

**Phonological output impairments in aphasia: different subgroups
requiring different therapies?**

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Abstract

Background: One of the few studies to describe therapy for phonological assembly difficulties in aphasia is a single case by Franklin, Buerk and Howard (2002). Their client improved significantly in picture naming for treated and untreated words after therapy targeting auditory awareness and self-monitoring.

Aims: This thesis comprises two studies. Study one aimed to determine whether the generalised improvements reported by Franklin et al (2002) are replicable with other people with impaired phonological assembly, and to explore any differences in outcome. Study two aimed to compare the effectiveness of Franklin et al's therapy with a production-focussed approach. The overall aim of both studies was to discover whether different subgroups of people with phonological assembly difficulties may respond differently to therapy, and whether any differences in treatment outcome may provide insight into theoretical models of phonological output processing.

Method: A case series of eight participants with aphasia with mixed impairments including phonological assembly difficulties is reported. In study one, four participants received a replication of the treatment described by Franklin et al. In study two, four further participants received a novel production therapy in addition to Franklin et al's therapy.

Outcomes: No participant responded in the same way as Franklin et al's original client. All post-therapy naming improvements were item-specific, except for one participant, who also showed signs of spontaneous recovery. Two participants showed no significant naming improvements after either treatment.

Conclusions: Whereas Franklin et al's original client had a relatively pure post-lexical phonological assembly impairment, six of the eight participants in the current study had phonological assembly difficulties combined with either lexical retrieval or motor speech impairments. The item-specific naming gains were proposed to reflect improved mapping between semantics and lexical phonology, rather than improved phonological assembly. These results support a model of speech production containing both lexical and post-lexical levels of phonological processing.

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Chapter 1 Introduction

1.0 Aims of chapter

In aphasia, one group of people typically presents with spoken output that is characterised by the production of phonological errors, i.e. phoneme substitutions, additions, omissions or transpositions. Within a classical paradigm (Goodglass and Kaplan, 1972; Kertesz, 1982), people presenting with this profile have frequently been diagnosed with conduction aphasia, a syndrome characterised by fluent output with good comprehension and poor repetition. In recent years, however, the limitations of such broad classification systems have been recognised, mainly due to variability within groups (Caramazza and Coltheart, 2006; Hillis, 2007; Marshall, 2010) with conduction aphasia being particularly heterogeneous as a diagnostic category (Nickels, 1997; Ouden and Bastiaanse, 2005). The emergence of cognitive neuropsychology in the 1970's and 1980's (e.g. Marshall and Newcombe, 1973; Coltheart, Patterson and Marshall, 1980) signalled a move towards diagnosis in aphasia in terms of the underlying processes impaired in a given individual, using psycholinguistic models of normal speech production (Nickels and Howard 2000; Whitworth, Webster and Howard, 2005). These so-called "box and arrow" models have been criticised, however, for being underspecified regarding the processes involved. The recent development of connectionist, computational models, as well as a renewed interest in brain imaging studies, has led some to question the continued relevance of cognitive neuropsychology (Harley, 2004; Patterson and Plaut, 2009). Despite its limitations, the cognitive neuropsychological approach has nevertheless contributed substantially to the field of clinical aphasiology, by providing a framework for detailed examination of language functioning, and thereby aiding identification of targets for treatment (Laine and Martin, 2012; Whitworth, Webster and Howard, 2012). Cognitive neuropsychological models, therefore, offer a means by which to understand the linguistic deficits that can give rise to the production of phonological errors by people with aphasia, as well as a basis for treating this impairment.

This chapter begins by describing two models of spoken word production and discussing the key differences between them, before moving onto theoretical accounts of motor speech processing, speech monitoring and the links between speech comprehension and production, thereby providing the theoretical grounding for the thesis. Approaches to the treatment of phonological output impairments in aphasia will then be discussed, as well as the question of when generalisation to untreated words may be predicted, concluding with an exploration of the use of treatment studies to

evaluate cognitive neuropsychological theory. The thesis aims will be outlined at the end of the chapter.

1.1 Models of spoken word production

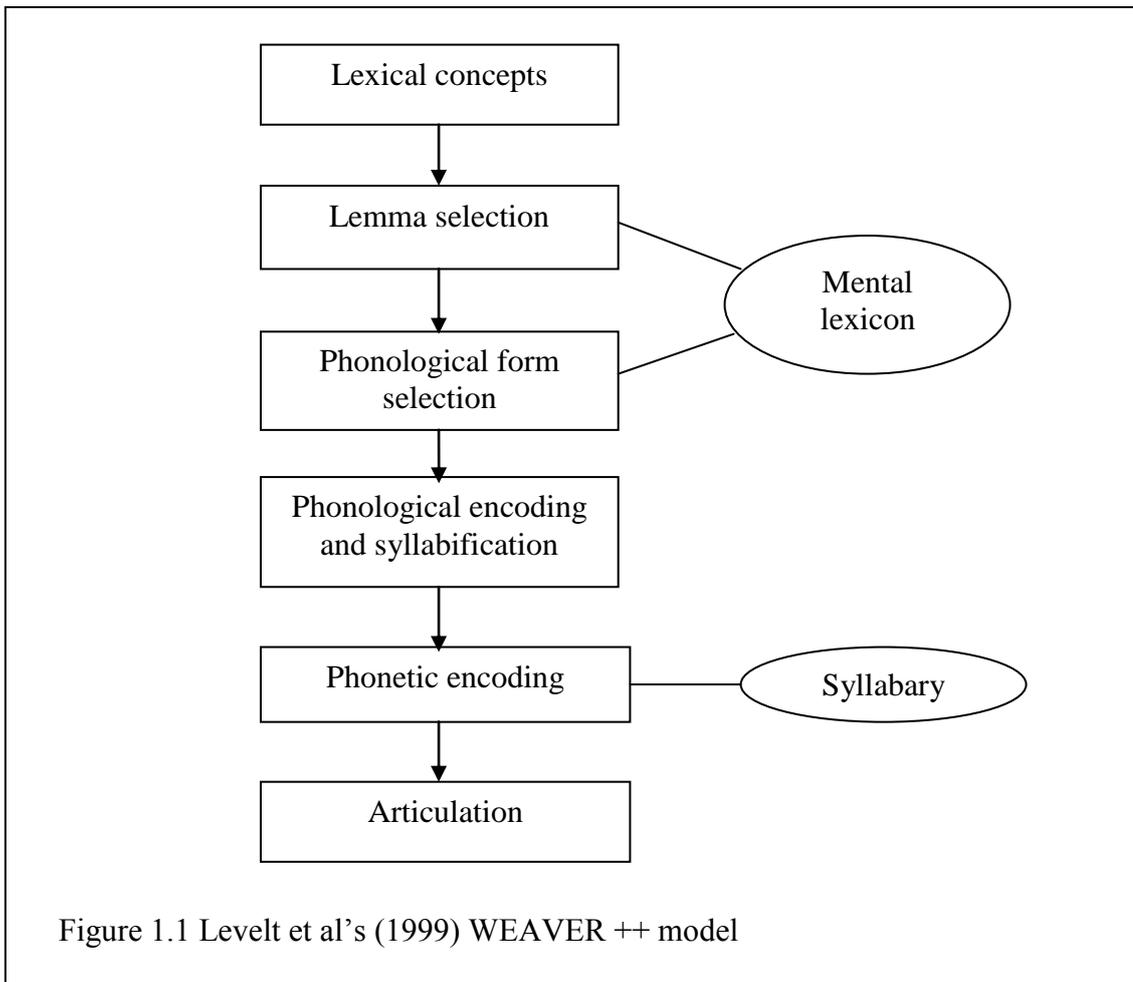
Within the cognitive neuropsychological paradigm, different models of spoken word production have been proposed, including those where deficits in either spoken naming (Lambon Ralph, Moriarty and Sage, 2002) or reading aloud (Plaut, 1997) are explained only in terms of impaired semantics, phonology or orthography. These models have been criticised, however, for being unable to explain how lexical decision is performed, due to the absence of a lexical level of representation (Coltheart, 2006; Bormann and Weiller, 2012). Perhaps the two most widely discussed models of spoken word production are those of Levelt, Roelofs, and Meyer (1999) and Dell, Schwartz, Martin, Saffran, and Gagnon (1997).

1.1.1 Levelt, Roelofs and Meyer's model

The WEAVER++ model proposed by Levelt, Roelofs, and Meyer (1999) is outlined in figure 1.1. In this model, Levelt et al (1999) suggested that when a spoken word is produced, a lexical concept, or semantic representation, must first be activated, which then triggers the retrieval of an abstract lemma (containing grammatical information) from the mental lexicon. Next, the word's phonological form is retrieved from the mental lexicon, containing information about the word's metrical structure and segmental properties. Following lexical retrieval, in the process of phonological encoding, segmental information is first inserted into the metrical frame, and the word is then divided into syllables according to context. This process has also been called phonological assembly¹ (e.g. Whitworth et al, 2005). After this, a process of phonetic encoding takes place, where the phonetic gestures for common syllables are retrieved from the mental syllabary, before articulation of the word. Levelt et al's (1999) model has been criticised, however, because the unidirectional feed-forward activation means that certain evidence from people with aphasia cannot be explained (Goldrick and Rapp, 2002). For example, Hillis and Caramazza (1995) demonstrated that the oral reading of three people with aphasia was facilitated by the provision of sub-lexical phonological

¹ The terms phonological encoding and phonological assembly will be used interchangeably in this thesis

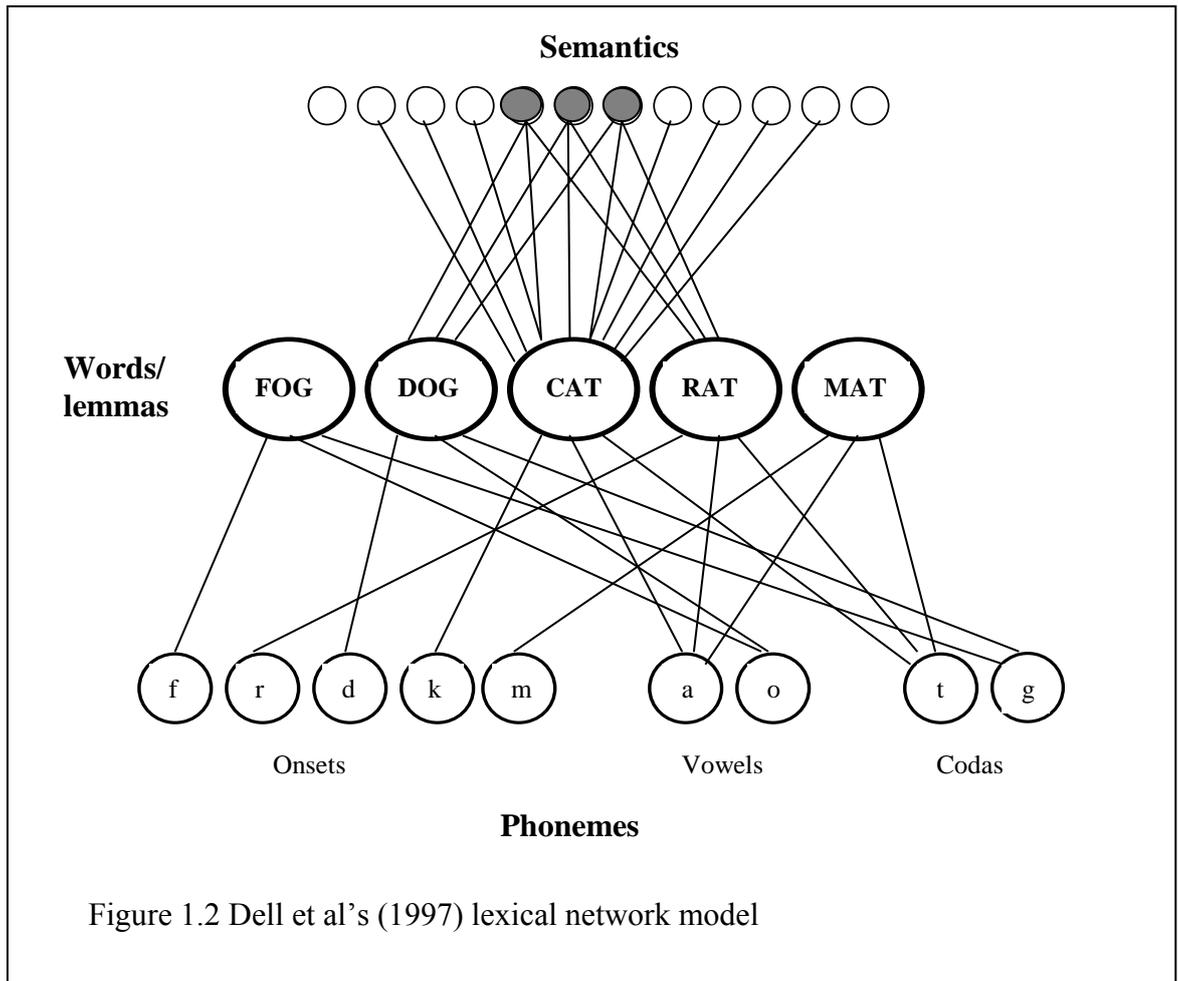
information, suggesting that there is feedback from the phonological encoding level to the phonological lexical level.



1.1.2 Dell, Schwartz, Martin, Saffran, and Gagnon's model

The interactive activation model of Dell et al (1997) (see figure 1.2) shares some features with that of Levelt et al (1999), in that activation of a semantic representation is followed by two stages of lexical access, the word (or lemma) level and the phonological level but, in contrast with Levelt et al's model, there is bidirectional interaction between levels, such that the lemma receiving most activation from both the semantic level above and the phonological level below will be selected. Subsequently, activation continues to spread both up and down from the lemma level, before the most highly activated phonemes are selected. Dell et al (1997) argued that the influence of phonology on lemma selection explains why speakers with aphasia can produce real word errors that are both semantically and phonologically related to the target, as well as explaining why phonological errors may be real words more often than would be predicted by chance (the lexical bias effect). Using this model, the speech production

errors of people with aphasia have been attributed to impairments in either connection weight or decay rates (Dell et al 1997) or in semantic or phonological weights (Foygel and Dell, 2000). A weakness of this model, however, is that it does not explain performance on repetition, reading aloud, production of non-words or multi syllabic words, although a supplementary non-lexical route between phonological input and output, proposed by Dell, Martin and Schwartz (2007), could be used for word and non-word repetition.



1.1.3 One or two sources of phonological errors?

Data from people with aphasia has provided a rich testing ground for exploring the two contrasting speech production models of Levelt et al (1999) and Dell et al (1997), particularly regarding their explanation of the production of phonological errors. Within Levelt et al's (1999) framework, there are two possible levels at which a breakdown could lead to the production of phonological errors in aphasia; retrieval of the word's phonological representation from the lexicon, or at the post-lexical phonological

encoding stage. Using this model, people with aphasia whose phonological errors are due to lexical retrieval difficulties are likely to show an effect of word frequency on naming (Jescheniak and Levelt, 1994) and naming may be more impaired than other spoken output tasks, such as repetition and reading, because of the greater lexical involvement (Olsen, Romani and Halloran, 2007; Sampson and Faroqi Shah, 2011). In contrast, people with aphasia whose phonological errors are caused by a post-lexical phonological encoding deficit typically show a word length effect, with shorter words more likely to be produced correctly than longer words (Caplan, Vanier and Baker, 1986; Pate, Saffran and Martin, 1987) and may experience a similar level of difficulty in all modalities of naming, reading aloud and repetition, as well as in production of non-words, due to phonological encoding being regarded as common to all spoken output tasks (Kohn, 1984, 1989). In addition, phonological errors caused by post-lexical encoding impairments are considered to be more closely related to the target than those arising from lexical retrieval impairments, because the correct phonological information has been retrieved, but an error has occurred in the process of assembling the information (Buckingham, 1992). Furthermore, Kohn and Smith (1995) argued that phonological errors of a post-lexical origin were more likely than lexical errors to show a serial position effect (decreasing accuracy towards the end of the word) because phonological encoding is a sequential process. It has also been argued that people with post-lexical phonological encoding impairments are able to access phonological information for words they cannot say aloud (Feinberg, Gonzalez Rothi and Heilman, 1986), indicating that phonological lexical retrieval is intact.

In contrast, Dell et al's (1997) model does not include a post-lexical phonological encoding stage. Instead, the lexical phonological layer is thought to contain fully ordered phonological representations, such that there is no additional stage where phonemes are sequenced (Wilshire, 2002). Dell et al's model, therefore, predicts that phonological errors produced by people with aphasia have only one possible source, an error in selection of phonemes at the phonological lexical level. Any differences in proximity of phonological errors to the target are attributed to severity of impairment.

Schwartz, Wilshire, Gagnon and Polansky (2004) examined the naming errors produced by 18 people with aphasia, hypothesising that if a difference between lexical and post-lexical errors existed then the latter should be more closely related to the target. No clear distinction between phonologically similar and distant errors was, however, found.

An artificial division of errors into proximate and remote categories was created, therefore, with errors containing 50% or more of the target's phonemes in the former and those containing less than 50% in the latter. Following examination of serial position, length and frequency effects, Schwartz et al found either no difference between the two groups of errors, or a difference in the opposite direction to that which they predicted. They argued that their results support a model such as that of Dell et al (1997) where there is only one possible source of phonological errors. A number of weaknesses may, however, be seen in this study. Schwartz et al examined only those naming errors classified as phonologically related to the target (target and response shared at least one phoneme in the same position or two phonemes in any position, excluding schwa) as unrelated errors were thought to either bear no definite resemblance to the target or may have resembled a semantically related word. As unrelated jargon errors have been attributed to lexical retrieval failure (Marshall, Robson, Pring and Chiat, 1998), it could be argued that if these errors had been included, a clear difference in phonological relatedness may have emerged, thus revealing two possible origins. A second weakness of Schwartz et al's (2004) study can be seen in their method of analysing the errors of people with aphasia as a group, which failed to take into account individual profiles. Where the error profiles of individuals have been considered, results have supported more than one source of phonological errors (e.g. Goldrick and Rapp, 2007, Olsen, Romani, and Halloran, 2007). Laganaro and Zimmermann (2010) examined the phonological errors produced on naming and reading aloud by two participants with conduction aphasia, focussing on the properties of two error types; phoneme substitution errors (i.e. the replacement of a phoneme with one not found elsewhere in the word) and phoneme movement errors (i.e. the shifting of a phoneme elsewhere in the word; all target phonemes present but mis-ordered). Results showed that phoneme substitution errors were more likely to be real words and were more similar in features to the target than the movement errors, and a syllable frequency effect was more likely to be present. These differences were proposed to support a model where breakdown at different levels was responsible for the two error types, with substitution errors arising due to either damaged or mis-selected lexical information, or to mis-ordering at the phonological encoding stage, or a combination, and movement errors occurring solely due to damage in post-lexical phoneme assembly.

1.1.4 Specification of syllable structure

Another difference between the models of Levelt et al (1999) and Dell et al (1997) surrounds the level at which syllables are stored. In Dell et al's (1997) model, phonemes in the stored lexical word forms are said to be pre-specified for syllable positions (e.g. onset and coda; see figure 1.2). Therefore, in order to explain the phenomenon of resyllabification, where syllable boundaries within words can vary depending on the morphological context (Cholin 2008), several forms of each word would need to be stored for each possible syllable variation. In contrast, in Levelt et al's (1999) model, syllable structure is not specified at the level of stored phonological lexical representations. Instead, division of phonological words into syllables occurs as part of the post-lexical phonological encoding process, according to the phonological context in which the word is being produced. Phonetic representations for the most commonly used syllables are subsequently retrieved from the mental syllabary. The existence of such a syllable store has been supported by studies in healthy speakers, which have found an influence of syllable frequency on speed of word and non-word production (e.g. Levelt and Wheeldon, 1994; Laganaro and Alario, 2006). In addition, Laganaro and Alario (2006) reported that the syllable frequency effect was eliminated when speakers produced words after a delay, but not when the delay was filled with articulatory suppression (e.g. repetition of "ba ba"). Based on the hypothesis that articulatory suppression interferes with the phonetic level of processing, they proposed that these findings were compatible with Levelt et al's (1999) theory that syllables are stored and accessed at a phonetic processing level.

