores (1 vs 2) and no interaction between time and condition. The synonym judgement scores were analysed with a one factor ANOVA (time), with five levels. The result was not significant. The two sets of priming data were subjected to three factor within subject analyses of variance. Factors were time (3 levels), treatment (2 levels: treated and untreated items) and condition (3 levels: misprime, neutral, and target prime). Results from both ANOVAs revealed no significant main effects and no interactions. Thus performance did not improve after either therapy programme. In both analyses the priming condition approached significance (Phonological p = .079; Semantic-phonological p = .074), with misprimed items scoring lowest.

The group analyses offered only very partial support for the second therapy hypothesis. Participants' judgements of picture names improved following both programmes of therapy. However, performance on the synonym and priming tasks remained unchanged. No further support was derived from the individual analyses. Figures 3 and 4 show the individual gain scores on the picture word verification and synonym judgement tasks, and Figures 5 and 6 show gains on the priming task. Significant changes were few, with almost as many negative as positive outcomes. There was no evidence that the semantic-phonological therapy particularly improved these tasks. Thus the second therapy hypothesis was not supported.

The third hypothesis stated that therapy would particularly improve the discrimination of treated words. The priming task, which tested treated and untreated words, explored this hypothesis. This showed no main effect of treatment and no interaction between time and treatment. Thus the third hypothesis was not supported.

Insert Figures 3, 4, 5 & 6 about here

The fourth hypothesis stated that both therapies would reduce participants' need for facilitation during tasks. This hypothesis was explored by recording the level of facilitation needed for each item on each task during therapy. Data from one task from each therapy programme were analysed. Tasks were selected because they were completed by all participants in all sessions, so providing a full data set, and because they required the least explanation to enable participants to comply. The latter criterion ensured that facilitation related to listening rather than task demands. The selected task for phonological therapy was minimal pair discrimination and for semantic-phonological therapy was spoken word to picture matching.

The mean facilitation score was computed for each participant in each session (see Table 3 for scoring criteria), and change in scores over time was explored. During each of the two therapy programmes, specific contrasts (place/voice and initial/final) had been treated at different stages, such that each contrast was treated in four sessions. Since discrimination of the different contrast types may have responded differently to treatment, data for each contrast type was therefore analysed separately. Thus, for each contrast type, data from those four sessions in which it had been treated were entered into the analysis. Ordinal regression analyses were used to explore changes in performance over time across the group. .

Results for the phonological therapy task (see Figure 7) showed a significant increase in facilitation scores across the group for all contrasts (Ordinal Regression $p < .001$). Results for the semantic-phonological therapy task (see Figure 8) showed a similar pattern. Significant increases in facilitation score were seen for all contrasts (Ordinal Regression: initial place, initial voice & final place $p = <.002$; final voice $p<.025$). Thus there is evidence that the need for listening support reduced during both therapy programmes, so the fourth hypothesis is supported.

Insert Figures 7 and 8 about here

The final hypothesis stated that therapy would benefit an everyday listening task: listening to telephone messages. Data from the telephone message task were analysed with a one factor ANOVA, the factor being time with 5 levels. This produced a significant main effect ($F (4, 28) = 2.874$, $p <.05$). Planned comparisons showed that the two post therapy scores (4 & 5) were significantly higher than the two pre therapy scores (1 & 2) ($F (4, 28) = 3.26$, $p <.05$). There was no difference between the two baseline scores (1 vs 2). Individual gain scores on the task following each programme of therapy are reported in Figure 9. Despite the significant group effect there were no significant individual gains on this task.

Discussion

This study aimed to evaluate two treatment programmes for word sound deafness. Both programmes involved systematic and hierarchical word discrimination tasks. In the semantic-phonological therapy, phonological judgements were supported by a meaningful context. In the phonological therapy this was less available.

The first study hypothesis stated that therapy would improve speech discrimination. This hypothesis was not supported. Tests of word and nonword discrimination showed no change across the group, and no individual showed a clear pattern of improvement. There was also no interaction between time and noise condition. We therefore had to conclude that therapy was not successful in remediating the participants' impairments in auditory analysis in either ideal quiet or non-ideal noise conditions. This null result requires consideration, particularly in the light of the positive single cases reported elsewhere (e.g. Morris et al., 1996; Grayson et al., 1997).

Some reasons for the negative outcome may relate to the content and delivery of therapy. In the context of production therapies, there has been discussion about the optimal number of words to include (Snell, Sage & Lambon Ralph, 2010). A very large number of words were treated in this study, in the hope that this would maintain interest and bring about generalised gains. It is possible that a smaller therapy set, tackling fewer contrasts, would have induced more change, as reported by Tessier et al (2007) and in a subsequent case study by Woolf and Caute (in preparation). However, there are contra-indications for this proposal. For example, Morris and colleagues (1996) used a large number of items per task (ranging from 33 to 50). The therapy stimuli used in this study were also confined to real words. This is different from previous studies, which included non words in treatment (Morris et al, 1996). Employing non words in the phonological therapy might have increased participants' focus on phonemic contrasts, because of the absence of lexical cues, and further differentiated the treatment from the semantic-phonological therapy. Conversely, we made the clinical judgement that non word tasks might be confusing and demotivating for participants.

The modest therapy dose used in our study (12 sessions over 6 weeks) may have been another limiting factor, given that high dosage is associated with positive outcomes in aphasia therapy (Bhogal, Teasell & Speechley, 2003). However, previous studies have achieved change from low dose regimes (Morris et al, 1996; Hessler & Stadie, 2008). Tessier et al (2007) employed an errorless approach to therapy, which may have contributed to the positive outcome. However, other successful programmes have not taken this approach (e.g. Grayson et al, 1997; Morris et al 1996); and although benefits have been demonstrated from errorless therapy in aphasia gains are equal to errorful approaches (Fillingham, Sage & Lambon Ralph, 2005; 2006).

Candidacy is a further consideration. All participants in this study demonstrated general symptoms of aphasia. None therefore had pure word sound deafness, and at least one (AA) showed signs of a central semantic deficit in addition to auditory processing difficulties. The sample may, therefore, have included individuals who were poor candidates for the treatment. Previous successful evaluations of discrimination treatments included participants with varying presentations, so do not provide clear prognostic markers. Two individuals had selective impairments in auditory processing (Hessler and Stadie, 2008; Tessier et al, 2007) but two did not (Grayson et al, 1997; Morris et al, 1996). For example, JS, who was treated by Morris et al (1996), had impaired written word comprehension, (scoring 68% on Written Synonym Judgement) and made errors on the Pyramids and Palm Trees test. He therefore had a similar test profile to AA, yet responded well to discrimination therapy. Unfortunately, the results of this study do not further illuminate the question of candidacy. For example, there is no indication that those with central semantic problems (AA and possibly HH) achieved worse outcomes than those with comprehension difficulties that were confined to the auditory channel.

Another factor may be hearing loss; i.e. our 40 db screen permitted mild detriments of hearing (see Table 2) and these may have been sufficient to sabotage a therapy that depends on fine phonological discriminations. Applying more stringent recruitment criteria might improve outcomes. However, even if this was the case, there is the concern that such ideal candidates would be difficult to find for a group study, and not reflective of a typical clinical case load. It is also worth noting that the individual who was successfully treated by Tessier et al (2007) had mild hearing loss (-40db). Other factors that might have affected outcomes include age, time post-onset, and severity of the auditory processing deficit. A larger group study may shed light on these and other issues of candidacy.

The lack of change may also have been due to the measures used in the study. Tests of auditory input require selection responses, so are susceptible to chance effects. In the context of therapy evaluation, this may limit the opportunity for significant gain, particularly if baseline performance is high. However, tables 5 and 6 demonstrate that participants' baseline scores allowed a clear margin for improvement. The outcome measures used in the study involved computer delivery. This ensured that conditions were identical across test occasions. It also eliminated researcher bias or the introduction of unintentional cues during testing. On the down side, computer testing is remote from normal listening conditions, so may mask therapy gains. Follow up testing with each participant compared performance on 64 word-discrimination test items presented live (without lipreading) and by computer. This revealed a significant advantage for live testing (live testing mean = 55, range 39-64, SD 7.4; computer testing mean = 50, range 40-55, SD 5.6; $p<.05$). However, interpreting this finding is difficult. It may show that live testing better enables participants to reveal their skills, or it may indicate that such testing is subject to the lack of rigour outlined above. Further studies might revisit this question, e.g. by testing in both live and computer conditions. Morris et al (1996) followed a similar approach by administering outcome measures with both taped and live stimuli (they also compared conditions that did and did not allow lip-reading). Encouragingly, significant discrimination gains were observed in all administrations.

The second hypothesis stated that therapy would develop semantic bootstrapping skills, or enable participants to exploit semantic information when attempting to discriminate speech. The semantic-phonological therapy particularly aimed to develop such skills. This hypothesis would be supported by improved performance on input tasks that provide a semantic context. Three such tasks were administered. One, picture word verification, showed improvement over time. This may point to the better use of the semantic information in pictures to support speech discrimination. However the remaining tasks, synonym judgement and priming, did not improve. The individual analyses also revealed very few gains, and offered no evidence that the tasks particularly profited from the semantic phonological therapy. Thus the results offer minimal support for the second hypothesis.

Many of the factors already discussed may account for this second disappointing finding, and particularly the issue of candidacy. The application of semantic bootstrapping presupposes that semantic information is available. Some of our participants (AA and HH) showed evidence of semantic impairments in addition to their phoneme discrimination impairments, and most were impaired to some extent on written synonym judgement. Therefore the prognosis for improvement on semantic tasks may have been poor. Indeed it may be relevant that the one task that did improve (picture word verification) engaged relatively shallow semantic processing, given that the distractors in the task were phonologically, rather than semantically related to the target. This task was also distinctive in that it offered a pictorial, rather than verbal semantic context, which may have facilitated some participants. Again, people with pure word deafness may be better candidates for the semantic phonological therapy. Alternatively, therapy may need to place an even stronger emphasis on meaning, e.g. by reducing the auditory discrimination component and increasing the focus on the semantic connections between words.