1.2 Motor speech processing

Phonological assembly difficulties in aphasia frequently co-occur with apraxia of speech (AOS), a motor planning disorder thought to involve a phonetic encoding deficit (Ziegler, 2002). Speakers with AOS who made phonetic distortions were excluded from Dell et al's (1997) model simulations, such that interpretation of AOS is not possible within Dell's framework. Further, in a recent simulation of an extended version of Dell et al's model by Abel, Huber and Dell (2009) non-fluent speakers with mild AOS were included but it was deemed that they could not be accurately diagnosed using this framework, due to the possibility of falsely classifying phonetic errors as phonological. Levelt et al's (1999) model of speech production, therefore, represents the best current

attempt to link the phonological and motor aspects of speech production, although it remains under-specified.

While there is agreement in the literature that the underlying impairment in AOS is primarily one of motor planning and therefore at a phonetic encoding level, the precise nature of the phonetic deficit is still unclear. Varley and Whiteside (2001) proposed a dual route theory in which people with AOS were thought to have difficulty in retrieving stored high frequency phonetic gestures and instead had to rely solely on the mechanism for assembling motor plans from scratch, normally only used for unfamiliar or low frequency words. This theory does not map easily onto Levelt et al's (1999) model, however, because the stored high frequency phonetic gestures in Varley and Whiteside's proposal were for whole words, not syllables (Varley, Whiteside, Windsor and Fisher, 2006). Indeed, syllable frequency effects have been reported in people with AOS (Aichert and Ziegler, 2004; Laganaro, 2008; Laganaro, Croisier, Bagou and Assal, 2012), a factor inconsistent with a deficit in accessing all stored phonetic representations from the mental syllabary (Cholin, 2008). Rather, Laganaro (2008) explained these findings as evidence of partial degradation to the syllabary, with the highest frequency syllables being more resistant to damage and therefore easier to access.

The stages involved in phonetic processing were elaborated by Van der Merwe (1997), who proposed that, following phonological encoding when phonemes are selected and ordered, there is a motor planning stage followed by a motor programming stage, followed by execution. At the motor planning stage, stored core motor plans must be retrieved, which specify the place and manner of articulation for each of the phonemes in the word. These core motor plans are then adapted based on the context, taking into account, for example, co-articulation with surrounding phonemes, in order to create motor goals. Motor programming then occurs, whereby these motor goals are converted into specific muscle commands for movement before the word is produced. AOS, using this model, can be considered an impairment of the motor planning stage, possibly due to an impaired ability to retrieve core motor plans, or to plan, adapt and synchronise consecutive movements.

The clinical task of differentially diagnosing between phonological assembly impairments and AOS can be a challenging one (McNeil, Doyle, and Wambaugh,

2000). Both are considered post-lexical impairments and therefore share many features, e.g. sound substitutions, repeated attempts at the target, difficulty producing phoneme sequences and a tendency to find shorter words easier to produce (Duffy, 2005). Certain distinguishing features of AOS, thought to reflect the specific deficit in motor planning, have been identified, however, including sound distortions, prolonged segment and intersegment durations as well as disturbed prosody (McNeil, Pratt and Fossett, 2004).

1.3 Monitoring

People with aphasia who make phonological errors often produce sequences of repeated attempts at the target, a feature that has been termed “conduite d’approche” (Joanette, Keller, and Lecours, 1980). These repeated attempts may not always result in the correct response (Gandour, Akamanon, Dechongkit, Khunadorn, and Boonklam, 1994), but they do frequently move closer to the target (Joanette, Keller, and Lecours, 1980; Lee, Yiu, and Stonham, 2000). Together with the observation that the correct phonemes of the target word may all be present somewhere in the sequence (Kohn 1984), this provides further support for a locus of impairment after the correct phonological lexical form has been retrieved (Kohn 1988). Moreover, these repeated attempts at the target demonstrate an awareness of errors and therefore intact monitoring (Kohn, 1984; Gandour et al, 1994). In contrast, people with jargon aphasia, whose lexical retrieval is frequently impaired (Marshall, 2006), typically demonstrate few attempts at self-correction and therefore show limited awareness of their errors (Marshall et al, 1998).

As reviewed by Postma (2000), there are two types of speech monitoring, overt or external monitoring of speech output after articulation, and covert or internal monitoring of inner speech prior to articulation. According to Levelt et al’s (1999) WEAVER++ model, both overt and covert monitoring are performed by the same speech comprehension processes that are involved in understanding another person’s speech, with covert monitoring utilising an internal feedback loop between phonological output and speech input (the perceptual loop theory). While there is general agreement that external monitoring is performed this way (Nozari, Dell and Schwartz, 2011), the locus of the internal monitoring mechanism is more contentious. One method which has been used to address this question is internal phoneme monitoring where participants must decide, without speaking aloud, whether a picture name contains a particular phoneme. Ozdemir, Roelofs and Levelt (2007) reported that response latencies of normal

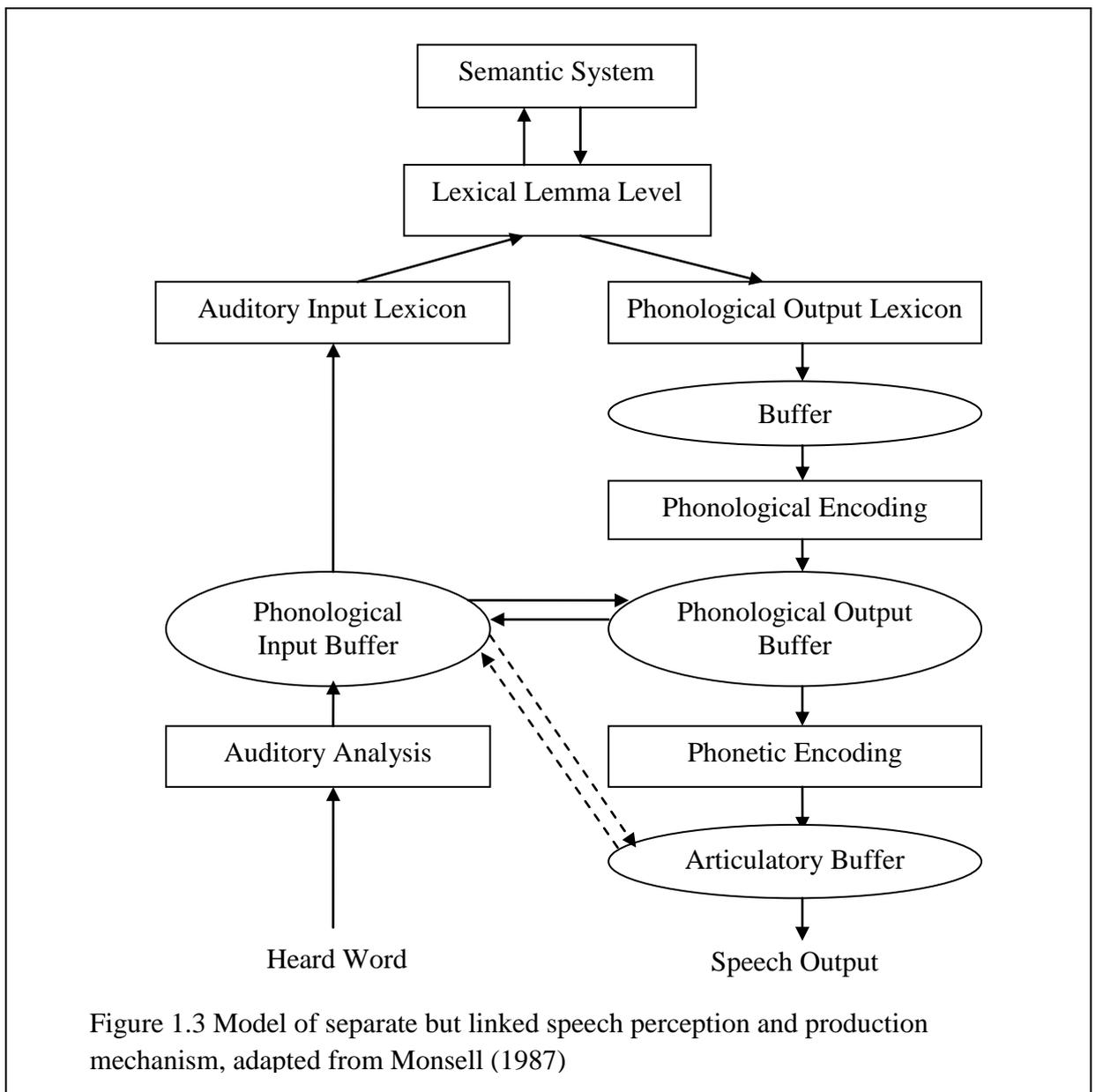
participants on this task were shorter when the target phoneme was further away from the uniqueness point of the word (the phoneme at which the word becomes different from any other), thus supporting Levelt et al's (1999) theory of perception-based internal monitoring.

Huettig and Hartsuiker (2010), however, argued that the processes used by speakers to monitor their inner speech on metalinguistic tasks, such as phoneme monitoring, are not the same as those used when speaking aloud and, moreover, that inner speech may not actually be monitored at the same time as overt speech is being produced. In a task involving tracking of eye movements, Huettig and Hartsuiker (2010) found that healthy speakers showed the same pattern of eye movements towards a phonologically related written word, during both picture naming and when listening to the picture name. On both tasks, speakers fixated their eyes on the phonologically related word after the onset of word production or comprehension. Huettig and Hartsuiker argued that if internal speech was being monitored by the speech comprehension system alongside overt production, then eye movements would have fixated on the phonologically related word before the onset of picture naming. Furthermore, studies of people with aphasia have failed to establish a link between auditory comprehension and monitoring abilities (Nickels and Howard, 1995; Sampson and Faroqi-Shah, 2011), and dissociations have been reported, both in cases of good auditory comprehension and poor monitoring (Maher, Gonzalez Rothi and Heilman, 1994) as well as poor comprehension but good monitoring (Marshall, Rappaport, and Garcia-Bunuel, 1985). These findings have led to the proposal of a production-based internal speech monitoring system, which does not involve speech comprehension processes (Postma, 2000). One such production-based theory, based on Dell et al's (1997) interactive speech production framework, was proposed by Nozari et al (2011), in which errors are detected when a high level of conflict arises between potential choices of words or phonemes, but this model is yet to be thoroughly tested.

1.4 Relationship between speech comprehension and production

Although the mechanism used for internal monitoring of speech output continues to be debated, a large body of evidence supports a close link between the speech comprehension and production systems, such as would be required for Levelt et al's (1999) perceptual loop theory. For example, Schriefers, Meyer and Levelt (1990)

showed that naming latencies in normal subjects were influenced by the presentation of auditory distracter words. Brain imaging studies have further revealed overlap between the neural regions involved in phonological input and output (Buchsbaum, Hickok and Humphries, 2001), as well as demonstrating that articulatory features of speech sounds are accessed during speech perception tasks (Pulvermuller, Huss, Kherif, Martin, Hauk, and Shtyrov, 2006; Mottonen and Watkins, 2011). These findings support a motor theory of speech perception (Liberman and Mattingly, 1985), which proposes that speech is perceived in terms of the phonetic gestures used to produce it.



One possible way in which speech comprehension and production processes may be linked is shown in figure 1.3. Levelt et al (1999) stated that, in their model, the lemma

level of lexical representation (containing syntactic information) is common to both comprehension and production, and the conceptual semantic level is also widely regarded as central to both (e.g. Monsell, 1987; Whitworth, Webster and Howard, 2005). The remainder of the input route shown in figure 1.3, in common with most current models of speech comprehension (e.g. Franklin, 1989; Jacquemot and Scott, 2006), comprises an auditory analysis stage, where phonemes in a heard word are identified, followed by a lexical selection stage, where the phonemes are recognised and matched with a stored entry in the auditory input lexicon, before semantic and syntactic information for the selected lexical entry is activated. The separation of the phonological lexical level into separate input and output lexicons is necessitated by reports of dissociations between comprehension and production ability in people with aphasia (e.g. Howard, 1995).

The output route shown in figure 1.3 corresponds to that proposed by Levelt et al (1999) with the addition of output buffers between each stage. Levelt et al (1999) did not explicitly include output buffers in their model, but some kind of short term storage facility is thought to be required in order to store the output of one level of processing as it is prepared for the next, particularly during production of connected speech (Nickels, 1997; Roelofs, 2002; Laganaro and Zimmermann, 2010). Such short term storage buffers are prominent in models of working memory. Baddeley and Hitch (1974) proposed that working memory contains three components; a central executive and two slave systems, the visuospatial sketchpad and the phonological loop. The phonological loop was further divided into a temporary storage system and a subvocal rehearsal system, used to refresh and maintain the stored auditory information. Jacquemot and Scott (2006) proposed that this model of working memory can map onto a speech processing model such as that shown in figure 1.3, with the temporary storage system corresponding to the phonological input and output buffers and the subvocal rehearsal system being the link between the two. Sub-lexical links are also thought to be required for non-word repetition tasks, which cannot be performed using a lexical route (Ellis and Young, 1996; Jacquemot, Dupoux, and Bachoud-Levi, 2007) as well as inner phonology tasks such as written rhyme judgment, which involve both output and input phonological processing (Howard and Franklin, 1990).

Caplan and Waters (1995) concluded that rehearsal utilises post-lexical phonological processing, based on a single case study of a client with phonological assembly

difficulties who could access phonological lexical representations but was unable to perform written rhyme judgment. Precisely which of the post-lexical output buffers are involved, however, remains unclear. In figure 1.3, this link has been placed after the phonological encoding stage and before phonetic encoding. This is based on findings by Wheeldon and Levelt (1995) where rehearsal was shown to be sensitive to syllable structure. They found that normal subjects performed a syllable monitoring task more quickly when the segments being monitored corresponded to the first syllable of the heard word (e.g. when asked to listen for the string /pic/, the word pic-ture would be faster than pi-cking). This suggested that subjects were utilising a level of output that has been syllabified, i.e. after phonological encoding. Furthermore, Wheeldon and Levelt (1995) found that articulatory suppression did not influence performance, implying that the level of inner speech required for this task occurred before phonetic encoding. In contrast, Waters, Rochon and Caplan (1992) found that people with AOS and normal subjects under articulatory suppression were impaired on written rhyme judgment tasks, suggesting that the level of inner speech required for this task occurred after phonetic encoding. The subvocal rehearsal link in figure 1.3, therefore, could also feasibly be placed after the phonetic encoding stage, at the level of the articulatory buffer.

If it is accepted that at least one output buffer is needed at some stage, then it is possible that clients with aphasia may present with impairments within either the phonological encoding mechanism or a phonological buffer however, in practice, it is very difficult to distinguish these two impairments (either phoneme ordering or phoneme short term storage) as both are post-lexical and both have been reported as presenting with very similar symptoms e.g. length and serial position effects and a deficit common to all modalities (Caramazza, Miceli and Villa, 1986). In fact, conduction aphasia has been explained as both a phonemic assembly deficit (Kohn, 1984, 1988) and an impairment of the phonological output buffer (Shallice, Rumiaty and Zadini, 2000; Gvion and Friedmann, 2012).

1.5 Therapy for phonological output impairments

The preceding sections of this chapter have discussed key theoretical aspects of phonological processing in speech production, thus providing a foundation for the understanding of phonological output impairments in aphasia. Detailed knowledge of

the linguistic impairment(s) of an individual with aphasia provides a basis on which to plan treatment, and may also allow predictions to be made regarding whether other people with a breakdown at the same level will show the same response to therapy (Marshall, 2010). As described by Best and Nickels (2000), however, there is no direct relationship between the type of impairment and the treatment that is most likely to be successful. This may be due, at least in part, to the large amount of variation between individuals in non-linguistic factors such as pre-morbid education, intelligence, medical co-morbidities, motivation and family support (Hillis and Caramazza, 1994). Subtle differences in linguistic impairment may also lead to different responses to therapy. For example, Laganaro, DiPietro and Schnider (2006) described three people with aphasia with similar language profiles, who were impaired in spoken and written naming. All three improved in spoken naming of treated words after therapy targeting written naming, but one client needed more sessions to reach the criteria of 80% correct and was more consistent in the items he could not name. Laganaro et al (2006) suggested that this client's lexical representations were lost or severely degraded, whereas the other two clients had impaired access to intact lexical representations. Furthermore, Best and Nickels (2000) reported data from four people with aphasia with different language profiles who all improved in picture naming after therapy using orthographic and phonological cueing, but for different reasons, due to different components of the task. Only through detailed description of both the individual's linguistic impairment and the task components, therefore, will the question of which therapy works for which person be understood. The next part of this chapter will review the literature to date on therapy for phonological output impairments.

1.5.1 Previous therapy studies

In a review of naming therapy studies, Nickels (2002) drew a distinction between phonological therapy tasks and therapy for phonological impairments. Many studies have shown positive effects of using phonological tasks in therapy, but these have typically involved participants with a range of underlying causes underpinning their word finding difficulties, mostly either within or in accessing the phonological representation from the lexicon. For example, Hickin, Best, Herbert, Howard, and Osborne (2002) reported a case series of eight participants with a range of linguistic impairments. All received phonological cueing therapy, involving picture naming with a choice of either phonological or orthographic cues, beginning with the initial phoneme

or grapheme, working up to the first syllable and finally word repetition. Seven out of eight participants improved significantly in naming of treated items after therapy, with the mechanism thought to be improved mapping between semantics and phonology.

Relatively few treatment studies have focussed specifically on therapy for people with phonological encoding (assembly) impairments. Cubelli, Foresti and Consolini (1988) were the first to describe therapy specifically for this group of clients. Three people, diagnosed with conduction aphasia, received therapy comprising a range of tasks, including matching a written word to a picture with a range of visually similar written words as distractors, matching written sentences to pictures, assembling a word from a choice of written syllable segments or a choice of written letters, and changing the order of words to make a sentence. All tasks were followed by reading aloud of the target word. All three participants showed improvements on naming, repetition and reading aloud after therapy, but the results are flawed by the fact that all were between one and three months post-stroke, and there were few measures in place to control for the effects of spontaneous recovery. Furthermore, the data description was limited to percentage figures and no statistical value was given as to their significance. Kohn, Smith and Arsenault (1990) also reported therapy specifically aimed at a person with conduction aphasia. Sentence repetition tasks were used, with the aim of improving fluency by reducing lengthy repair sequences, rather than reducing phonemic errors per se. Significant improvements were seen in the number of content words produced correctly in sentences after therapy, but the authors provided limited theoretical explanation of how therapy might have worked.

More recently, Corsten, Mende, Cholewa and Huber (2007) reported treatment for a single client with phonological encoding difficulties. Computer assisted therapy was administered twice a day, five days a week, for six weeks and utilised monosyllabic minimally contrastive words and non-words. Three types of treatment tasks were used; same-different discrimination, spoken word to written word matching and reproduction via repetition and reading aloud. Improvements were seen on the reproduction treatment task for real words with coda contrasts, but the authors acknowledged that this was likely due to the client's good reading aloud ability. On production of untreated items after therapy, a significant improvement in repetition of words and non-words was reported and taken to indicate improved post lexical phonological encoding. The untreated control tests, however, were repeatedly administered during the treatment

period, with real word repetition scores gradually increasing each time, such that the gains may have reflected practise effects. Furthermore, two pre-therapy baseline assessments of repetition were obtained but they were performed over successive days, thus giving limited information as to the stability of the client's performance over a longer period. Finally, a significant gain in spoken naming of untreated items was also reported after therapy, a task which was not repeatedly assessed during therapy. It is difficult to reliably attribute this change to therapy, however, as no repeated baselines were taken for naming pre-therapy. Furthermore, the client received functional communication training alongside the phonological therapy, which may have influenced his naming.