The third therapy hypothesis stated that therapy might particularly improve the discrimination of treated words. Such a gain was anticipated because treated words could benefit from two potential mechanisms of change: an item specific priming effect and a general improvement in phonemic discrimination. This hypothesis was explored by the priming task, which included both treated and untreated words. Disappointingly, this task showed no benefit for treated words, and no interaction between time and treatment. Thus even an item specific gain was not observed. It is possible that more focussed practice on a smaller treatment set may have engendered different results, by strengthening the level of exposure to treated words.

The fourth therapy hypothesis stated that therapy would reduce need for listening support and enable participants to make better use of acoustic and visual cues to phoneme identity. This was supported by evidence of a reduced need for facilitation during therapy. Examination of the data shows that in the early stages of phonological therapy, mean facilitation scores across all contrast types ranged from 3.8 to 4 (out of a potential range of 0 - 6). When the same contrasts were targeted in later sessions, the scores ranged from 4.2 to 4.3. In the early stages of semantic phonological therapy, mean scores ranged from 4.4 to 4.6, while in the later stages they ranged from 4.6 to 4.9. Although the gains in mean facilitation scores were modest, they were nevertheless functionally meaningful. So, at the start of phonological therapy participants often needed both to lip-read and to hear the target repeated before responding correctly. By the final session correct responses were usually achieved without requiring repetition. In the semantic therapy, where the tasks provided a meaningful context to support discrimination, participants initially required lip-reading but later in therapy were sometimes able to respond correctly when the therapist covered her mouth. It is interesting that even after therapy participants still relied much of the time on lip information to support the interpretation of speech, particularly in the absence of semantic cues. This underscores their continuing disadvantage with the computerised experimental tests where no mouth information or repetition was available.

While encouraging, the facilitation data are far from conclusive. Other factors, such as practice effects on tasks, may have reduced the need for facilitation during therapy. There is also no evidence that participants' listening behaviours changed outside the therapy context, although there were encouraging anecdotal comments from some individuals:

> *'Definitely better … when I see you I can understand you. When [name of friend] comes she looks at me and I look at her mouth'* (SL)

The final hypothesis stated that therapy might improve performance on an everyday communication task: listening to telephone messages. Here the group analysis showed a main effect of time, with post therapy scores being higher than pre therapy scores. However, individual scores were unimpressive, since neither programme of therapy consistently improved participants' performance on the measure.

In summary, across all results there is little evidence that the therapies used in this study improved the auditory discrimination or auditory comprehension of the participants. In the group analyses, only two of the six experimental measures showed a significant gain over time, giving rise to concerns about type one errors. Indeed the levels of significance ($p<.05$) would not survive correction for multiple comparisons. The individual analyses also failed to show a consistent pattern of gains. Two individuals improved on none of the measures (JC & JP), four participants improved on only one (HH, WS, JY, & AA) and SL improved on two. JG had the highest tally with three significant gains. However, even this was moderate given that six measures were assessed across two programmes of therapy. The individual analyses also produced no evidence that one therapy was more effective than the other, with five individual gains arising from phonological therapy and four from semantic phonological therapy.

Further evaluations of discrimination therapy for word sound deafness are merited, e.g. using more stringent recruitment criteria, different or more personally tailored tasks, or a smaller set of therapy stimuli. Changes in outcome measures may also be called for, e.g. to include both live and computer delivery. Given the repetitive nature of the tasks, it would also be interesting to explore the use of technology to raise the treatment dose. Indeed there is some evidence that computer delivered therapy can achieve gains in auditory comprehension, although not specifically with participants who have word sound deafness (Archibald, Orange & Jamieson, 2009). Testing treatments with a larger group of participants would also permit the investigation of candidacy, by exploring the relationship between baseline factors and treatment gains. Our results suggest that achieving gains in auditory discrimination is challenging. While this may be possible for some individuals, others may need alternative approaches, such as the training of communication partners. Investigating these alternatives is also a priority.

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Table 1: Participant details and screening test results (% correct)[4]

ID	Age	Gender	Time Post Stroke (months)	Nonword Maximal Pairs (N=20)	Nonword Minimal Pairs (N= 64)	Spoken Synonym Judgement (N = 60)	Written Synonym Judgement (N = 60)	Written Word to Picture Matching (N = 40)	Pyramids & Palm Trees (N = 52)	BORB Object Decision Test (N = 32)
HH	59	F	68	**78***	**58**	**50**	67	90	**87**	94
JC	71	M	8	100	**66**	**67**	82	95	98	97
SL	76	F	24	**75**	**59**	**55**	88	93	96	94
WS	45	F	48	100	**73**	**78**	95	100	98	97
JY	74	F	7	**79***	**59**	**75**	92	98	100	100
JP	59	M	44	**95**	**75**	**58**	100	100	100	97
AA	81	F	18	**75**	**61**	**72**	70	93	**77**	87
JG	44	M	10	100	**73**	**57**	87	100	96	100

*Scores for HH and JY were derived from a 32 item test

[4] Scores in **bold** are outside the range of unimpaired controls; note that normative data is not available for the Written Synonym Judgement task

Table 2: Participant hearing levels in dB screened with pure tone audiometry

ID	Left			mean	Right			Mean
	1kHz	2kHz	4kHz	mean	1kHz	2kHz	4kHz	Mean
HH	20	30	20	23	25	35	50	37
JC	20	15	45	27	10	10	30	17
SL	10	10	10	10	15	5	10	10
WS	10	5	5	7	0	5	5	3
JY	25	20	10	18	30	35	30	32
JP	-5	10	25	10	-5	15	20	10
AA	25	35	45	35	15	30	35	27
JG	5	15	20	13	15	10	20	15

Table 3. Facilitation levels used in therapy

Facilitation Level		**Phonological Therapy**	**Semantic Therapy**
Minimal support	6	Background noise	Background noise
	5	Mouth covered	Mouth covered
	4	Free voice	Free voice
	3	Repetition	Repetition
	2	Exaggeration of mouth shapes and articulatory features	Verbal semantic cue (Additional meaning about the word)
Maximal support	1	Use of articulograms (Pictures of mouth shapes and voicing)	Non-verbal semantic cue (Gesture and drawing)
	0	Written cue	Written cue

Table 4: Example items from the three conditions of the priming task

	Condition		
	Primed	**Misprimed**	**Neutral**
Written prime	Needle	Rubbish	XXXX
Spoken stimulus word	"pin"		
Written word choice	bin tin pin		

Table 5: Mean number correct (SD) at each test point on 5 experimental measures

	Time 1 (baseline1)		Time 2 (baseline2)		Time 3 (post therapy 1)		Time 4 (post therapy 2)		Time 5 (maintenance)	
	quiet	noise	quiet	Noise	Quiet	noise	quiet	noise	quiet	noise
Non word discrimination N = 64	45.37 (6.12)	38.37 (6.91)	47.62 (6.52)	38.37 (4.53)	49.50 (5.34)	40.50 (5.34)	49.25 (7.40)	40.5 (5.07)	48.12 (4.91)	40.75 (4.89)
Word discrimination N = 64	48.12 (6.62)	41.12 (8.90)	49.37 (6.34)	44.75 (6.61)	51.12 (6.71)	44.87 (5.03)	51.12 (4.15)	45.75 (6.18)	49.50 (6.87)	44.87 (7.72)
Picture word verification N = 64	43.00 (9.10)	40.12 (7.79)	45.12 (8.29)	39.87 (6.94)	45.87 (9.33)	41.87 (8.63)	47.25 (8.01)	43.00 (8.86)	45.25 (9.13)	42.25 (7.92)
Synonym Judgement N = 60	40.00 (7.69)	N/A	41.87 (8.79)	N/A	40.5 (7.23)	N/A	44.25 (8.51)	N/A	42.87 (10.02)	N/A
Telephone Message Task N = 20	13.75 (4.37)	N/A	12.75 (2.37)	N/A	14.9 (3.97)	N/A	15.00 (3.29)	N/A	15.12 (3.31)	N/A

Table 6: Mean number correct (SD) on the priming task pre and post each episode of therapy

Phonological discrimination therapy			
	Pre Therapy	Post Therapy	Follow Up
Treated Items (N = 120)	91.75 (16.84)	92.62 (19.26)	97.12 (18.83)
Untreated Items (N = 120)	90.62 (17.99)	90.12 (20.75)	91.25 (19.93)
Semantic-phonological therapy			
	Pre Therapy	Post Therapy	Follow Up
Treated Items (N = 120)	92.37 (16.77)	94.12 (17.22)	92.37 (20.86)
Untreated Items (N = 120)	91.12 (14.86)	88.87 (20.06)	86.87 (20.86)