One of the few treatment studies to use a well designed format specifically targeting phonological assembly impairments was reported by Franklin, Buerk, and Howard (2002) with a single case study, MB, who presented with a post-lexical phonological output deficit, characterised by the production of phonological errors on all tasks, as well as sequences of "conduite d'approche", with a phoneme length effect present in all spoken output modalities. Therapy was carried out in two phases, with the first aimed at improving MB's auditory awareness through tasks including choosing the first sound for a spoken word, whilst the second aimed at improving her self-monitoring skills, through tasks requiring the identification of phonological errors and judgment of their location in the word. A significant improvement in picture naming for both treated and untreated words was seen after both phases, and these improvements were maintained two months later. Significant gains in repetition, reading aloud and self-correction of errors were also found. The authors acknowledged, however, that the reasons why this therapy caused MB's speech to improve were unclear, as although their original aim was to teach a self monitoring strategy, this did not actually occur. Following therapy more pictures were named correctly immediately and fewer "conduite d'approche" responses were present. Rather, an improvement in the process of phonological encoding was proposed, shown by a reduction in phoneme substitution errors in naming after therapy.

1.5.2 Generalisation of therapy effects

Franklin et al's (2002) client, MB, showed generalised improvements after therapy across both tasks and items, i.e. from naming to repetition and reading, as well as from

treated to untreated words. The finding of generalisation across tasks supports Franklin et al's claim that treatment was acting at a level common to all spoken production tasks, i.e. post-lexical phonological assembly. Generalisation to untreated words is more unusual because many word retrieval treatment studies have found only item-specific effects (e.g. Miceli, Amitrano, Capasso, and Caramazza, 1996; Fillingham, Sage, and Lambon Ralph, 2005). Howard (2000) argued that item-specific effects are likely following therapy targeting the link between semantics and lexical retrieval, and generalisation to untreated items should only be expected when a strategy is taught, or when the target of therapy is a post-lexical process. Therapy targeting phonological encoding, therefore, should be more likely to achieve generalisation to untreated items than therapy targeting specific lexical entries, because the mechanism of inserting phonemes into the word frame is common to all speech production tasks. Moreover, people with post-lexical impairments may be more likely than those with lexical deficits to show generalisation to untreated items, even if therapy does not specifically target this area. Best, Greenwood, Grassly, Herbert, Hickin and Howard (submitted) reported that of 16 people with aphasia who received a cueing hierarchy picture naming therapy, 15 improved significantly in naming of treated items, but generalised improvement in naming of untreated items was only seen in three participants, all of whom had a post-lexical phonological encoding deficit in the absence of a semantic deficit. Further support comes from treatment studies that have focussed on written output. For example, in a study with three clients, Rapp (2005) found that while one client with orthographic output lexicon damage showed item-specific improvements in spelling to dictation following treatment targeting spelling, two clients with graphemic output buffer impairments improved in spelling of untreated and treated words after the same therapy.

The question of identifying which people with aphasia are most likely to show generalisation to untreated items is more difficult to answer when using a model of speech production such as that of Dell et al (1997), which does not distinguish between a phonological lexical level and a post-lexical phonological encoding level. Greenwood, Grassly, Hickin and Best (2010) provided a detailed profile of one of the three participants studied by Best et al (submitted) who showed generalisation to naming of untreated items after therapy, and concluded that the most likely mechanism for this was via feedback from the phoneme level to the lemma level, as in Dell et al's model

(see figure 1.2). Greenwood et al (2010) proposed that generalisation to untreated items occurred when activation from phonemes in treated words fed back to other lexical items containing those phonemes. If this were the case, however, it is unclear why generalised improvements would not be seen in all people with aphasia following treatment incorporating spoken word production. Similarly, Fisher, Wilshire and Ponsford (2009) described a single case study, TV, proposed to have a deficit at the phonological level of Dell et al's (1997) model, who improved in naming of treated and untreated items following therapy involving naming pictures presented in triplets of phonologically similar words. Fisher et al (2009) suggested that this generalisation to untreated items may have occurred via strengthened links between a word's lexical representation and its associated phonemes. An alternative explanation, not considered by Fisher et al (2009), is that TV actually had a post-lexical phonological assembly deficit, evidenced both by phonological errors and an effect of word length on naming and repetition as well as impaired non-word production. Therapy may, therefore, have acted in a similar way as with MB, Franklin et al's (2002) client, i.e. by improving the process of phoneme assembly. The most parsimonious explanation of the varying patterns of generalisation to untreated items seen in the literature may be to assume the existence of a post-lexical phonological encoding stage such as that described in Levelt et al's (1999) model, which occurs after the phoneme level of lexical processing in Dell et al's (1997) model, as proposed by Goldrick and Rapp (2002).

1.6 Therapy influencing theory

Comparing the predictions made by different theoretical models regarding generalisation of treatment effects is one way in which treatment studies can have an important role in contributing to the development of cognitive neuropsychological models (Nickels, Kohnen and Biedermann, 2010). For example, Biedermann and Nickels (2008) found that phonological cueing therapy resulted in improved naming of both treated and untreated homophones, thus providing evidence of shared phonological lexical representations. Similarly, Schoor, Aichert and Ziegler (2012) examined patterns of generalisation from treated to untreated words, controlled for syllable structure overlap, following treatment for apraxia of speech. Schoor et al demonstrated transfer of treatment effects for certain sub-syllabic elements, thus disputing Levelt et al's (1999) proposal that phonetic motor plans are stored as whole syllable units. These examples highlight the possibilities for cognitive neuropsychological theory in both informing

therapy and being informed by therapy, although the potential for the latter remains relatively unexplored.

1.7 Summary and study aims

Evidence for the effective treatment of people with aphasia with phonological assembly difficulties is limited. The approach taken by Franklin et al (2002) holds most promise, particularly given the findings of generalised improvement, but uncertainty remains around the mechanism of improvement and its applicability to other clients, given the single case study design (Pring, 2005). A case series approach would allow investigation of which other people may benefit from this treatment. In this method, a small group of participants receives the same assessment and therapy but each are analysed as single case studies, such that comparisons between participants can be drawn (Howard, 2000; Marshall, 2006). Furthermore, differences between participants in their response to therapy, particularly regarding patterns of generalisation across items and tasks, can provide information to aid development of theoretical models of speech production (Nickels et al, 2010).

The aims of this thesis were to use a case series design to:

1. Investigate whether the findings of generalised improvement reported by Franklin et al (2002) are replicable with other people with aphasia with impaired phonological assembly
2. Explore any differences in outcomes for each participant, with a view to identifying any factors which might suggest different language profiles will respond differentially to this therapy
3. Explore alternative approaches to therapy for those clients who may not benefit from Franklin et al's therapy
4. Determine whether the different responses to different therapies can inform theoretical models of phonological assembly.

These aims were addressed in two separate studies. In study one, four participants with impaired phonological assembly underwent a replication of Franklin et al's auditory and monitoring therapy. The design and participants in study one will be reported in chapter two, while the results of therapy for each participant in study one will be provided in

chapter three. In chapter four, each individual's results are interpreted in conjunction with their pre-therapy linguistic assessment profile, in order to identify possible reasons for any differences in outcome. Based on the results of study one, chapter four concludes by proposing three different subgroups of people with phonological assembly difficulties, some predicted to benefit from Franklin et al's therapy, and others predicted to benefit more from an alternative approach. In study two, four further participants with impaired phonological assembly received both Franklin et al's therapy and a novel therapy focussing directly on speech production rather than monitoring. The design and participants in study two will be reported in chapter five, while the results of therapy for each participant in study two will be provided in chapter six. In chapter seven, the results of study two are discussed, focussing on whether the predictions about subgroups, proposed in chapter four, were upheld, and the theoretical and clinical implications of both studies will be explored.

Chapter 2 Method Study One

2.0 Aims of chapter

The aim of study one, as described in chapter one, was to use a case series design to replicate the treatment programme used by Franklin et al (2002) with other people with impaired phonological assembly, and through this, to explore any differences in the outcomes for participants and to identify any factors which might suggest which people will benefit most from this therapy approach. This chapter will describe the design of study one and the participants.

2.1 Study design

Franklin et al's (2002) therapy protocol was replicated with all participants, each undergoing two consecutive therapy phases, detailed in section 2.8. Language assessment was carried out with each participant on five occasions. Two assessment periods took place prior to the intervention period and were one month apart, the third and fourth took place after each therapy phase, and a final assessment was carried out two months after therapy. All assessment and therapy was administered by the researcher, a qualified Speech and Language Therapist.

Spoken picture naming was the primary outcome measure, and was assessed using the Nickels naming test (Nickels, 1992) at all five assessment periods. This test, used in the Franklin et al (2002) study, would permit direct comparisons to be made with the earlier study and, owing to the large number of items (130) orthogonally varied by number of syllables and word frequency, would allow both measurement of any change and an examination of whether either of these two variables had an impact on word production. Reading aloud and repetition of the words from the Nickels naming test were also tested before therapy and after each therapy phase, to compare participants' spoken output on different tasks and to look for any differences across tasks in patterns of improvement after therapy.

After the initial assessment, the items from the Nickels naming test were randomly divided into two sets, one to be used in treatment, the other to be left untreated, with the constraint that each contained equal numbers of items named correctly on the first attempt (not including self-corrections) and the sets were approximately matched for syllable length and word frequency (high or low, taken from the Nickels naming test

classification). The items selected for treatment, therefore, varied slightly for each participant, depending on their pre-therapy naming performance.

A series of additional linguistic and cognitive assessments, including a selection of subtests from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay, Lesser, and Coltheart, 1992), were administered during the first assessment period, to gain a detailed picture of each participant's language processing abilities and to hypothesise their level, or levels, of breakdown. Auditory processing was assessed using discrimination of word and non-word minimal pairs and auditory lexical decision. Phonological processing was assessed using auditory and picture rhyme judgment, homophone decision and non-word repetition and reading aloud. Semantic processing was assessed using spoken and written word to picture matching and the Pyramids and Palm Trees test (Howard and Patterson, 1992). Non-linguistic cognitive processing was assessed using the Camden Short Recognition Memory Test for Faces (Warrington, 1996) and the Wisconsin Card Sorting Test (Grant and Berg, 1993), and working memory was assessed using digit matching span. Details of all assessments are provided in section 2.5. In addition, hearing acuity was assessed at the start of the study using pure tone audiometry; results are provided in section 2.4.

Following the initial assessment period there was a break of one month, during which no therapy or assessment was carried out. Spoken naming, using the Nickels naming test, was then reassessed, to ensure that any change seen following therapy was greater than any seen during a period of no therapy. After each phase of therapy, spoken naming, repetition and reading aloud of the Nickels naming test words were re-tested. Further tests from the pre-therapy assessment battery were also repeated following the second therapy phase, namely, non-word repetition and reading aloud, word minimal pair discrimination and auditory lexical decision, to ascertain whether therapy had brought about any wider language changes in phonological or auditory processing. Finally, spoken naming was reassessed using the Nickels naming test two months after the end of therapy to establish whether any gains had been maintained. The written version of the Test for Reception of Grammar (TROG) (Bishop, 1982) was also administered before and after therapy as a control task, as it was not anticipated that written sentence comprehension would improve after therapy targeting auditory discrimination or monitoring. During all assessments, published task instructions were adhered to, and no feedback was given on any task with respect to correct or incorrect

responses. Where two tests used the same stimuli, e.g. spoken and written word to picture matching, these were administered on separate testing occasions.

2.2 Recruitment

Participants were recruited through local Speech and Language Therapy services, according to procedures approved by the Local Research Ethics Committee. Criteria for inclusion in the study required that all participants recruited to the project had acquired aphasia following a stroke and were more than three months post-onset. This ensured that people with progressive aphasia, and those who may still be in a period of rapid spontaneous recovery, were excluded from the study. In addition, participants needed to be judged by their Speech and Language Therapist as having sufficiently good comprehension to give informed consent, and suitable for twice weekly assessment and therapy that would focus explicitly on their speech and language impairment. People with significant cognitive difficulties or dementia, or any speech or language difficulties that were not a result of their stroke, were excluded from the study. People whose first language was not English were not excluded from the study, but participants were expected to be able to participate in assessment and therapy presented in English. These criteria were implemented via report from the referring Speech and Language Therapist.

Finally, all participants recruited to the project were required to demonstrate evidence of a spoken word production deficit consistent with a primary impairment in post-lexical phonological assembly. This was defined as an impairment affecting spoken picture naming, word repetition and reading aloud, characterised by the production of phonologically related errors on all spoken output tasks (Kohn, 1984, 1989). The presence of a phonological assembly impairment was judged, firstly, by the referring Speech and Language Therapist, and secondly, through a screening assessment carried out by the researcher, described below. People with co-occurring language impairments, including apraxia of speech, were not excluded from the study, providing the phonological assembly impairment was considered most prominent. The high co-morbidity of apraxia of speech and phonological assembly difficulties, as well as the difficulty distinguishing between these, is well documented (e.g. McNeil, Doyle and Wambaugh, 2000; Duffy, 2005). Furthermore, heterogeneity among the participants was considered an advantage when exploring the factors involved in identifying the best candidates for Franklin et al's therapy.

Once potential participants were identified by their local Speech and Language Therapist, a preliminary meeting took place between the researcher and the prospective participant and, where possible, a relative or carer, to provide information on the study and carry out a brief language screening assessment. Focussing on the client's spoken output deficit, the screening assessment consisted of the spoken picture naming, picture description, word repetition and reading aloud subtests of the Comprehensive Aphasia Test (Swinburn, Porter and Howard, 2004). This assessment permitted comparison of participants' spoken output and error types across different modalities, in addition to sampling performance in connected speech, within a relatively small number of items that could be administered within a short time. Information was also gained regarding the influence of word length and frequency on spoken production, which aided diagnosis; an effect of word length on spoken output has been reported as a common characteristic of phonological assembly difficulties (e.g. Caplan, Vanier and Baker, 1986), whereas word frequency effects are more commonly associated with lexical retrieval impairments (Jescheniak and Levelt, 1994).

If performance on the screening assessment supported the diagnosis of a phonological assembly impairment, i.e. impaired spoken naming, repetition and reading aloud, with phonologically related errors evident on all tasks, clients were asked to sign a consent form to confirm their participation in the study. If their aphasia prevented them from providing written consent, verbal consent was gained and witnessed by an impartial health professional.

2.3 Participants

Four people with aphasia were recruited to take part in study one. Background information is shown in Table 2.1. All participants were right-handed, monolingual English speakers. Variation was present in time post-onset, with two participants in a chronic stage of recovery, i.e. greater than two years, and two still relatively acute, i.e. less than six months. Information about lesion site was limited to that provided by the referrer.

	SD	BB	HS	PL
Gender	Female	Female	Male	Male
Age	75 years	76 years	63 years	82 years
Medical history	Left parietal lobe infarct	Left middle cerebral artery infarct	Left parietal lobe infarct	Left middle cerebral artery infarct
Months post-onset	5	32	45	5

Table 2.1: Study one participant details

2.3.1 Participant SD

SD lived at home with her husband. Her spontaneous speech was fluent, with many content words substituted with unintelligible phonemic paraphasias, which she repeatedly tried to correct (*conduite d'approche*). She presented with some receptive language difficulties, frequently needing questions and instructions repeating. She was, despite these difficulties, able to maintain a simple social conversation successfully, and enjoyed socialising with visitors at home.

2.3.2 Participant BB

BB lived alone in sheltered accommodation, with her daughter, whom she saw frequently, living nearby. Her spontaneous speech was non-fluent; she rarely initiated conversation and her responses were usually short and without any obvious struggle. While much of BB's spoken output was unintelligible, she made fewer attempts at correcting herself than SD. Receptive language skills were intact. BB's social activities were limited due to her speech output difficulties.

2.3.3 Participant HS

HS lived at home with his wife and was a highly proficient speaker in conversation. His receptive language was good. His speech was fluent with only occasional phonemic paraphasias which, usually recognisable as the target, tended not to disrupt the flow of conversation. Nonetheless, HS reported his speech difficulties had compromised his confidence in conversing with unfamiliar people.

2.3.4 Participant PL

PL lived in a nursing home and his daughter visited often. His spontaneous speech was non-fluent and showed many signs of articulatory struggle, often causing him to give up part way through an utterance. This resulted in considerable frustration and, although he did initiate conversations, he was able to contribute only a limited amount of information within conversation. PL had some hearing loss, detailed below, which impacted on comprehension but improved when information was presented at a raised volume.