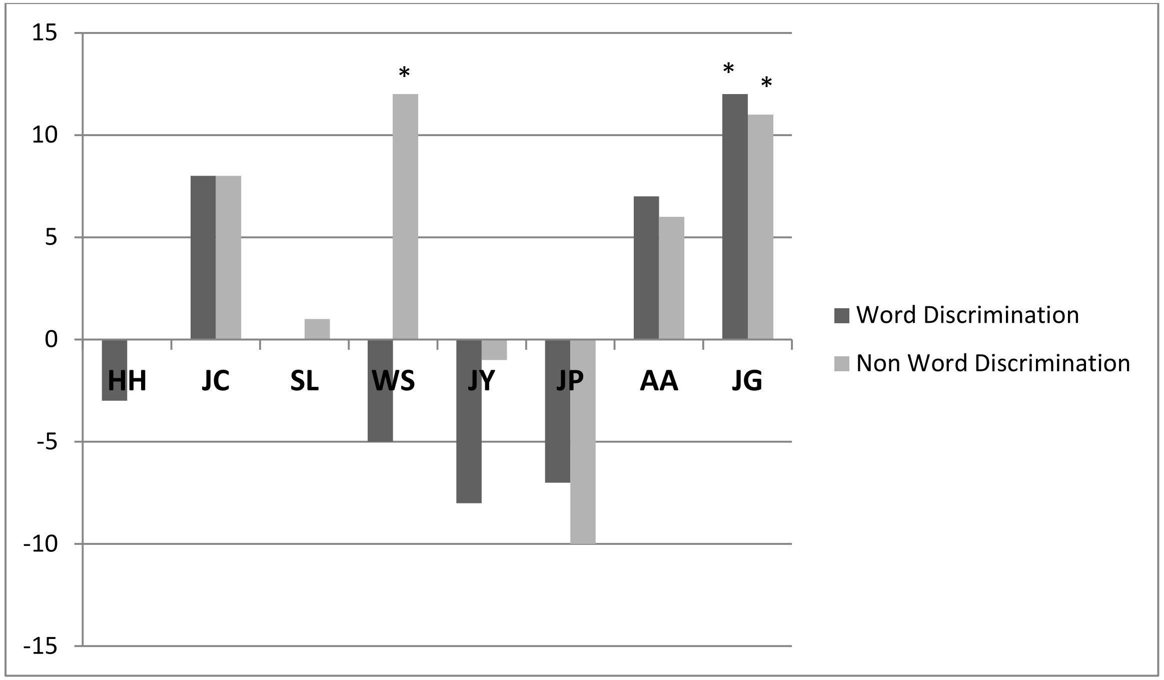


Figure 1: Discrimination Gain Scores arising from Phonological Therapy (*p<0.05)

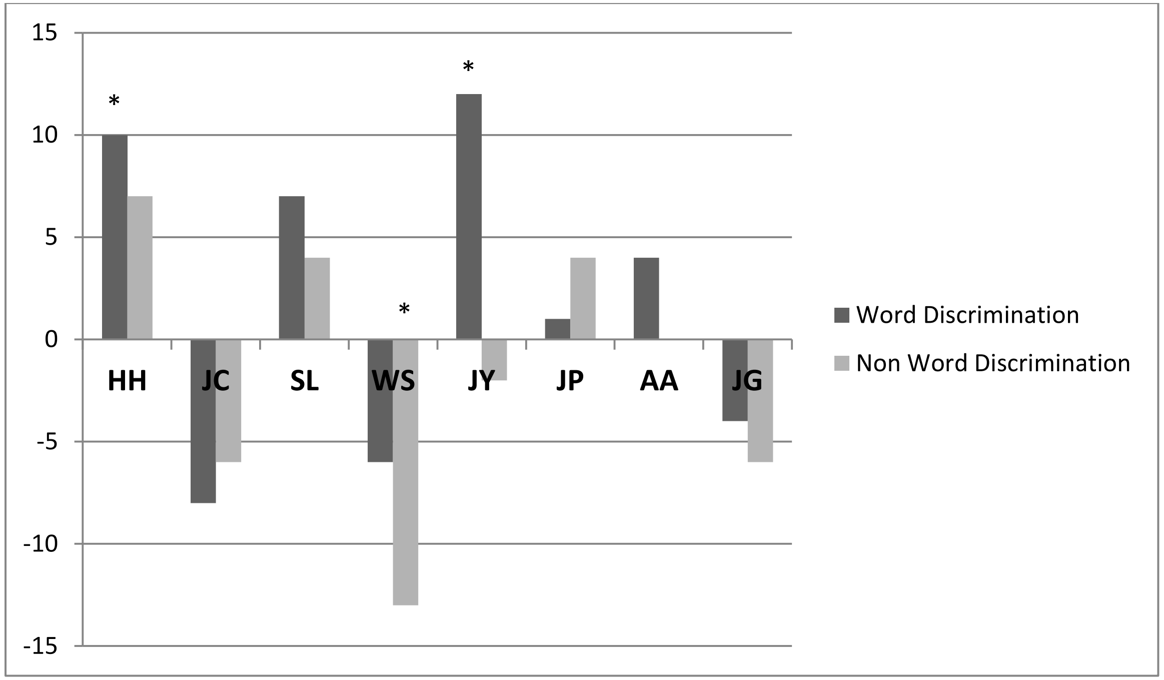


Figure 2: Discrimination Gain Scores arising from Semantic-Phonological Therapy (*p<0.05)

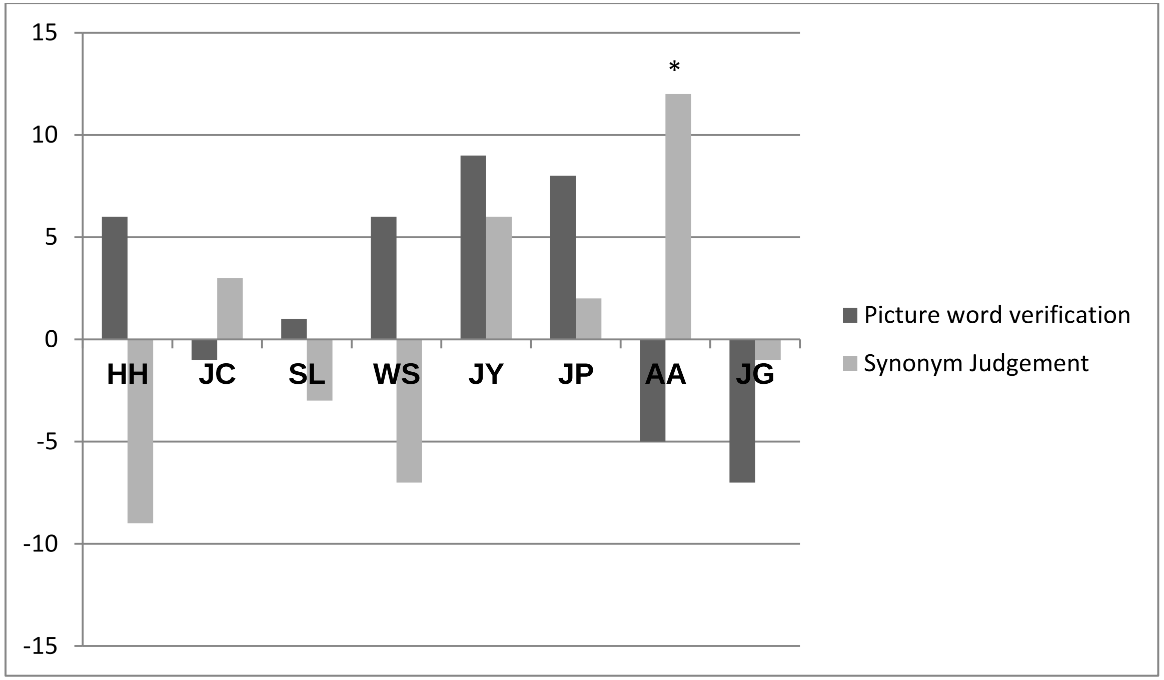


Figure 3: Gain Scores on Semantic Tasks arising from Phonological Therapy (*p<0.05)

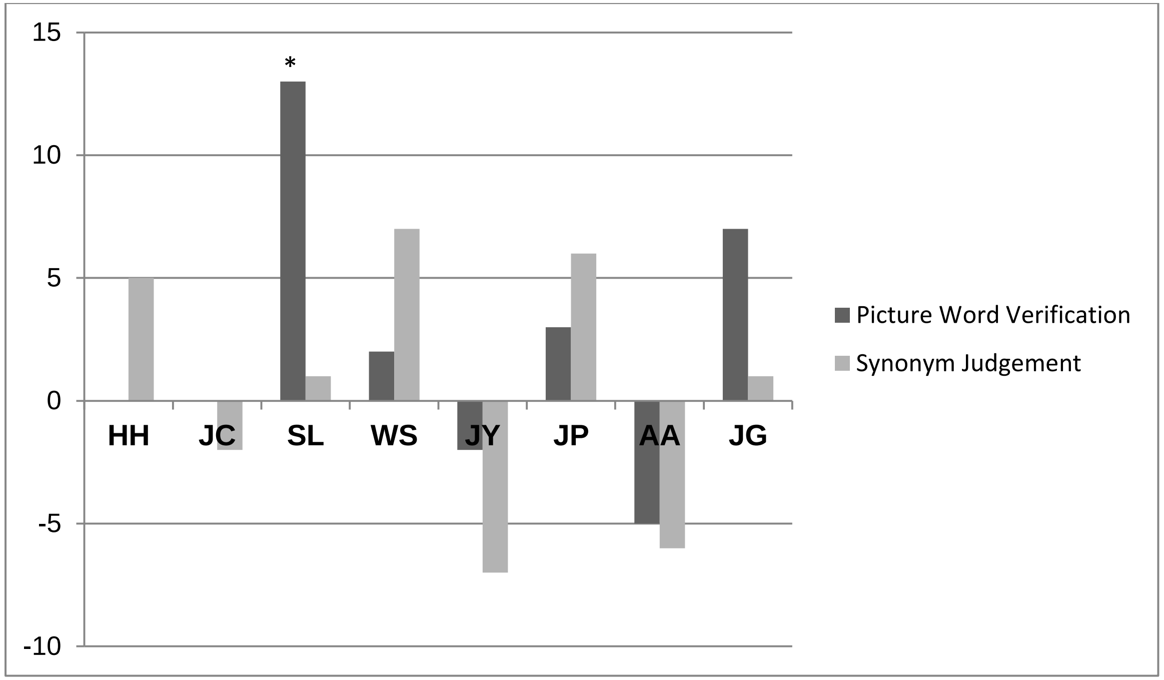
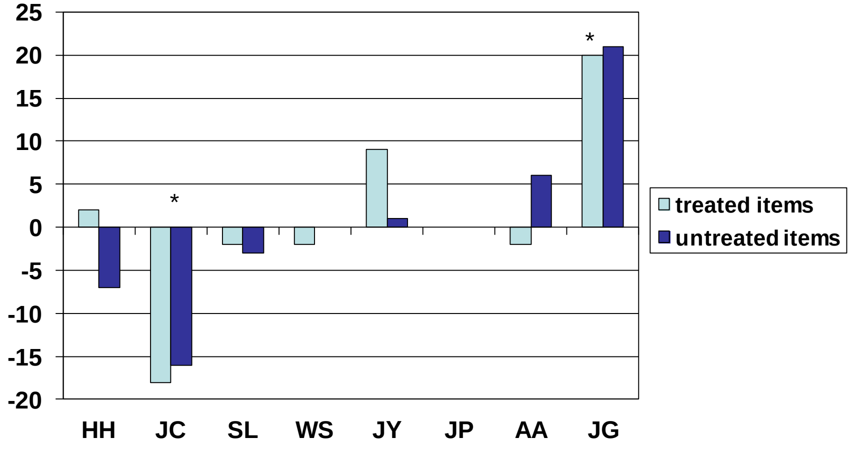
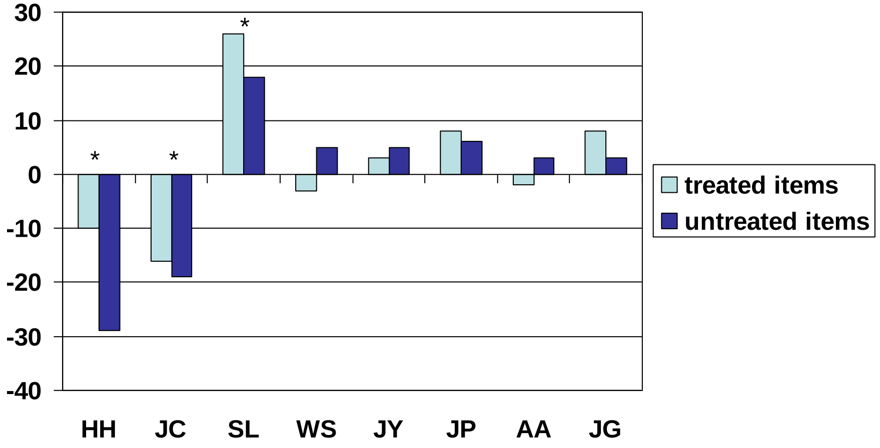