2.4 Pure tone audiometry assessment

Audiometric testing was carried out according to the British Society of Audiology's (2011) recommended procedure and took place in participants' homes, in ambient noise but with the room made as quiet as practically possible. Identifying the presence of any hearing impairment that may have been impacting on the participants' auditory processing skills was important given that many of the therapy tasks focussed on listening. The results for each participant are shown in table 2.2, alongside normal data from Cruickshanks et al (1998). The normal data specifically relates to participants' gender and age, so SD and BB's results were compared to the normal mean and standard deviation for females aged 70-79, while HS's were compared to the normal range for males aged 60-69 and PL's to the normal range for males aged 80-92. Thresholds that were greater than the normal range are highlighted in table 2.2 in bold. SD, BB and HS were all shown to have some degree of hearing loss, particularly for the higher frequencies, but all their scores were within the age adjusted normal limits reported by Cruickshanks et al (1998). PL wore a hearing aid in his left ear for all assessment and therapy, including the audiometry test. Even when aided, PL had a moderate hearing loss (threshold of 50-60dB) in his left ear between 250 and 1000 Hz that was outside the normal range, but only a mild loss (threshold of 35-40dB) for these frequencies in the right ear, which was within the normal range. PL's hearing at 2000 Hz was moderately impaired (threshold of 70-75dB) and outside the normal range in both ears, and for the highest frequencies of 4000 and 8000Hz, he had a severe loss (threshold of 60-90dB) but this was within the normal range for his age. To compensate

for PL's mild to moderate hearing loss, all auditory input assessments were presented with a raised voice and the therapist sat on his right hand side.

		female aged 70-79			male aged 60-69		male aged 80-92	
Frequency (Hz)		SD	BB	normal mean (standard deviation)	HS	normal mean (standard deviation)	PL	normal mean (standard deviation)
Left ear	250	25	15	18.8 (15.9)	20	13.4 (11.5)	60	27.4 (16.8)
	500	20	15	19.1 (16.5)	20	12.1 (11.6)	55	27.8 (18.1)
	1000	10	10	22.1 (17.6)	15	16.4 (12.8)	50	34.8 (19.5)
	2000	30	45	28.3 (18.7)	20	28.6 (19.3)	70	50.4 (17.7)
	4000	55	20	40.9 (19.8)	45	55.1 (21.7)	70	71.3 (16.8)
	8000	80	40	61.6 (20.4)	45	61.2 (22.7)	90	79.7 (15.5)
Right ear	250	25	15	19.8 (15.8)	15	15.2 (13.3)	40	30.6 (20.3)
	500	20	20	19.7 (16.6)	15	12.2 (13.6)	40	31.8 (22.9)
	1000	20	10	22.9 (17.4)	20	15.8 (14.6)	35	38.2 (22.7)
	2000	30	25	27.6 (18.6)	15	26.2 (20.9)	75	52.3 (19.9)
	4000	40	25	39.0 (19.8)	15	54.0 (23.7)	60	70.5 (17.3)
	8000	60	55	60.3 (21.2)	30	59.5 (23.9)	90	81.3 (15.5)

Numbers in bold = Thresholds outside the normal range

Table 2.2: Study one participants' pure tone audiometry thresholds (dB)

	SD	BB	HS	PL	Normal Mean
PALPA 1 Auditory Discrimination of Non-Word Minimal Pairs	19/36 (.53)	21/36 (.58)	35/36 (.97)	53/72 (.74)	70/72 (.97)
PALPA 2 Auditory Discrimination of Word Minimal Pairs	38/72 (.53)	61/72 (.85)	36/36 (1.00)	62/72 (.86)	70/72 (.97)
PALPA 5 Auditory Lexical Decision	129/160 (.81)	132/160 (.83)	154/160 (.96)	141/160 (.88)	155/160 (.97)
PALPA 15 Auditory Rhyme Judgment	37/58 (.64)	39/58 (.67)	57/58 (.98)	55/58 (.95)	not available
PALPA 14 Picture Rhyme Judgment	24/40 (.60)	16/40 (.40)	21/40 (.53)	22/40 (.55)	not available
PALPA 28 Homophone Decision	30/60 (.50) Regular: 12/20 Exception: 10/20 Nonword: 8/20	47/60 (.78) Regular: 17/20 Exception: 18/20 Nonword: 12/20	41/60 (.68) Regular: 16/20 Exception: 15/20 Nonword: 10/20	43/60 (.72) Regular: 17/20 Exception: 17/20 Nonword: 9/20	54/60 (.92) Regular: 18/20 Exception: 18/20 Nonword: 18/20 (Nickels & Cole-Virtue, 2004)

Table 2.3: Study one participants' background assessment results

	SD	BB	HS	PL	Normal Mean
PALPA 13 Digit Matching Span	3.5	4.9	4.5	5.5	6 (Salis, personal communication)
PALPA 47 Spoken Word-Picture Match	38/40 (.95)	39/40 (.98)	39/40 (.98)	39/40 (.98)	39/40 (.98)
PALPA 48 Written Word-Picture Match	33/40 (.83)	37/40 (.93)	39/40 (.98)	37/40 (.93)	39/40 (.98)
Pyramids and Palm Trees (3 picture version)	36/52 (.69)	45/52 (.87)	49/52 (.94)	46/52 (.88)	51/52 (.98)
Camden Short Recognition Memory Test for Faces	15/25 (.60) <5 th centile	21/25 (.84) 25 th centile	25/25 (1.00) 90 th centile	19/25 (.76) 10 th centile	see centile result
Wisconsin Card Sorting Test	0 categories correct 6-10 centile 69% error responses 6 th centile	0 categories correct 6-10 centile 66% error responses 8 th centile	3 categories completed > 16 th centile 46% error responses 12 th centile	2 categories completed > 16 th centile 56% error responses 27 th centile	see centile result

Table 2.3 cont'd: Study one participants' background assessment results

2.5 Background assessments

The results of each participant's pre-therapy assessment are set out in Table 2.3. Raw scores and proportions correct are given for each participant, as well as mean performance from normal controls where available.

2.5.1 Assessment of auditory input processing

Participants' auditory input processing was assessed using PALPA minimal pair discrimination for real and non-words (listening to two words or non-words and deciding if they sound the same) and PALPA auditory lexical decision (listening to a word or non-word and deciding if it is real). According to Franklin (1989) impaired minimal pair discrimination can indicate a deficit at the level of auditory analysis, while superior performance in discrimination of real word compared to non-word minimal pairs suggests that lexical or semantic information is being used to support a weakened auditory analysis system (Whitworth, Webster and Howard, 2005). Impaired auditory lexical decision, meanwhile, can indicate a deficit at the level of the auditory input lexicon (Franklin, 1989). Assessment of participants' auditory processing abilities was necessary in order to aid differential diagnosis; phonological errors on repetition could be caused by difficulties with auditory input as well as with phonological output (Morris, Franklin, Ellis, Turner and Bailey, 1996). It was also important to identify any difficulties in this area that may have impacted on participants' ability to perform the therapy tasks.

HS scored within normal limits on both minimal pair discrimination tasks, and near to normal performance on auditory lexical decision (shown in table 2.3). BB and PL were impaired compared to normal performance on discrimination of both word and non-word minimal pairs but were better at discriminating real words, suggesting they may have been using some intact lexical processing to help make this decision. Further evidence for BB and PL having access to lexical information for heard words comes from their scores on auditory lexical decision, which were similar to their real word minimal pair discrimination scores (above 80%). SD was severely impaired at discrimination of both word and non-word minimal pairs with performance at chance level. SD's superior performance on auditory lexical decision, however, suggests that her auditory discrimination abilities may be better than predicted by performance on

minimal pair discrimination. Interestingly, participants' scores on assessment of auditory processing did not appear related to their pure tone audiometry results. PL had the most impaired hearing but performed relatively well on minimal pair discrimination, while HS performed within normal limits on these tasks despite having a similar mild hearing loss to SD and BB.

2.5.2 Assessment of phonological processing

Phonological processing was further explored through PALPA auditory rhyme judgment (listening to two words and deciding whether they rhyme), PALPA picture rhyme judgment (looking at two pictures and, without naming them aloud, deciding whether the two words rhyme), and PALPA written homophone decision (reading two words silently then deciding whether the two words would sound the same if they were said out loud). People with post-lexical phonological assembly difficulties may show superior abilities in accessing phonological information for a word without saying it aloud, compared to those with lexical retrieval difficulties (Goodglass, Kaplan, Weintraub and Ackerman, 1976; Feinberg, Gonzalez Rothi and Heilman, 1986). Performance on these tasks, therefore, could aid differential diagnosis. On the auditory rhyme judgment task, two items were omitted for all participants as the local accent resulted in two of the non-rhyme word pairs rhyming. Scores are therefore out of 58 instead of 60.

BB, HS and PL performed better on homophone decision than on picture rhyme judgment (see table 2.3), although the difference was only statistically significant for BB (Fisher exact $p=0.0001$). BB, HS and PL also performed better on auditory rhyme judgment than picture rhyme judgment, although BB still showed some difficulty with the auditory task (PL and HS scored above 90% on the auditory version). SD was similarly impaired on both auditory and picture rhyme judgments as well as homophone decision, scoring close to chance for all three tasks.

Besner, Davies and Daniels (1981) found that normal subjects can perform homophone judgment but not written rhyme judgment when performing articulatory suppression tasks, demonstrating that articulatory rehearsal is required for the latter but not the former. Similarly, Howard and Franklin (1990) reported a single client with impaired subvocal rehearsal who could perform homophone judgment but not written rhyme

judgment. They proposed that homophone judgment could be performed by accessing output phonology alone, whereas rhyme judgments required additional access to auditory input information, in order to segment the word into onset and rime. Nickels, Howard, and Best (1997) argued that these findings are best explained using a processing model that incorporates separate input and output lexicons with sub-lexical links between them, such as that described in chapter one and shown in figure 1.3. The pattern shown by BB, HS and PL of relatively good performance on homophone judgment and auditory rhyme judgment compared with poor performance on picture rhyme judgment is compatible with a deficit in the sub-lexical rehearsal loop between phonological output and input. This was also seen in five participants studied by Nickels et al (1997) and in six participants with AOS studied by Waters, Rochon and Caplan (1992). Alternatively, the difficulties with picture rhyme judgment faced by BB, HS and PL could be due to a problem in lexical retrieval. Both Nickels et al (1997) and Waters et al (1992) used written rhyme judgment, which does not require lexical retrieval. It is also plausible that the picture rhyme judgment task is more difficult than the written version. To confirm a deficit in the sub-lexical output-input link, scores on both written and picture rhyme judgments would be needed.

Furthermore, BB, HS and PL all scored significantly higher on homophone decision for real words compared with non-words (Fisher exact one tailed $p=0.019$, $p=0.032$ and $p=0.002$ respectively) with BB and PL scoring within or close to the normal range for real words. Similarly, four out of five participants with AOS studied by Rochon, Caplan and Waters (1990) performed well on real word homophone judgment but scored at chance on pseudohomophone judgment where a decision was required as to whether a written non-word would sound like a real word if it were said aloud. Rochon et al (1990) argued that real word homophone judgment could be performed by using whole word phonological lexical representations whereas the pseudohomophone task required the use of sub-lexical spelling to sound correspondences, and therefore their participants must have been unable to derive phonology from written input using this method. It is possible, then, that BB, HS and PL were able to access whole word phonological information from the lexicon for real words, but had difficulty using sub-lexical spelling to sound correspondences to generate a phonological plan for non-words, which do not have a lexical representation. This is supported by the finding, discussed below, that all participants also scored very poorly on non-word repetition and reading aloud.

2.5.3 Assessment of working memory

As discussed in chapter one (section 1.4), the sub-lexical rehearsal loop that is needed to perform certain tests of phonological processing, such as picture or written rhyme judgment, is also thought to be involved in working memory (Jacquemot and Scott, 2006). Indeed, people with phonological assembly difficulties may also present with short term memory impairments (Baldo, Klostermann and Dronkers, 2008).

Participants' working memory, therefore, was examined in more detail using the PALPA digit matching span task.

The digit matching span task required participants to listen to two strings of numbers and decide whether the numbers were presented in the same or different order on the second presentation. This task was chosen instead of a digit span recall task as participants' phonological output difficulties were likely to confound verbal repetition performance. The assessment was presented in a stepwise manner whereby, if a correct answer was given for a two digit pair, the next item presented was a three digit pair, increasing in length until an incorrect answer was given, at which point the next item presented was the previous shorter length, and so on. The average score was gained by adding up the total number of digits presented (e.g. if two two-digit pairs, four three-digit pairs and two four-digit pairs were presented this would equal 24) and dividing this by the number of trials (in the previous example this would be two plus four plus two, making eight, so the average span would be three). As two strings of each length were required for comparison, the actual number of digits retained was double the average.

The normal mean score of 6 for digit matching span, shown in table 2.3, was gained from 20 participants without aphasia, aged 70 or over (Salis, personal communication). Of the four participants in the current study, PL had the greatest span memory, scoring close to the normal mean, followed by BB, HS and SD, who all scored below the normal mean, with SD's the lowest score (see table 2.3). Despite all participants scoring lower than the normal mean, an average span of more than three was achieved by all four, requiring at least six digits to be retained. In the light of the proposal made above, in section 2.5.2, that a difficulty with sub-lexical rehearsal may have impeded clients' performance on picture rhyme judgment, it might have been expected that participants would experience more difficulty with the digit span task. It has been suggested,

however, that numbers and non-number words are processed differently within working memory e.g. Jefferies, Patterson, Jones, Bateman and Lambon Ralph (2004) found that four people with semantic dementia performed normally on a digit span test but were impaired on non-number word recall. It is possible, therefore, that any difficulties with verbal sub-lexical rehearsal may have been better detected using a linguistic test of span memory, such as the task used by Caplan and Waters (1995), which required their participant to listen to a series of words and then point to pictures of the words in the correct sequence.

2.5.4 Assessment of semantics and cognitive skills

Finally, participants' ability to access the semantic representations of words from both spoken and written input was assessed using PALPA spoken and written word to picture matching (choosing a picture out of five, including semantic and visual distracters, that corresponds to a spoken or written word). Semantic comprehension is usually intact in people with phonological assembly impairments (e.g. Caramazza, Berndt and Basili, 1983) therefore participants would not be expected to have difficulty with this task. Table 2.3 shows that all four participants scored above 90% correct on spoken word to picture matching, and all participants, with the exception of SD who scored 83%, also scored above 90% on the written version.

Participants' access to non-verbal semantic information was assessed using the three picture version of the Pyramids and Palm Trees test (Howard and Patterson, 1992). This task involves deciding which of two pictures is related in meaning to a third picture. As well as assisting in distinguishing between phonological and semantic impairments, the results of the Pyramids and Palm Trees test may also be informative when considering treatment outcomes, as this assessment has been a key predictor of therapy success in other studies (Lambon Ralph, Snell, Fillingham, Conroy and Sage, 2010). HS performed within the normal cut-off of 90% on this task (see table 2.3) indicating that his access to the semantic system from pictures was largely intact. BB and PL scored just below normal limits on this test, and SD scored well below normal performance (69%), showing that her non-verbal semantic system may have been impaired, despite good access to semantics on the easier word to picture matching tasks.

Participants' non-linguistic cognitive abilities were also assessed using a test of recognition memory, the Camden Short Recognition Memory Test for Faces (Warrington, 1996), and a test of executive function and problem solving, the Wisconsin Card Sorting Test (WCST) (Grant and Berg, 1993). In a study on the use of errorless learning to treat anomia, Fillingham, Sage, and Lambon Ralph (2005) found that participants who performed well on these tests also made the greatest gains in therapy. Furthermore, Purdy and Koch (2006) demonstrated that cognitive flexibility, shown by good performance on the WCST, is important for predicting whether people with aphasia will use alternative communication strategies. These scores may therefore be relevant when explaining any differences in treatment outcomes. On the recognition memory test, participants were asked to decide whether a series of pictures of faces looked pleasant or not. Immediately afterwards, they were asked to choose which face they had seen before, from a series of pairs. On the WCST, participants were asked to match response cards to one of four stimulus cards; one red triangle, two green stars, three yellow crosses and four blue circles. Only the researcher knew the target category (colour, shape or number) and feedback was given only in respect to correct or incorrect response. Once ten consecutive cards had been matched correctly, the category changed but the participant was not informed. This continued until either all the response cards had been used or six categories had been completed. In table 2.3, scores are shown both for how many categories a correct run of 10 matches was completed, and for the percentage of participants' responses that was incorrect. This latter figure gives information about how quickly they were able to problem-solve; a high percentage of error responses is likely to indicate that participants were unable to shift from one category.

HS had no difficulty on the recognition memory test (see table 2.3), indicating good non-verbal working memory. BB and PL scored within the lower end of the normal range for elderly controls, and SD performed well below the normal range. SD and BB were both unable to perform the card sorting test. HS and PL fell at the 12th and 27th percentile respectively for percentage error responses. Given that the percentile results are determined according to the participant's age, HS made fewer error responses than PL but fell at a lower percentile due to his relatively younger age.

2.6 Assessment of spoken word production

Participants' spoken word production difficulties at the single word level were examined by comparing performance on spoken naming, repetition, reading aloud and production of non-words. Using a hierarchical model of spoken word production (Levelt et al 1999), described in chapter one (see figure 1.1), only spoken naming demands retrieval of the word's phonological form from the mental lexicon. In real word repetition and reading aloud the phonological form is provided, either auditorily or visually, respectively, and therefore the lexicon can be bypassed. In non-word repetition and reading, there is no lexical representation to be accessed. All modes of spoken output, however, must use the same phonological assembly processes prior to articulation. If a pure deficit was present at the phonological assembly level, therefore, a similar overall score would be expected across all modalities (Kohn, 1989). In contrast, if a lexical retrieval difficulty was present, a lower overall score would be expected on spoken naming, and repetition and reading aloud of words and non-words may be intact (Goldrick and Rapp, 2007). Similarly, assessment of non-word production may aid the analysis of which aspects of spoken word production were altered following therapy. A change in non-word production would only be predicted if treatment had improved participants' post lexical phonological assembly processes; no change would be expected if treatment had acted at a phonological lexical level.

On all assessments of spoken word production, responses were scored as correct if all the correct phonemes were present in the correct order, even when intonation was incorrect or articulation mildly distorted. Responses containing morphological errors (e.g. "tomatoes" for "tomato") or responses containing the target word within a longer word (e.g. "hairbrush" for "brush") were scored as incorrect. Circumlocutions, filled pauses and false starts containing only a single phoneme were not counted as a response. In the event of no response, the researcher directed participants' attention to a specific part of the picture on the naming assessment, and gave an extra presentation on the repetition assessment. No other cueing was given, and no further assistance was provided once the client had made a response. Participants' spoken responses were transcribed by the researcher online and also recorded using a Roland Edirol R-09 digital audio recorder to enable transcriptions to be checked.

In order to evaluate inter-rater reliability in scoring of the spoken word production assessments, a quasi-random sample of 10% (i.e. 13 items) of each of the four

participants' pre-therapy naming, repetition and reading aloud responses were transcribed by a Speech and Language Therapist who was not involved in the study. Of the 156 audio-recorded items that were listened to and scored by the independent rater, 147 (94%) were in agreement with the researcher regarding whether the response was correct or incorrect. Of the 78 incorrect responses, however (excluding no-responses), only 23 (29%) were transcribed identically by both the rater and the researcher. This discrepancy was partly due to disagreement in identification of the first response. Excluding those items (14) where the rater and the researcher had transcribed a different response, the percentage of agreed phonemes (i.e. the total agreed phonemes divided by the total agreed and disagreed phonemes, multiplied by 100) was 73%. This figure was judged as acceptable given the difficulties with variability in phonetic transcription (e.g. Shriberg and Lof, 1991), especially with some responses including distorted articulation, and because many discrepancies arose from the substitution of very similar phonemes (e.g. /ʌ/ for /ə/), a factor not accounted for using this method of calculation (Cucchiaroni, 1996).

The results from tests of single word spoken production for each participant at the first assessment period are presented in Table 2.4. Raw scores and proportions correct are given. The final response, i.e. including self-corrections, was scored in order to gain the most information about participants' communicative success. All participants showed a deficit in producing spoken words. HS had the highest scores across all tasks, followed by BB, then SD, with PL scoring lowest across all tasks. All participants were impaired across all modalities to some degree, and were impaired for non-words as well as real words. Using Levelt et al's (1999) model of spoken word production, described earlier, a deficit involving all spoken output tasks, i.e. a post-lexical impairment in phonological assembly, is suggested for all participants. In addition, PL showed some of the characteristics of apraxia of speech (AOS) suggested by McNeil, Pratt, and Fossett (2004), including vowel distortions, slowed speech rate and articulatory groping. Further assessment on the Apraxia Battery for Adults (Dabul, 1979) supported a diagnosis of moderate to severe AOS, with PL gaining a positive score in four of the six subtests. On the Dysarthria Profile (Robertson, 1982), PL scored within normal limits on 19/20 dimensions for facial musculature, suggesting no influence of muscular weakness on performance.

		SD	BB	HS	PL
Spoken picture naming: Nickels naming test	Total correct (n=130)	32 (.25)	48 (.37)	73 (.62)	4 (.03)
	High Frequency (n=65)	21 (.32)*	20 (.31)	37 (.57)	3 (.05)
	Low Frequency (n=65)	11 (.17)*	28 (.43)	36 (.55)	1 (.02)
	1 syllable (n=50)	16 (.32)*	20 (.40)	35 (.70)*	1 (.02)
	2 syllable (n=50)	12 (.24)*	19 (.38)	27 (.54)*	2 (.04)
	3 syllable (n=30)	4 (.13)*	9 (.30)	11 (.37)*	1 (.03)
Repetition of Nickels naming test words	Total correct	43 (.33)	79 (.61)	110 (.85)	17 (.13)
	High Frequency	24 (.37)	36 (.55)	56 (.86)	11 (.17)
	Low Frequency	19 (.29)	43 (.66)	54 (.83)	6 (.09)
	1 syllable	19 (.38)*	29 (.58)	44 (.88)*	9 (.18)
	2 syllable	20 (.40)*	31 (.62)	46 (.92)*	6 (.12)
	3 syllable	4 (.13)*	19 (.63)	20 (.67)*	2 (.07)
Reading Aloud of Nickels naming test words	Total correct	56 (.43)	69 (.53)	107 (.82)	12 (.09)
	High Frequency	32 (.49)	37 (.57)	58 (.89)*	6 (.09)
	Low Frequency	24 (.37)	32 (.49)	49 (.75)*	6 (.09)
	1 syllable	29 (.58)*	25 (.50)	46 (.92)*	6 (.12)
	2 syllable	22 (.44)*	30 (.60)	43 (.86)*	6 (.12)
	3 syllable	5 (.17)*	14 (.47)	18 (.60)*	0
PALPA 8 Nonword Repetition (n=30)		1 (.03)	12 (.40)	12 (.40)	0
PALPA 8 Nonword Reading (n=30)		0	3 (.10)	5 (.17)	0

* = significant difference at p<.05 one tailed using Fisher exact test (frequency) or Jonckheere Trend test (length)

Table 2.4: Study one participants' pre therapy assessment of spoken word production

2.6.1 Frequency and length effects

In addition to examining participants' total correct scores, the influence of psycholinguistic variables, e.g. word frequency and length, on spoken word production can also provide information about the nature of the underlying linguistic deficit. Typically, word frequency effects have been associated with lexical retrieval impairments, and word length effects with phonological assembly impairments (Butterworth, 1992). Table 2.4 shows participants' performance on high and low frequency and one, two and three syllable words on the pre-therapy spoken word production assessments, taking the final response correct score. Pairs and triplets with a significant difference are highlighted with an asterisk. A significant effect of word frequency on spoken naming was present for SD (Fisher exact test p=0.034 one tailed)

and on reading aloud for HS (Fisher exact test $p=0.034$ one tailed), with more high frequency words produced correctly than low frequency, but there were no significant effects of frequency on any other tasks, or for any other participant. Furthermore, SD and HS both showed significant effects of syllable length on all speech production tasks, with more one syllable words produced correctly than three syllable words (Jonckheere Trend Test, one tailed: for SD, naming $p=0.043$, repetition $p=0.037$ and reading $p<0.001$ and for HS, naming $p=0.003$, repetition $p=0.028$ and reading $p=0.001$). BB and PL did not show a significant effect of syllable length on any task (Jonckheere Trend Test, one tailed: for BB, naming $p=0.239$, repetition $p=0.346$ and reading $p=0.455$ and for PL, naming $p=0.457$, repetition $p=0.095$ and reading $p=0.088$).

2.6.2. Speech errors

Differential diagnosis of participants' spoken output impairments may also be aided by considering the errors produced on assessment. As phonological assembly is a common process to all spoken output tasks, the presence of a pure phonological assembly impairment would be expected to show similar error types across all tasks, whereas a lexical retrieval difficulty may present with a different pattern of errors on repetition and reading aloud in comparison to naming (Olson, Romani and Halloran, 2007).

Participants' incorrect responses on the three real word production tasks of spoken naming, repetition and reading aloud pre-therapy were classified as phonologically related, unrelated, semantically related, no response or perseveration. Error responses that were subsequently self-corrected were included in this analysis, so that the most information could be gained about the patterns of errors being produced. Where multiple error responses occurred for one item, only the first response was classified. Multiple responses are discussed in section 2.6.3.

In common with earlier studies (e.g. Olsen, Romani and Halloran, 2007) errors were classified as phonologically related if they shared 50% or more of their phonemes with the target in any order (e.g. /bɛdru:p/ for "bedroom", /kɔ:ri:/ for "holly"). Unrelated errors therefore shared less than 50% of their phonemes with the target (e.g. /bræp/ for "bear", /fɜ:n/ for "fork"). Vowel diphthongs and consonant affricates were counted as single phonemes for the purpose of this analysis. Phonologically related errors were considered to reflect a phonological encoding impairment; while the correct lexical

form had been retrieved, difficulties occurred in the process of assembling the phonemes (Buckingham, 1992). The source of unrelated errors is more ambiguous. They could occur because (a) an incorrect, unrelated, word form has been retrieved from the lexicon (b) a severe phonological assembly difficulty has rendered the correct word form unrecognisable or (c) through a combination of both (Dell et al, 1997). The semantic error category incorporated real words with a broad semantic relationship to the target (including those that were semantically and phonologically related to the target) as well as non-words that shared 50% or more of their phonemes with a semantically related word (e.g. “pear” for “lemon”, /bi:kəl/ for “spider”). Semantic errors were taken as evidence that an incorrect lexical form had been retrieved (Nickels, 1997). No-responses included those items where participants produced a circumlocution or a comment on the task but did not actually make an attempt at the target, as well as those items where nothing was produced. This type of error could occur either because of a difficulty retrieving any information from the lexicon or for reasons such as a motor speech difficulty. Perseverations were defined as either a whole or part word repetition (e.g. /wɪnd/ was a part word repetition of an earlier response /wɪndəʊ/), of a word or non-word that had already been produced at any earlier point in the assessment. This could have been either a correct or an error response, and could have occurred at any point during the response. Perseverations that were semantically or phonologically related to the target were included in the perseveration error category but blended perseverations, i.e. responses incorporating repetition of phonemes from previous words, were not. According to Moses, Nickels and Sheard (2007) perseverations occur when the residual activation from a previously produced word is greater than the activation from the target, which can be due to reduced language processing efficiency at any level.

Figure 2.1 shows the different types of error made by each participant on spoken naming, real word repetition and reading aloud pre-therapy, as a proportion of the total number of incorrect first responses. Error percentages for naming both the full 130 items from the Nickels naming test and for an edited set of 63 of the items which gained 90% naming agreement with elderly controls are shown, as the remaining 67 items achieved 90% naming agreement only with younger controls (Nickels and Howard, 1994).

For SD, BB and HS, performance in repetition and reading aloud were similar (see figure 2.1). The majority of errors on these tasks were phonologically related to the target, supporting the diagnosis of a post-lexical phonological assembly impairment. On spoken naming, however, these three participants made a range of different error types, including many semantically related errors, suggesting an additional lexical retrieval difficulty. The edited set of words, described above, excluded those pictures with poor naming agreement in older controls, such that errors produced by participants on words from the edited set were unlikely to have been caused by difficulties interpreting the picture. The finding, therefore, that SD, BB and HS still produced a sizeable proportion of semantically related errors on the edited set, supports a lexical retrieval difficulty that is greater than normal variation in picture naming.

PL's pattern of errors was different to that of the other three participants. His was the most consistent across the three tasks, showing very few semantic errors, but with high numbers of no responses across all three tasks. PL also produced more perseverations than any other participant, particularly on reading aloud and mainly consisting of non-word fragments that recurred over several consecutive items. While verbal recurrent perseverations are common in severe AOS (Wambaugh and Mauszycki, 2010), the small volume of literature in this area has concentrated on people with aphasia. Moses et al's (2007) proposal, however, that perseverative errors can be due to reduced language processing efficiency at any level is still likely to be applicable in clients with AOS. It may be assumed that when PL was unable to activate the motor plans for the target word, he acted in the same way as a client unable to retrieve anything from the lexicon (e.g. Ackerman and Ellis, 2007); he either made no attempt, or he produced the only movement that was available in order to fill the gap where a response was expected; the previously activated earlier response.

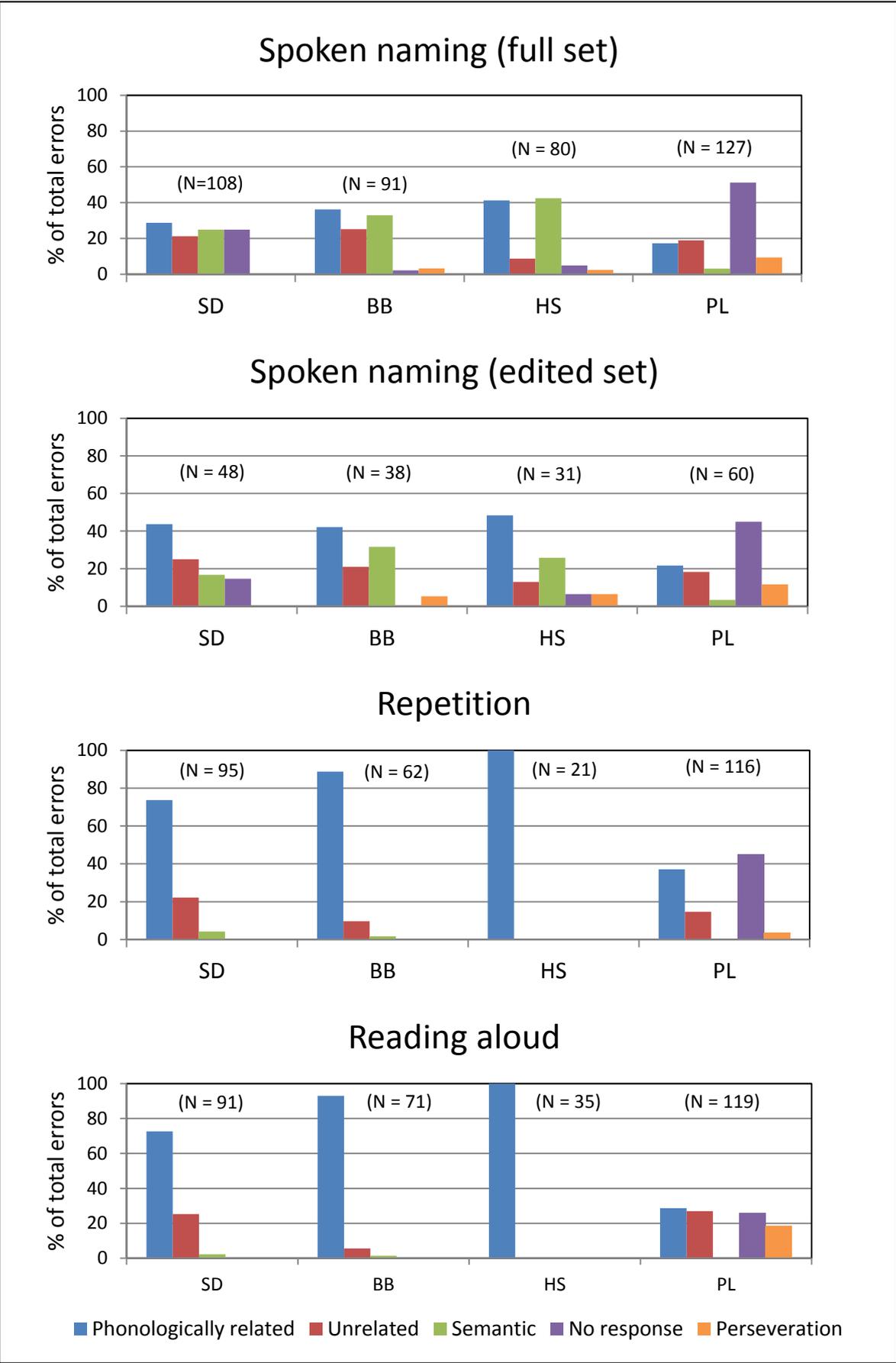


Figure 2.1: Study one participants' speech error types on pre-therapy naming, repetition and reading aloud

2.6.3. Errors with multiple attempts

In addition to examining error types on the first response, participants' multiple attempts at the target on the tests of spoken word production were analysed (see figure 2.2). The proportion of incorrect responses, excluding items named correctly straight away and items with no response, which were (a) not followed by any further attempt at the target, (b) followed by at least one further incorrect attempt (including items where the first response was simply repeated) and (c) successfully self-corrected, are shown in figure 2.2 in green, red and blue respectively.

The combination of red and blue areas represents the total proportion of error responses that were followed by at least one further attempt. This combined figure is taken as an indication of monitoring ability, highlighting that participants were aware that their first response was wrong and that they needed to correct it. It is however likely to be an underestimate of participants' awareness of their errors as, for each of the four participants, there were several occasions when they showed awareness of being incorrect (e.g. saying "no") but then did not produce another response. Furthermore, there were no occasions when any participant produced a word correctly immediately but then went on to have a further, incorrect attempt, lending further support to the proposal that their monitoring ability was good. In spoken naming, all participants had one or more further attempts at the target, on at least 50% of their errors. In repetition, the proportion of errors that were followed by another attempt was less than in naming for all participants, a factor possibly attributed to the more transient nature of the stimulus, whereas in reading aloud, the pattern was more variable. PL had the greatest proportion of error responses with more than one attempt (78% across all three tasks) and BB had the lowest (40% across all tasks). Despite these many attempts at the target, however, for SD, BB and PL, few of these resulted in the correct target (shown by the blue areas of figure 2.2). This pattern was especially marked for PL who made the fewest self corrections (2% of his total error responses over all three tasks). HS made more self-corrections than the other participants but was still only able to successfully correct 27% of his total error responses over all three tasks.

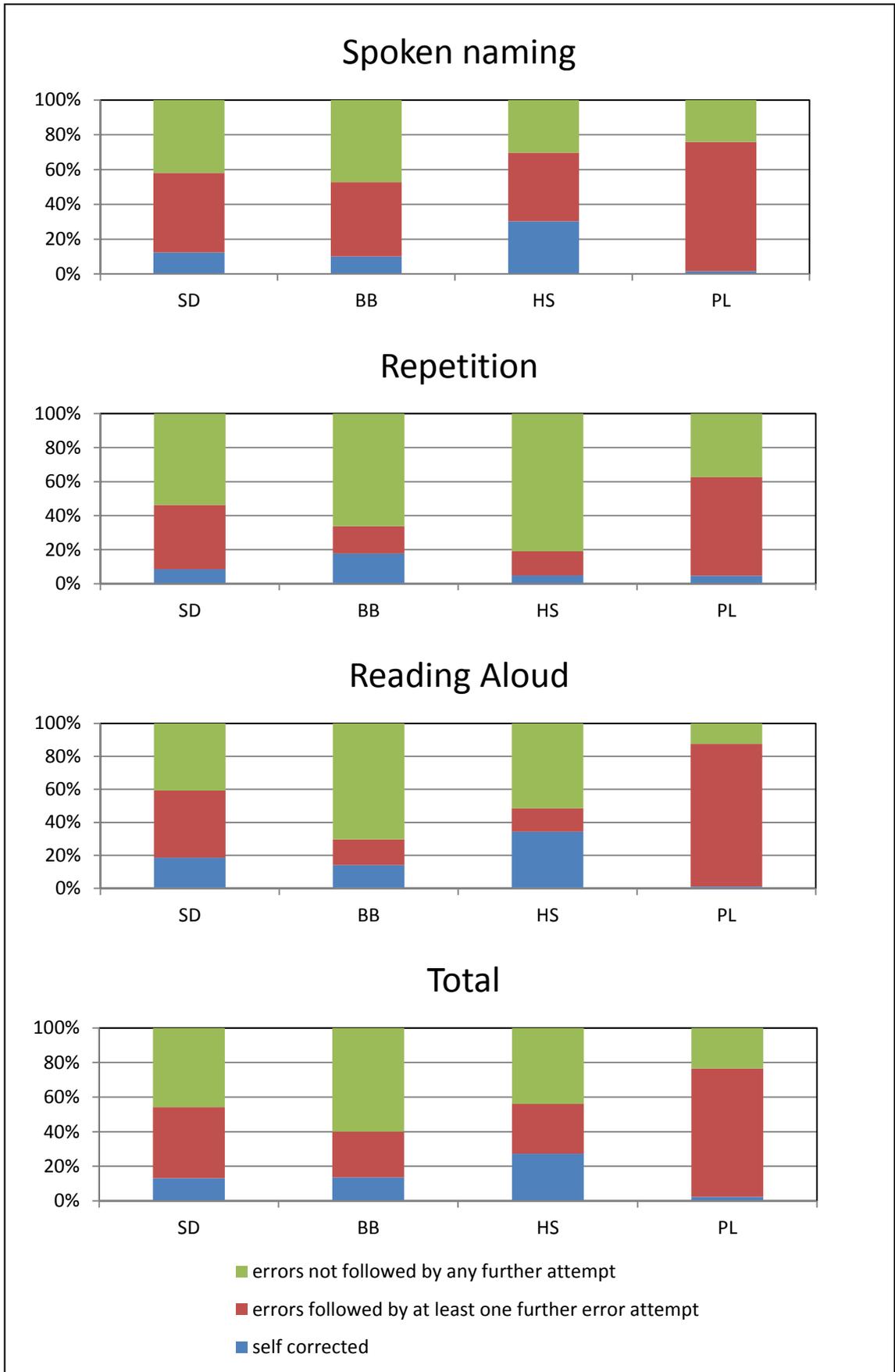


Figure 2.2: Study one participants' multiple error responses on pre therapy naming, repetition and reading aloud

2.7 Summary of linguistic impairments

In summary, all four participants showed evidence of a post-lexical phonological assembly deficit, with all spoken output modalities impaired, phonological errors occurring on all output tasks, and SD and HS showing effects of word length on spoken production. In addition, SD, BB and HS presented with co-occurring lexical retrieval difficulties, evidenced by semantic errors on picture naming and lower scores on naming compared with repetition and reading, and additionally an effect of word frequency on naming for SD. In contrast, PL had co-occurring AOS, shown by many no-responses on all tasks, and features such as vowel distortions and articulatory groping.

2.8 Therapy procedure

Participants received two consecutive treatment phases, replicating the therapy protocol set out by Franklin et al (2002). The two phases of therapy were given in the same order to all participants in order to achieve a true replication of Franklin et al's (2002) therapy, which viewed the first auditory discrimination phase to be a necessary precursor to the second monitoring phase. Participants were seen for therapy twice a week in their homes with sessions of approximately 45 minutes duration. The first phase of therapy aimed to improve auditory discrimination and was administered over six sessions. Tasks were (1) single sound to letter matching, (2) selecting the initial or final sound for a spoken word, (3) deciding whether two heard words had the same or different final sound, (4) and choosing a written word that rhymes with a spoken word. The second phase of therapy aimed to improve monitoring of speech errors and took place over 14 sessions of a similar length. There were three stages within the second phase. For the first six sessions of the monitoring therapy, participants listened to the therapist naming a picture and were required to decide if the word sounded right or wrong. If the therapist had named the picture correctly, participants repeated the word back before moving on to the next item. If the therapist had made an error, participants were asked to decide whether the phonological error was at the beginning, middle, or end of the word (by pointing to a written prompt sheet), and then they were asked to produce the word correctly. In the next four sessions, the participants were audio recorded while they named the pictures themselves. They then heard their responses played back and were asked to decide if they had said the word correctly. If they had

made an error, they had to decide on the location of their error and then correct themselves. In the final four sessions, this was carried out without the audio recording and participants were asked to make the judgments about their own errors online. During all three stages of the monitoring therapy, if participants made an incorrect judgment about the location of either the therapists' or their own error, a series of steps of feedback was used. First, the therapist wrote down the incorrect response alongside the "beginning, middle or end" prompt sheet, and asked participants to point to the error. If they were still incorrect, the therapist told them which part of the word was wrong (by crossing out that part of the written word) and participants were then asked to try and produce the word correctly. In the final stage, the correct replacement sound was given by the therapist, in both spoken and written forms, and then a model of the whole word was provided for repetition if necessary.

The only change made to the procedure used by Franklin et al (2002) was that participants were given homework after every session, introduced to maximise therapy effects and in response to the participants' keenness to carry out work independently. All homework was based on the same tasks that were carried out in the session. For the phase one auditory discrimination homework tasks, the participant's family member was required to read aloud words while the participant chose, for example, the first or final sound from a written sheet. As the phase two monitoring therapy tasks were less transferable into home practice, a simplified version of the task was given, omitting the stage where participants decided whether the therapist's error or their own error was at the beginning, middle or end of the word. Instead, once participants had decided whether the picture had been named correctly, they were asked to have a further attempt and, if unsuccessful, a model was provided for them to copy.