Figure 4: Gain Scores on Semantic Tasks arising from Semantic-Phonological Therapy (*p<0.05)



*McNemar Chi Square p<0.05

Figure 5: Gain Scores on the Priming Task arising from Phonological Therapy



*McNemar Chi Square p<0.05

Figure 6 Gain scores on the priming task arising from the semantic-phonological therapy

Figure 7: Changes in facilitation scores during phonological therapy over the four sampled sessions

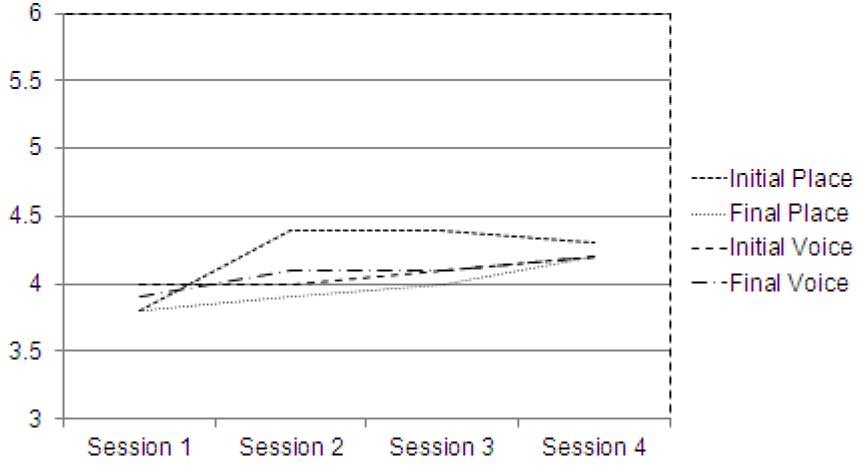
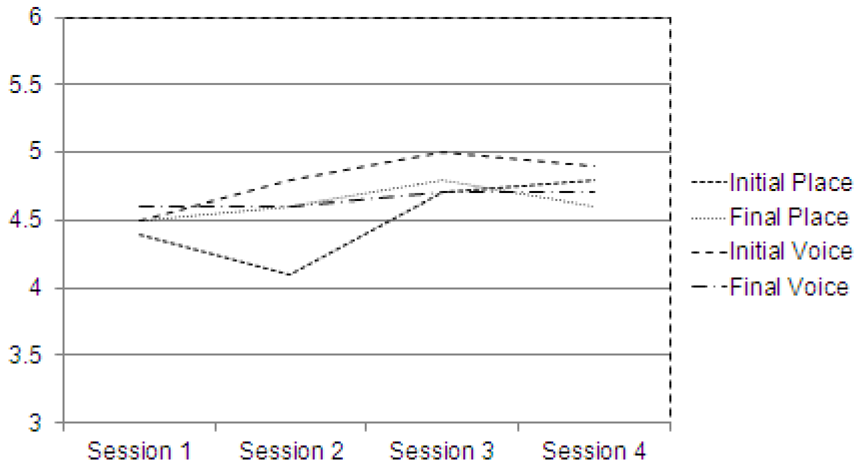


Figure 8: Changes in facilitation scores during semantic-phonological therapy over the four sampled sessions