2.9 Summary

This chapter has described the participants and the design of study one. Four participants with aphasia were recruited; three with impaired phonological assembly with additional lexical retrieval difficulties and one with impaired phonological assembly with concomitant apraxia of speech. All received two consecutive phases of therapy, replicating Franklin et al's (2002) auditory and monitoring treatment. Assessment took place on two occasions prior to therapy, after each therapy phase and

then two months after therapy. Chapter three will set out the outcomes for each participant following intervention.

Chapter 3 Results Study One

3.0 Aims of chapter

This chapter will describe the results of therapy for the four participants in study one. As reported in chapter two, therapy consisted of the two phases outlined in Franklin et al's (2002) study, the first being an auditory therapy phase and the second a monitoring therapy phase. Naming, repetition and reading aloud of all the Nickels naming test items were assessed after each therapy phase. Selected tests from the pre-therapy background assessment battery were also repeated after the second therapy phase in order to examine any broader language changes. The final response correct score was used for all analysis on the spoken word production tests, i.e. including self-corrections.

3.1 Control measures

No participant showed any significant improvement on the written TROG between the start and end of therapy (see table 3.1) nor showed any significant change in spoken naming between the repeated baselines of the two pre-therapy naming assessments, taken one month apart (see table 3.2). Taken together, this supports the hypothesis that any positive changes in spoken word production seen after treatment were due to therapy.

	SD	BB	HS	PL
Written TROG pre therapy	25/44 (.56)	45/60 (.75)	63/80 (.79)	40/52 (.77)
Written TROG post therapy	29/44 (.66)	46/60 (.77)	67/80 (.84)	41/52 (.79)
McNemars test (one tailed)	p=0.194	p=0.500	p = 0.212	p=0.500

Table 3.1 Study one participants scores pre and post therapy on written TROG

	SD	BB	HS	PL
Naming Pre therapy 1	32 (.25)	48 (.37)	73 (.56)	4 (.03)
Naming Pre therapy 2	25 (.19)	42 (.32)	82 (.63)	6 (.05)
McNemars test (one tailed)	p=0.946	p=0.854	p=0.088	p=0.313

Table 3.2 Study one participants scores on pre-therapy spoken naming repeated baseline (n=130)

3.2 SD therapy outcomes

SD's scores in naming, repetition and reading aloud of treated and untreated items from the Nickels naming test at all assessment points during the study are shown in figure 3.1. For all participants, scores were analysed using a one tailed McNemar's test, to compare successive tests, and a one tailed Fisher exact test, to compare treated and untreated items at each testing occasion. There was a significant improvement in the number of treated items named correctly by SD after phase one of therapy, compared with her previous pre-therapy 2 score (McNemar's $p=0.001$ one tailed), but naming of untreated items did not improve ($p=0.073$). A significant difference was seen between treated and untreated items (Fisher exact $p=0.005$ one tailed) after phase one of therapy. No change was seen in SD's spoken naming scores after phase two of therapy when compared to scores after phase one ($p=0.598$ and $p=0.500$ for treated and untreated items respectively). When assessed two months following therapy, SD's score on naming of treated items had fallen slightly such that the difference between naming of treated and untreated items was no longer significant ($p=0.095$), however, her score in naming of treated items was still significantly higher than it had been before therapy ($p=0.011$ comparing pre-therapy 2 score with 2 months post therapy score). SD also showed a significant improvement in repetition of treated items after phase one of therapy ($p=0.038$) but repetition of untreated items did not improve ($p=0.192$) and there was no further improvement in repetition after phase two of therapy ($p=0.500$ and $p=0.895$ for treated and untreated items respectively). SD showed no significant change in reading aloud after phase one ($p=0.192$ and $p=0.166$ for treated and untreated items

respectively) or phase two of therapy ($p=0.500$ and $p=0.910$ for treated and untreated items respectively). At the end of both treatment phases, SD showed a significant improvement in auditory discrimination of word minimal pairs, (56/72 compared with 38/72 pre therapy, $p=0.001$) but not in auditory lexical decision (138/160 compared with 129/160 pre therapy, $p=0.094$).

3.3 BB therapy outcomes

BB's scores in naming, repetition and reading aloud of treated and untreated items from the Nickels naming test, at all assessment points during the study, are shown in figure 3.2. As with SD, the number of treated items named correctly by BB improved significantly after phase one of therapy compared with the previous pre-therapy 2 score ($p=0.047$) but naming of untreated items did not improve ($p=0.324$). There was a significant difference between treated and untreated sets ($p=0.004$) after phase one of therapy. No significant change in BB's naming was seen after phase two of therapy when compared to performance after phase one ($p=0.212$ and $p=0.895$ for treated and untreated items respectively). The improvement in naming of treated items was not, however, maintained two months after the end of the study ($p=0.155$ comparing pre-therapy 2 score with 2 months post therapy score) although the difference between treated and untreated sets remained significant ($p=0.001$). BB showed no significant change in repetition or reading aloud of treated or untreated items after either therapy phase. After therapy, BB's auditory discrimination of word minimal pairs did not change significantly (66/72 compared with 61/72 pre-therapy, $p=0.166$), and neither did auditory lexical decision performance (67/80 compared with 69/80 pre-therapy, $p=0.387$).

3.4 HS therapy outcomes

HS's scores in naming, repetition and reading aloud of treated and untreated items from the Nickels naming test, at all assessment points during the study, are shown in figure 3.3. HS showed a significant improvement in the number of treated items named correctly after phase one of therapy compared with his previous pre-therapy 2 score ($p=0.032$). Unlike SD or BB, there was a further significant improvement in naming of treated items after phase two of therapy ($p=0.006$). He did not show any significant improvement in naming of untreated items ($p=0.773$ following after phase one and

$p=0.113$ after phase two). Significant differences were seen between treated and untreated sets after both therapy phases ($p=0.004$ and $p=0.001$, respectively). As with SD, on reassessment two months after the end of therapy, HS's score in naming of treated items had fallen slightly but was still significantly higher than it had been before therapy ($p=0.006$ comparing pre-therapy 2 score with 2 months post therapy score). HS did not show any improvement in repetition after phase one of therapy ($p=0.927$ and $p=0.788$ for treated and untreated items respectively), but he did show a significant improvement in repetition of treated ($p=0.001$) and untreated items ($p=0.029$) after phase two of therapy in comparison with his previous scores after phase one. HS showed no improvement in reading of treated items after either therapy phase ($p=0.113$ and $p=0.313$ after phase one and phase two respectively). He did show a significant improvement in reading of untreated items after phase one ($p=0.011$), but not after phase two ($p=0.969$). HS did not show any difficulty with minimal pair discrimination or lexical decision at the first assessment so these were not re-tested after therapy.

3.5 PL therapy outcomes

PL's scores in naming, repetition and reading aloud of treated and untreated items from the Nickels naming test, at all assessment points during the study, are shown in figure 3.4. No significant changes were seen in PL's spoken naming over successive tests after either therapy phase for treated or untreated items. After phase two of therapy, there was a significant difference between naming of treated and untreated sets ($p=0.019$) due to a small increase in the score for treated items and a decrease in the score for untreated items, but at all other assessment periods the difference between sets was not significant. PL showed no significant improvement in repetition of treated or untreated items, in fact his scores on real word repetition decreased over the course of the study. His reading aloud of treated words did improve significantly after phase one of therapy ($p=0.011$) but returned to pre-therapy levels after phase two, and no change was seen in reading aloud of untreated items ($p=0.637$ and $p=0.938$ after phase one and phase two respectively). When PL's auditory discrimination was re-tested after therapy, there was no change in his scores on word minimal pair discrimination and no significant change on auditory lexical decision (146/160 compared with 141/160 pre-therapy, $p=0.192$).

3.6 Changes in speech errors

In addition to examining any changes in the total number of words produced correctly after therapy, participants' speech error types were analysed after each therapy phase with a view to obtaining any insights into the mechanism of treatment (Bose, Laird, Rochon and Leonard, 2011). Only errors produced on spoken naming were analysed as this task showed the greatest change in total number correct after therapy, and a greater variety of error types were produced on this task pre-therapy, in comparison with repetition and reading, suggesting greater potential for change. Figure 3.5 presents the numbers of different error types produced by each participant in naming of treated and untreated items as a proportion of the total number of error responses before therapy and after each therapy phase. As with the analysis of speech errors before therapy (see chapter two, section 2.6.2), participants' first responses were used such that errors that were subsequently self-corrected were included.

For SD, there was a significant change in error type in naming of treated items after therapy (chi square (8) = 17.37 $p=0.027$) but not for untreated items (chi square (8) = 11.08 $p=0.197$). The proportion of phonologically related errors made by SD in spoken naming increased for treated items after the second phase of therapy only (see figure 3.5). For BB, there was a significant change in error type in naming of treated items (chi square (8) = 21.81 $p=0.005$) and a trend towards a change in untreated items (chi square (8) = 15.22 $p=0.055$). Figure 3.5 shows that, like SD, the proportion of phonologically related errors made by BB increased for treated items after the second phase of therapy, but additionally, when naming untreated items, the proportion of unrelated errors decreased and the proportion of semantic errors increased during this period. For HS, there was no significant difference in error type for naming of treated items (chi square (8) = 4.75 $p=0.784$) or untreated items (chi square (8) = 7.75 $p=0.458$), although a trend was seen, after both phases of therapy, towards an increase in the proportion of phonologically related errors and a decrease in the proportion of semantic errors for both treated and untreated items (see figure 3.5). For PL, there was a significant change in error type in naming of treated items after therapy (chi square (8) = 21.13 $p=0.007$) but not for untreated items (chi square (8) = 9.55 $p=0.298$). Figure 3.5 shows an increase in phonologically related errors and a decrease in no responses in naming of treated items after the first phase of therapy, with the proportions returning to pre-therapy levels after the second phase. This could reflect either an improvement in PL's

phonological processing after the first therapy phase or simply an increase in willingness to respond.

3.7 Changes in self-correction

Given the focus on monitoring in the second therapy phase, self-correction of spoken naming errors was also studied for evidence of any change following intervention. As with the examination of changes in speech error types, it was anticipated that this may contribute to hypothesising the mechanism by which treatment had worked. The self-correction skills of Franklin et al's (2002) client MB were unchanged after therapy; rather she produced more words correctly straight away. This was interpreted by Franklin et al as evidence that MB's phoneme assembly processes had improved, rather than her monitoring ability.

Figure 3.6 shows the proportion of naming errors, excluding no responses, for each participant that were (a) not followed by any further attempt at the target, (b) followed by at least one further incorrect attempt and (c) successfully self-corrected, in green, red and blue respectively, for treated and untreated items, pre-therapy, post therapy phase 1 and post therapy phase 2. Any significant changes after therapy were identified using a Jonckheere trend test, taking the number of self-corrections as a proportion of the total number of error responses with more than one attempt (i.e. the size of the blue area, out of the combined red and blue parts of the graphs in figure 3.6).

SD and BB showed no significant change in the proportion of self-corrections on naming of either treated or untreated items across the three time conditions. Both HS and PL, however, showed significant gains in the proportion of errors that were self-corrected in naming of treated items after therapy ($p=0.036$ and $p=0.047$ respectively) with no change on untreated items ($p=0.500$ and 0.433 respectively). It is not possible to ascribe the change on treated items to either one of the two treatments in particular given the significant trend observed over both treatment periods. This improvement in self-correction of treated items shown by PL may explain the difference in total naming score between treated and untreated items found after therapy phase two. For HS, meanwhile, the increase in proportion of errors that were self-corrected may reflect not only an improvement in self-correction ability but also improved naming more

generally i.e. HS named more pictures correctly immediately after the second phase of therapy, meaning that far fewer error responses were produced.

3.8 Changes in non-word production

Further information about the effect of treatment on participants' phonological output abilities was gained by examining non-word repetition and reading aloud (PALPA subtest 8) before therapy and after the second, monitoring, phase of therapy. The total number of non-words produced correctly by each participant, including self-corrections, before and after therapy, as well as the mean number of correct phonemes present in the most accurate response (including correct responses) is set out in figure 3.7. The latter would reflect any change in the phonological similarity of participants' attempts compared with the target, even if their total correct score did not change. Mean phonemes correct scores were calculated by totalling the number of phonemes shared between each response and the target, and dividing this figure by the total number of responses (i.e. excluding no responses). Where there was more than one response for an item, the most accurate was defined as that which shared the greatest proportion of phonemes with the target. The mean number of phonemes in the target non-words, for comparison, was 5.1.

For SD, repetition and reading of non-words remained virtually at floor levels post therapy, and her responses actually contained fewer correct phonemes post therapy (see figure 3.7). Similarly, no significant changes were seen in BB's non-word repetition or non-word reading scores (McNemar's one tailed $p=0.656$ and $p=0.145$ respectively), and there were also no significant changes in the mean number of correct phonemes produced by BB on either task (Wilcoxon matched pairs one tailed $p=0.310$ and $p=0.166$ for non-word repetition and reading respectively). HS also showed no significant change in non-word repetition and non-word reading scores after therapy ($p=0.055$ and $p=0.172$ respectively), although there was an increase in repetition that approached significance. There was, however, a significant increase in the mean number of phonemes produced correctly by HS in non-word repetition after therapy ($p=0.006$), but not in reading ($p=0.500$). PL's reading and repetition of non-words remained at floor levels after therapy and, as with SD, his responses contained fewer correct phonemes post therapy.

3.9 Participants' performance on therapy tasks

During the monitoring therapy phase, differences in how participants performed the tasks were observed, in contrast with the auditory therapy tasks, which were completed in a similar way by all participants. Best, Howard, Bruce and Gatehouse (1997) argued that investigation of what happens during therapy tasks may aid understanding of the underlying treatment process. Participants' performance on the monitoring therapy, therefore, was analysed by separating the main task components, and the results are shown in figure 3.8. The monitoring therapy phase consisted of three stages (see chapter two, section 2.8). In stage one, the three main components were (a) deciding whether the therapist had named a picture correctly, (b) if incorrect, deciding whether the error was at the beginning, middle, or end of the word and (c) producing the word correctly (including repetition if the therapist's production was correct to begin with). All four participants could judge the therapist's production as correct or incorrect with a high degree of accuracy (between 89% and 99% of items, see figure 3.8). The error location judgment was more difficult for all, but there was variation, with BB the most successful (78% of items) and SD the least (41% of items, which was not significantly better than chance, Binomial test exact one tailed $p=0.149$). On production of the word there was also wide variation between participants, with HS able to produce 97% of words correctly, BB 86%, SD 53% and PL only 20% (see figure 3.8).

Stages two and three of the monitoring therapy contained four main task components. Participants were required to (a) name a picture, (b) decide whether their own production was correct, either after listening to an audio recording (stage two) or immediately after production (stage three), (c) decide whether their own error was at the beginning, middle, or end of the word (with the help of an audio recording in stage two but not in stage three), and (d) produce the word correctly. All participants were good at deciding whether their own productions were correct (between 89% and 99% of items, see figure 3.8). The biggest difference seen between participants was in the proportion of words produced correctly, particularly at the end of the tasks. During therapy, HS named 95% of pictures correctly straight away, including immediate self-corrections (i.e. without needing the error location judgment task). Furthermore, of those that were not correct initially, 90% were named correctly after making the error location judgment (see figure 3.8). In contrast, SD, BB and PL named fewer pictures correctly straight away (67%, 79% and 23% respectively), and, most importantly, of those pictures that were not named correctly initially, most were still not produced correctly following the

error location judgment (only 19%, 34% and 21% correct respectively, see figure 3.8). As described in chapter two, if participants did not decide correctly on the location of their error during therapy tasks, a series of additional cues was provided by the therapist, regarding the part of the word that was wrong and the correct replacement sound, culminating in the provision of the correct word form for repetition. SD, BB and PL, however, frequently persisted in production of their original error response and were unable to produce the word correctly, despite the extra cues.

3.10 Summary

This chapter has reported treatment outcomes for the four participants in study one. Three participants, SD, BB and HS, significantly improved in naming of treated items after the first, auditory discrimination, phase of therapy, but only HS made further significant gains in naming of treated items after the second, monitoring, phase of therapy, and no participant made any improvements in naming of untreated items. The fourth participant, PL, did not show any significant improvement in naming of treated or untreated items after either phase of therapy. Limited improvements were seen in repetition and reading aloud. After the first therapy phase there were significant gains in SD's repetition of treated items, HS's reading of untreated items and PL's reading of treated items. Further, following the second therapy phase, HS's repetition of treated and untreated items significantly improved. In addition, in naming of treated items, SD and BB showed a significant change in the types of speech error produced, with a greater proportion of phonologically related errors after therapy, and HS and PL made a significant gain in the proportion of errors that were self-corrected. In non-word repetition, HS showed significant gains in the phonological similarity of his responses compared with the target, as well as an increase in total non-words repeated correctly that approached significance. No other significant changes in non-word production were seen for the other participants. Implications of these findings will be discussed in chapter four.

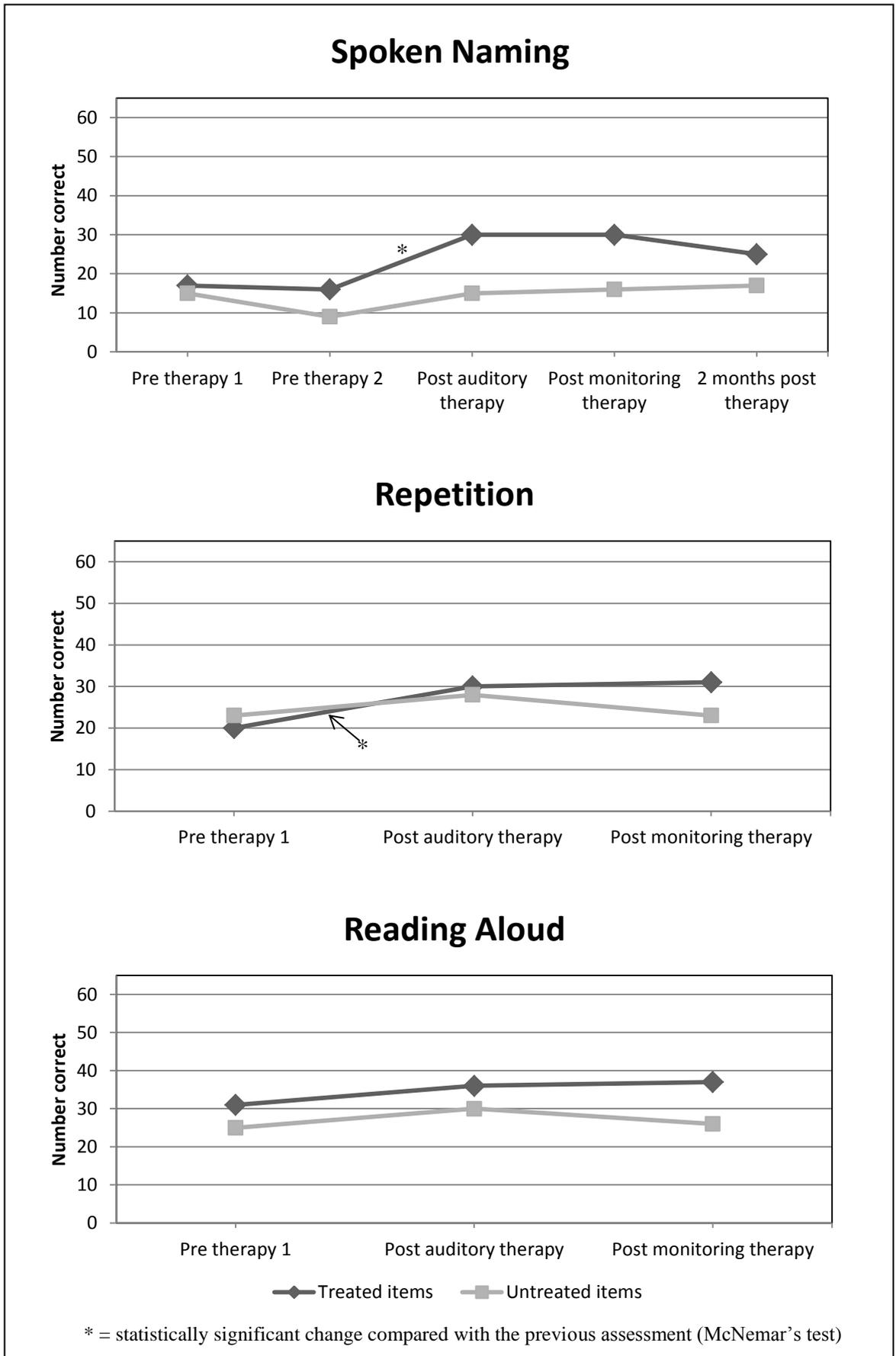


Figure 3.1 SD Spoken word production assessment results post therapy

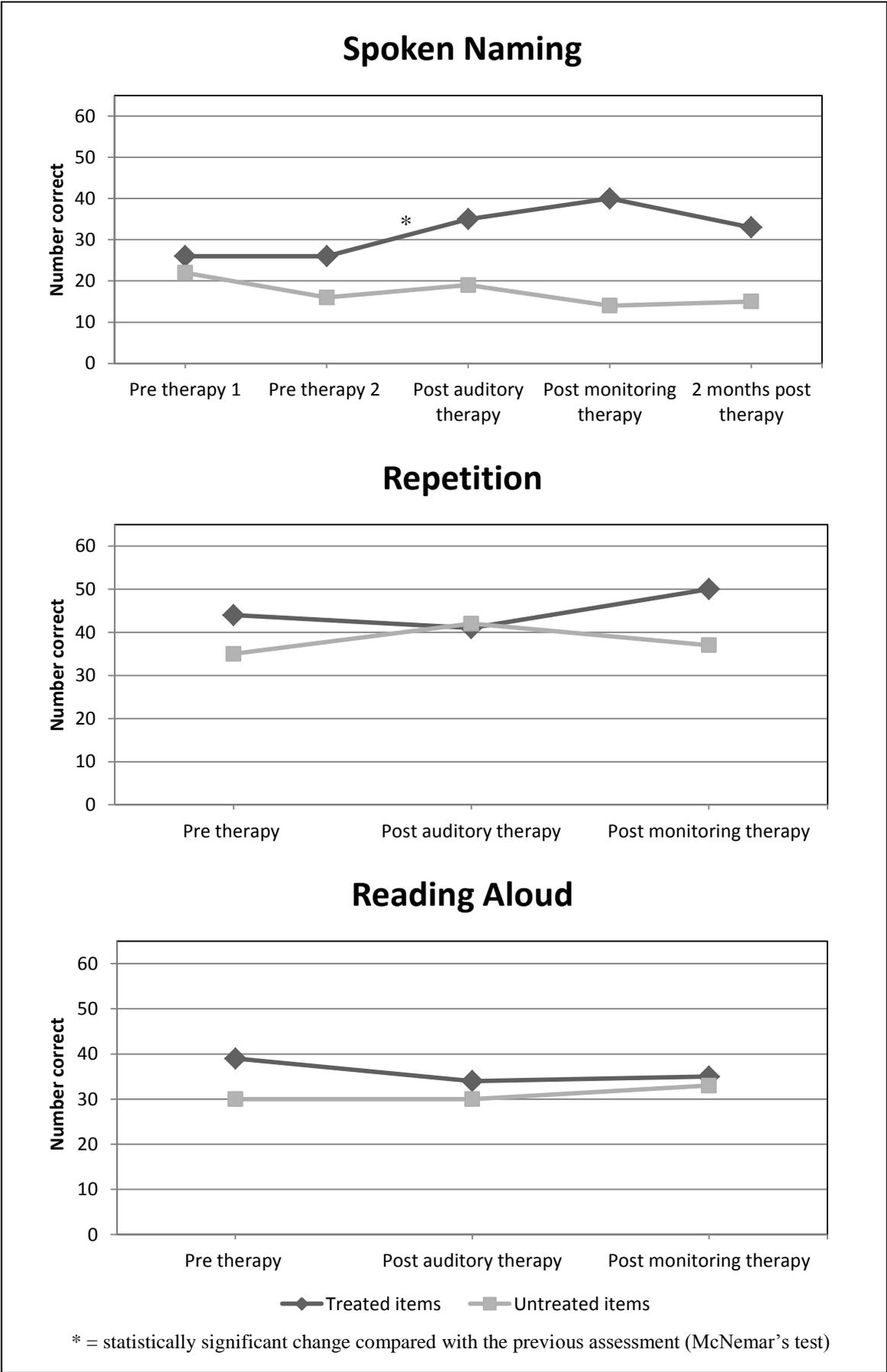


Figure 3.2 BB Spoken word production assessment results post therapy

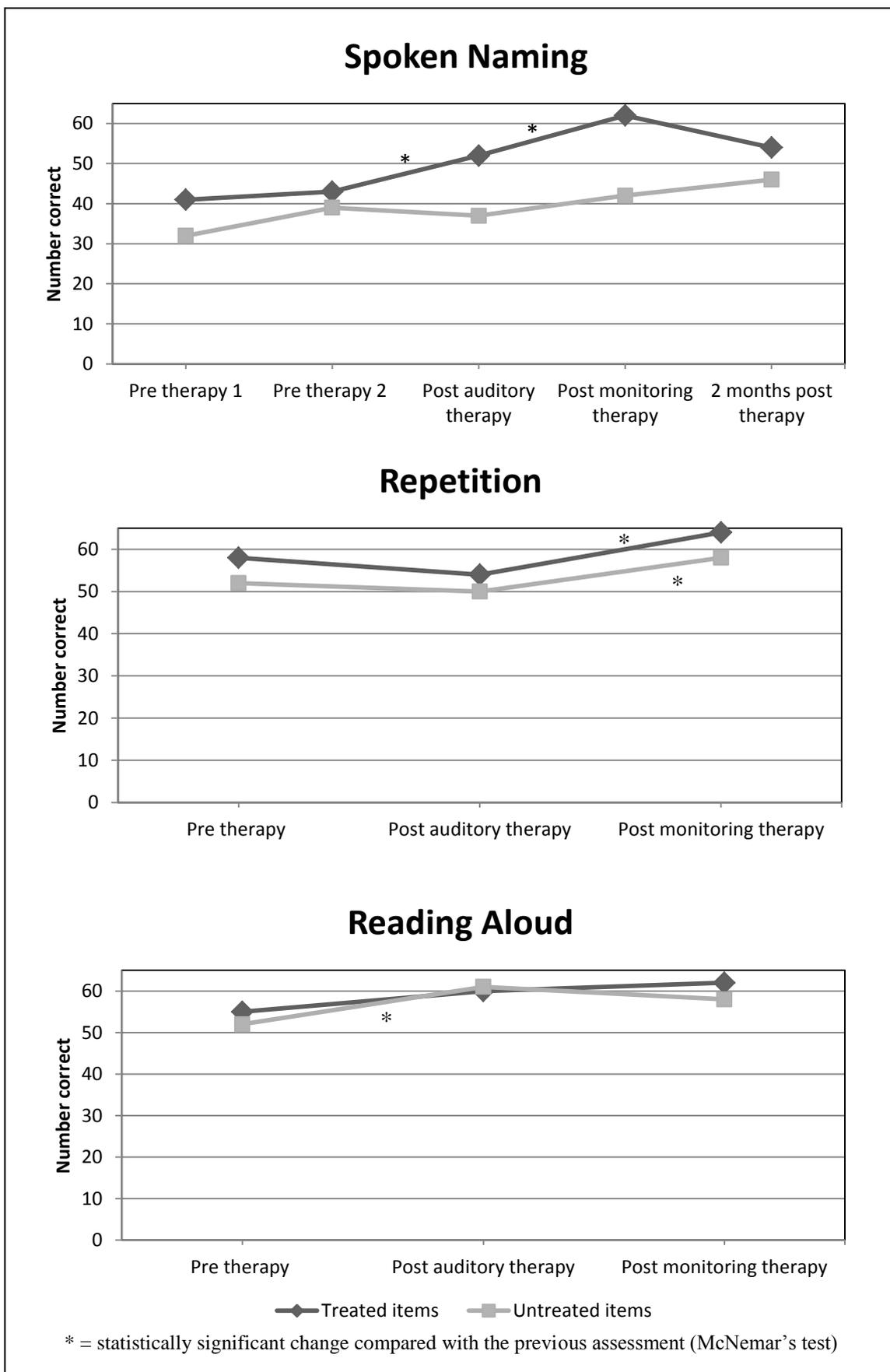
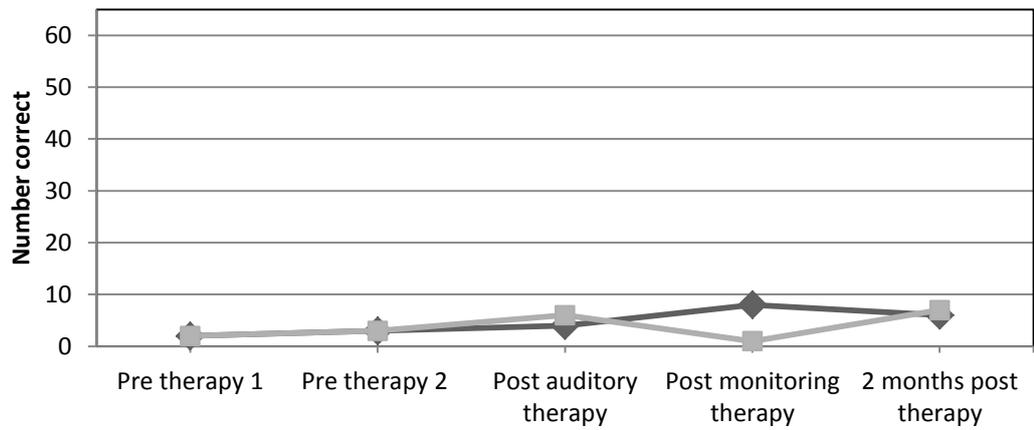
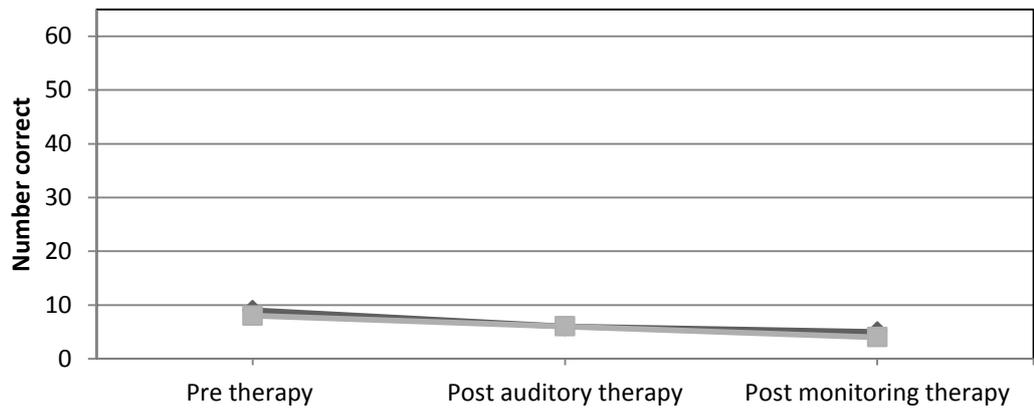


Figure 3.3 HS Spoken word production assessment results post therapy

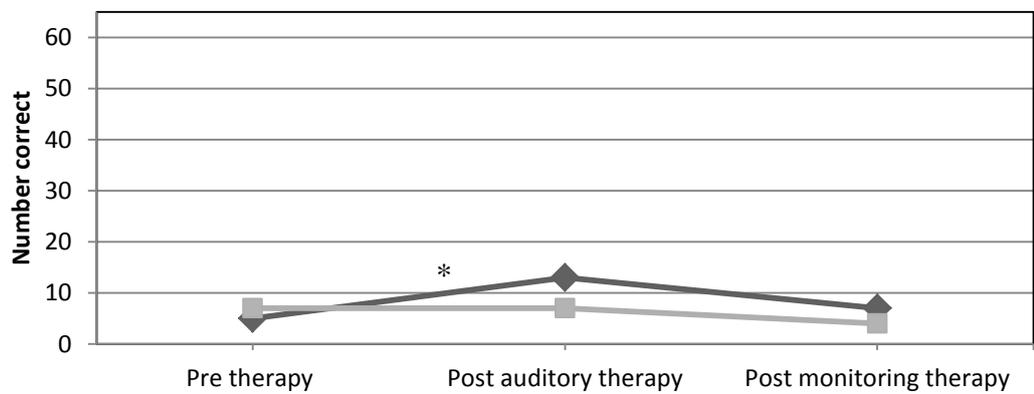
Spoken Naming



Repetition



Reading Aloud



* = statistically significant change compared with the previous assessment (McNemar's test)