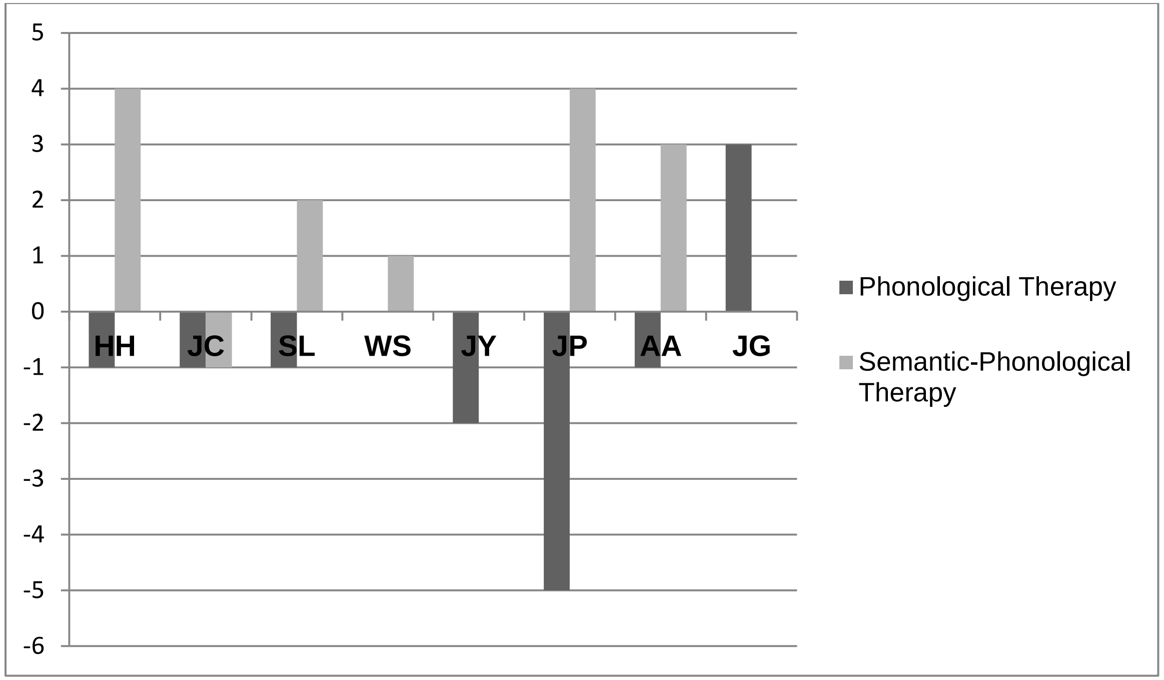


Figure 9: Gain scores on the Telephone Message Task arising from Phonological and Semantic-Phonological Therapy

Appendix 1: Examples of Therapy Tasks

Task	**Phonological Discrimination Therapy**	**Semantic-phonological Therapy**
MATCHING TASKS	*Spoken word to written word matching* The participant sees 3 phonologically related written words and hears them read aloud (e.g. *pan, tan, can*). A single word is then spoken aloud, and the participant is asked to point to the matching written word.	*Spoken word to picture matching* The participant sees 3 pictures and hears them named and semantically cued (e.g 'a statue of a head' *bust*, 'a blast of wind' *gust*). A single word is then spoken aloud, and the participant is asked to point to the matching picture.
DISCRIMINATION TASKS	*Minimal pair discrimination* The participant hears 2 words and has to identify if they sound exactly the same or different. The two words differ by one phonetic contrast (e.g. *pan – pan, pan - tan*).	*Minimal pair discrimination within a sentence* The participant hears a sentence and is asked to judge whether it makes sense or not. The sentence will either finish with an appropriate word, or an inappropriate minimal pair alternative (e.g. *The barmaid worked in the pub; The barmaid worked in the cub*).
CATEGORISATION TASKS	*Phonological Categorisation* The participant is shown 2 types of phonetic category (e.g. 'p' sounds made with the lips, 't' sounds made with the tongue behind the front teeth). They then hear a word, and are asked to assign it to a category (e.g. *Listen at the beginning, is this a p or a t sound…pan*). Stimuli comprise minimal pairs (e.g. bell and dell, big and dig, bun and dun)	*Semantic Categorisation* The participant is shown semantic category label (e.g. animals). They then hear a word, and are asked to indicate if it belongs to that category (e.g *cub*). Stimuli comprise minimal pairs (e.g *cub* and *pub*, *pear* and *bear*). If the word does not fit within the semantic category the participant points to a picture of a bin to indicate it should be discarded.

SENTENCE COMPLETION TASKS	*Phonological Sentence Completion* The participant sees 3 written words and hears them read aloud (e.g. *potts, totts, cotts*). They then hear a sentence, and are asked to point to the final word in the sentence. The sentence offers no semantic clue to the target as all three available words could provide a meaningful sentence completion (e.g. *The garden centre was owned by Mr Cotts*).	*Semantic Sentence Completion* The participant sees 3 pictures and hears them named (e.g. *pick, tick, kick)*. They then hear a sentence, and are asked to point to the picture that matches the final word in the sentence. The sentence offers a semantic clue to the target (e.g. *The footballer gave the ball a kick*).