Figure 3.4 PL Spoken word production assessment results post therapy

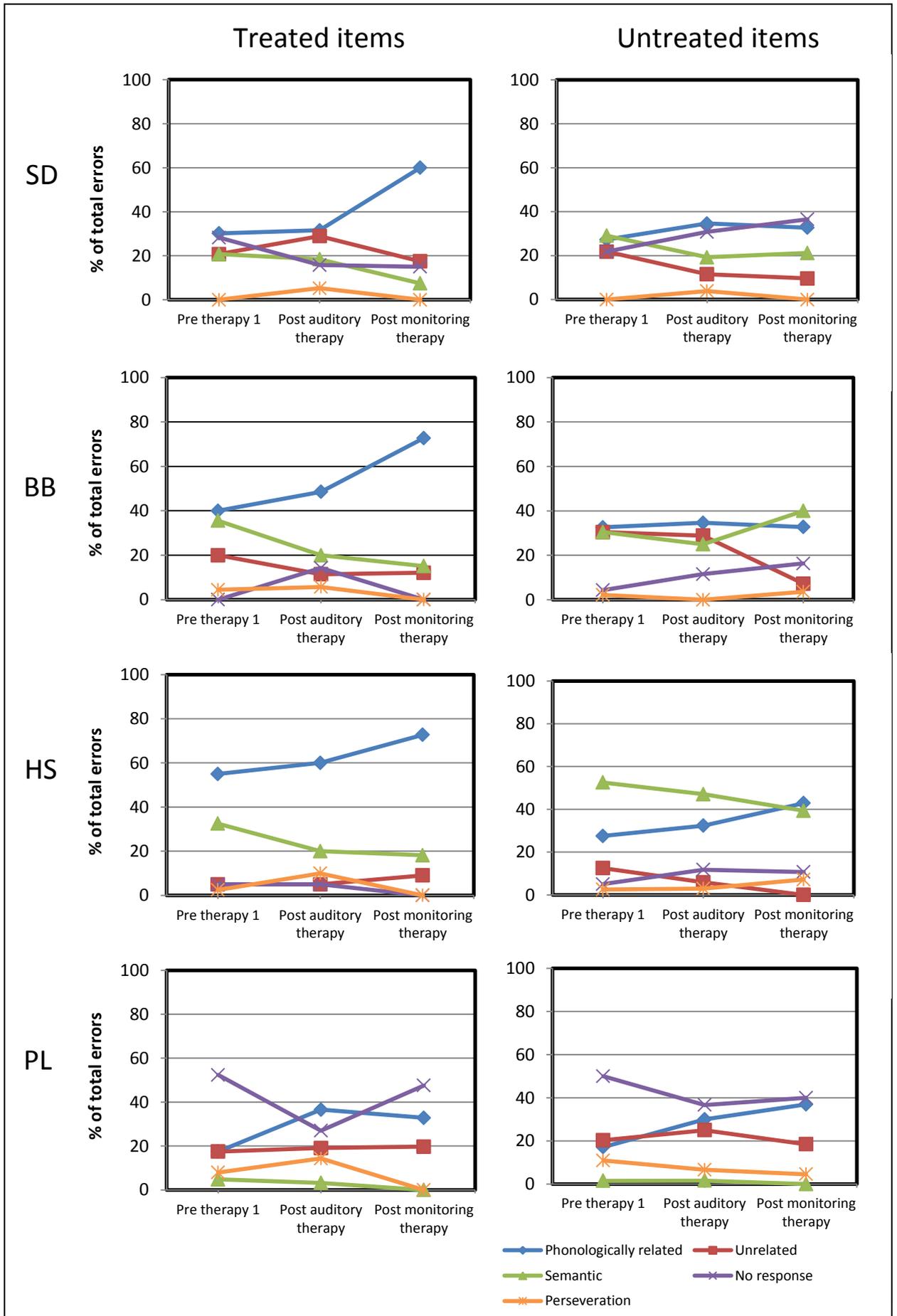


Figure 3.5: Changes in speech error types on spoken naming after therapy

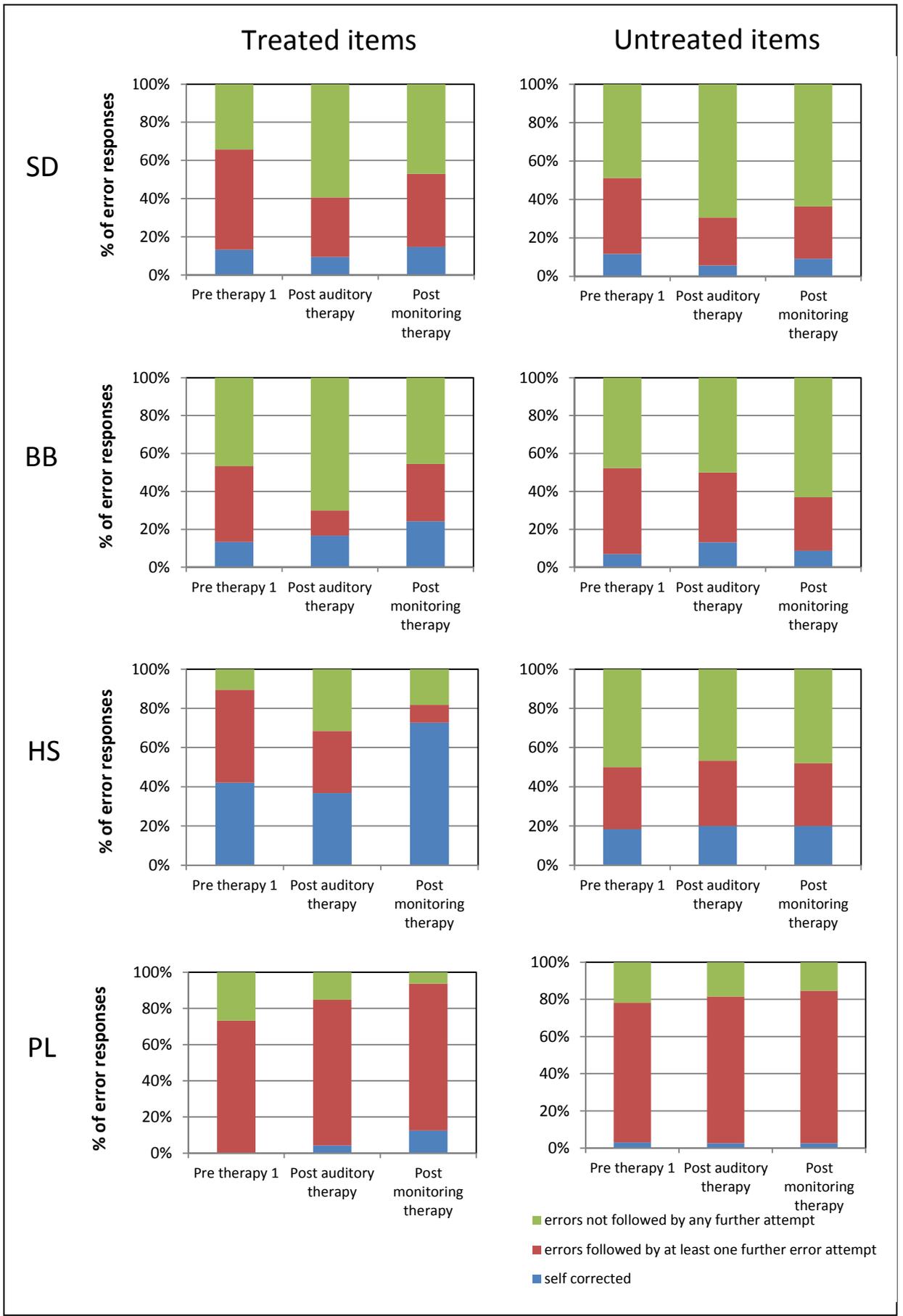


Figure 3.6 Changes in monitoring on spoken naming after therapy

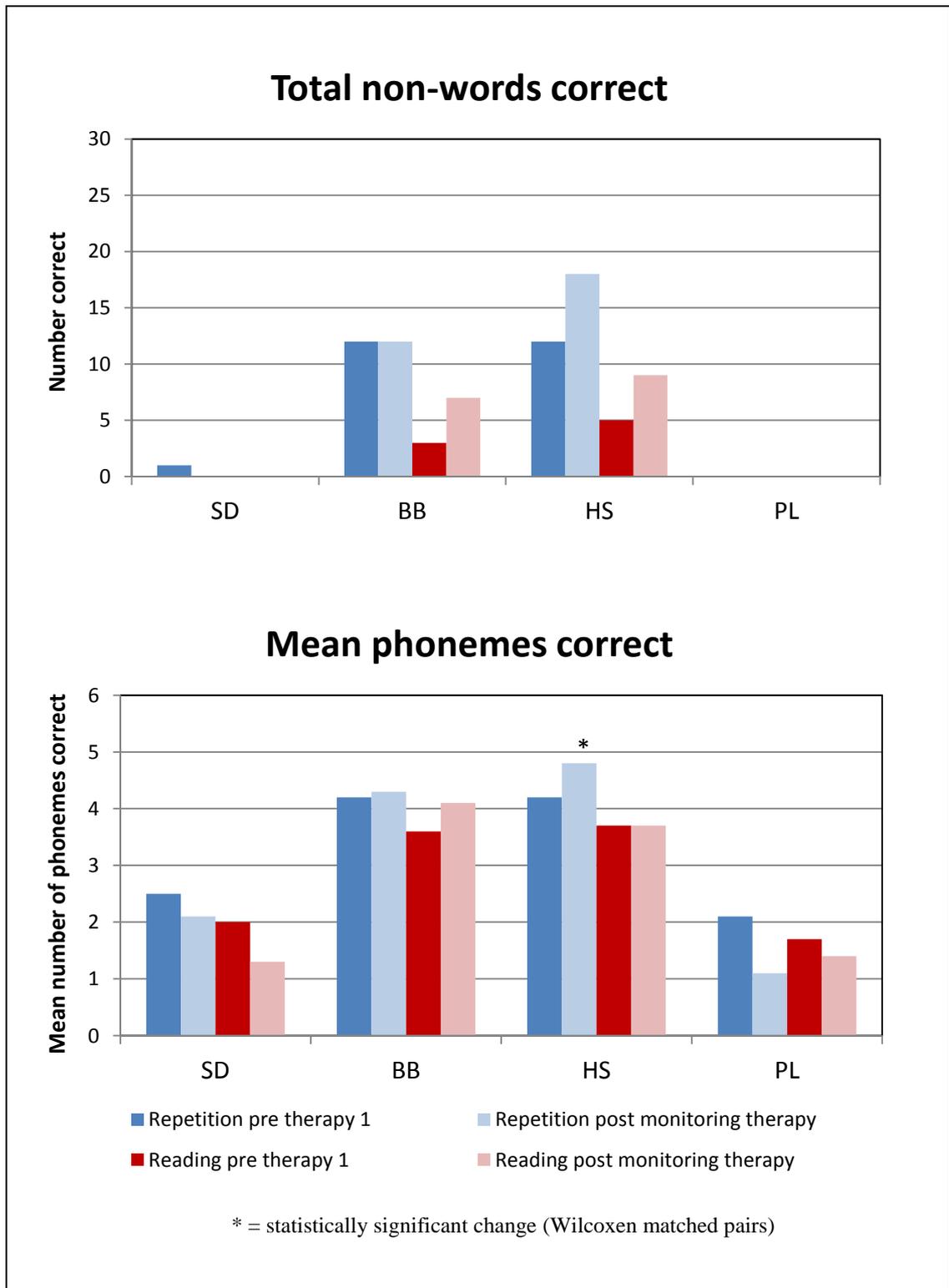


Figure 3.7 Changes in non-word repetition and reading after therapy

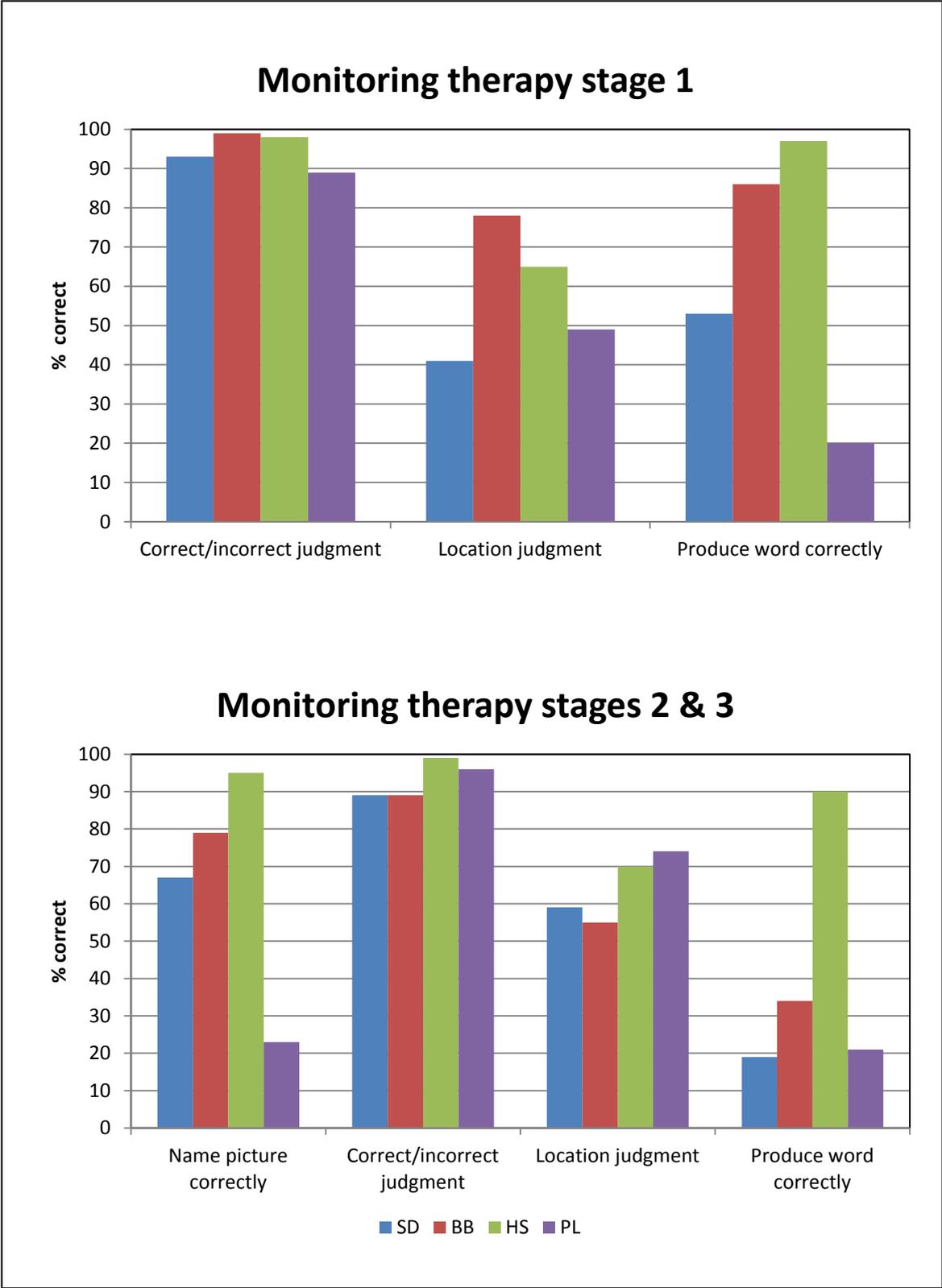


Figure 3.8 Performance on monitoring therapy tasks

Chapter 4 Interim Discussion²

² Parts of this chapter have been reported in Waldron, Whitworth and Howard (2011a)

4.0 Aims of chapter

The aim of study one, outlined in chapter one, was to investigate, using a case series design, whether the findings of generalised improvement reported by Franklin et al (2002) following treatment targeting auditory discrimination and monitoring are replicable with other people with aphasia with impaired phonological assembly. The results of this first study, reported in chapter three, demonstrated that Franklin et al's findings were not replicated, with none of the four participants responding in the same way as their original client. These differences in outcome will now be discussed in order to explore any factors which might suggest which people will benefit most from this therapy approach. The rationale for study two, designed to explore an alternative approach to the treatment of phonological assembly difficulties, will also be described.

4.1 Differences in outcomes

Franklin et al's original client, MB, improved significantly in naming of treated and untreated items after the first and second phases of therapy. This was explained as a generalised improvement in phoneme activation. In the current study, three participants, SD, BB and HS, improved significantly in naming of treated items after the first therapy phase, but only one, HS, made further significant gains in naming of treated items after the second therapy phase, and no improvements in naming of untreated items were seen. One participant, PL, showed no significant improvement in naming of treated or untreated items after either phase of therapy. These differences in outcome will be explored by examining each participant's underlying linguistic impairment.

MB had a relatively pure post-lexical phonological assembly deficit. She was impaired in all modalities of spoken output and showed an effect of phoneme length on all speech production tasks, with no effects of word frequency or imageability, made few semantic errors and many phonemic errors on naming, and was good at self-correcting her errors. In contrast, SD, BB and HS had a combination of impairments in both phonological assembly and lexical retrieval, which may explain why they responded in a different way than MB to the treatment described. Howard (2000) proposed that most treatments for word retrieval, whether the tasks are semantic or phonological, work through activating both the semantic representation and the output lexical phonology of the target word. As the mappings from word meaning to word form are arbitrary, Howard (2000) suggested that treatments that work in this way are likely to produce item-

specific effects (see chapter one, section 1.5.2). True generalisation to untreated items, he argued, can only be expected when a strategy is taught, or when the target of therapy is a post-lexical process. The finding, in study one, that the improvements in spoken naming made by SD, BB and HS were for treated items only, suggests that both phases of therapy worked by improving the mapping between semantics and lexical phonology. Although therapy had been aimed at self-monitoring, the nature of the tasks meant that lexical processing was an integral part; when participants had repeated opportunities to hear the target word in the first auditory discrimination therapy phase, and to see the picture and name the target word in the second monitoring therapy phase, the target word's semantic and lexical representation would have been activated. Therefore, although the first therapy phase did not entail seeing pictures or producing words aloud, the tasks still involved lexical and semantic access through exposure to real word stimuli.

An improvement in the link between semantics and lexical phonology may also explain the changes in speech errors and self-correction seen after therapy. A significant increase in phonologically related errors in naming of treated items after therapy was seen with SD and BB, and HS showed a significant increase in successful self-corrections in naming of treated items after therapy. These findings may be explained by these participants having a strengthened phonological lexical representation and therefore a more robust form of the target being aimed for.

Further support for a lexical-semantic locus of improvement for participants in study one is provided by the limited generalisation of improvement across different output modalities. Franklin et al's client, MB, showed significant improvements post-therapy in repetition and reading aloud of treated and untreated words, as well as in naming, and also showed significant gains in the number of correct phonemes produced in non-word reading. This was interpreted as evidence that therapy had acted at a post-lexical level. In the current study, most improvements seen after therapy were for naming only, although there were some exceptions. HS improved significantly in repetition of treated and untreated words following the second, monitoring, therapy phase, and his non-word repetition also improved after therapy, with significant gains seen in the number of correct phonemes produced. The monitoring therapy phase, therefore, may have caused some post-lexical phonological assembly improvements, which were prevented from manifesting in HS's spoken naming of untreated items by his lexical retrieval

impairment. Alternatively, these changes in repetition may be explained by improvements in the sub-lexical input-output loop (see chapter one, section 1.4), as changes were not seen in HS's non-word reading or in his production of untreated real words in other modalities (aside from an improvement in reading aloud of untreated items following the first therapy phase, which may be a false positive). Furthermore, after the first, auditory, therapy phase, SD made significant gains in repetition of treated words, while PL improved significantly in reading aloud of treated words. SD's improvement in repetition may have occurred through strengthened phonological lexical representations of treated words, or alternatively via her improved auditory input processing (shown by significant gains in minimal pair discrimination, see chapter three, section 3.2). PL's improvement in reading aloud may indicate a change in his post-lexical phonological assembly processes that was not revealed in any other modality.

4.2 Identifying who will benefit

Exploring the reasons why participants in study one responded differently to Franklin et al's (2002) therapy may help to identify which other people with aphasia would most likely benefit from this therapy approach, as well as which people with aphasia may benefit more from a different approach. Of the participants in study one, HS showed the greatest effect of therapy, with significant improvements in naming of treated items seen after both the first and second therapy phases, whereas SD and BB's naming of treated items improved only after phase one and PL showed no significant naming gains after either therapy phase.

It is possible that SD and BB had already achieved their maximum potential for improved naming after the first therapy phase, explaining the lack of further naming improvement after phase two, as the same set of words was treated in both phases; while SD and BB's naming scores after the first therapy phase remained relatively low, this may have been the limit of what they were able to achieve. Other differences between participants were also identified. HS was the youngest participant and the longest time post-stroke, and he also had the least severe speech production difficulties pre-therapy, whereas PL was the oldest with the most severe spoken output impairment. Due to having the most limited mobility following his stroke, PL was also wheelchair bound and lived in a residential care home, which reduced his opportunities for social

communication. It is not possible, however, given the small number of participants, to be conclusive about which of these factors, if any, contributed to the pattern of results. It is also unknown as to whether an alternative therapy approach may have resulted in greater improvements for SD, BB and PL. Some further differences between participants will now be explored, which may aid consideration of future candidates for Franklin et al's therapy, as well as possible alternative treatments.

4.2.1 Executive skills

During the monitoring therapy phase, participants were required to judge their own speech production and employ a self-correction strategy, thus requiring a high level of cognitive flexibility and problem solving. Whereas HS performed relatively well on the Wisconsin Card Sorting Test pre-therapy, SD and BB had considerable difficulty (see chapter two, section 2.5.4). It is possible, therefore, that an executive function impairment may have contributed to the lack of further naming improvements shown by SD and BB after the second therapy phase, and that a less strategic therapy approach may have been more successful.

4.2.2 Self-correction skills

On the pre-therapy spoken word production assessments, although difficulties were seen, HS showed greater self-correction ability than the other participants, with 27% of his errors across the three tasks of naming, repetition and reading aloud being self-corrected, compared with 13%, 14% and 2% for SD, BB and PL respectively (see chapter two, section 2.6.3). HS also had more success than the other participants in correcting his errors during the monitoring therapy tasks (see chapter three, section 3.9). For most items during the second and third stages of the monitoring therapy, HS produced the target word correctly, frequently self-correcting before making the judgment about error location, or producing it correctly afterwards. In contrast, SD, BB and PL produced very few picture names correctly during therapy, even after deciding on the location of the error and despite frequently being provided with a model for repetition. It is possible, therefore, that SD, BB and PL may have gained more from receiving support in how to repair their errors once identified, i.e. how to actually produce the word. Further, some retained self-correction abilities may be required in order to benefit from Franklin et al's therapy. This is supported by the finding that MB, Franklin et al's original client, in common with HS, showed some self-correction ability

before therapy, with 27% of her pre-therapy spoken naming errors being successfully self-corrected conduit d'approche responses.

4.2.3 Presence of AOS

Whereas HS, SD and BB had impairments in phonological assembly and lexical retrieval, and MB, Franklin et al's original client, had a pure phonological assembly deficit, PL's linguistic profile was different, presenting with phonological assembly difficulties combined with AOS. Where people with aphasia and AOS have been included in anomia therapy studies, positive results have been reported (e.g. Wambaugh, Linebaugh, Doyle, Martinez, Kalinyak-Fliszar and Spencer, 2001; DeDe, Parris and Waters, 2003). The presence of a motor speech disorder, therefore, is not always a barrier to improvements at a linguistic level. It remains, however, a difference between PL and the other participants, which could explain his lack of naming improvements; while the focus of Franklin et al's treatment was on identifying the location of speech errors, direct assistance in correct speech production was not provided. People with additional AOS, therefore, may require treatment with a more explicit focus on speech production.

4.3 Alternative therapy approaches

Tentative conclusions, then, can be drawn from the results of study one that people with aphasia with phonological assembly difficulties who are similar to HS, in having good executive skills, some ability to self-correct their speech errors and with no AOS, may be most likely to show improvements in naming after Franklin et al's auditory and monitoring therapy, whereas people with aphasia with phonological assembly difficulties who are more similar to SD, BB and PL may benefit from a different approach to treatment, with fewer executive demands and a greater focus on how to produce words correctly.

Exploration of alternative treatment approaches is also justified given the findings from both study one and Franklin et al (2002)'s original study, that participants did not have a monitoring impairment before therapy, and that therapy did not actually improve participants' monitoring abilities. In common with MB, at least 50% of naming errors produced pre-therapy by all four participants in study one were followed by another

attempt at the target (see chapter two, section 2.6.3), and there were no occasions pre-therapy when a participant named a picture correctly straight away and went on to have a further, incorrect attempt. In addition, all participants in study one performed the first part of the monitoring therapy tasks (identifying whether their own or the therapist's naming attempt was correct) with accuracy of 89% or over (see chapter three, section 3.9). Furthermore, Franklin et al reported that while therapy had aimed to give MB a strategy for self-correcting her errors, she actually produced more words immediately correctly post-therapy, without demonstrating use of the strategy, and therapy was proposed to have worked by improving the process of phoneme activation. In study one, while HS improved significantly in self-correction of errors in naming of treated items after therapy (see chapter three, section 3.7), it is unlikely that the monitoring element of the second therapy phase was responsible, as there was no evidence of a generalised self-correction strategy being used (the improvement was only for treated words) and the improvement was a significant trend over both treatment phases.

Franklin et al's (2002) auditory and monitoring approach is one of only a small number of therapy studies targeting people with phonological assembly difficulties (see chapter one, section 1.5), meaning few alternatives are present in the literature. While some studies have examined a phonological production approach to treatment in aphasia, none to date has been specifically addressed at clients with phonological assembly difficulties. One example of a phonological production approach carried out by Kendall, Rosenbek, Heilman, Conway, Klenberg, Gonzalez Rothi and Nadeau (2008) involved a modified Lindamood Phoneme Sequencing therapy, targeting oral awareness and articulation training using phonemes in isolation and in nonword sequences, with a case series of ten participants with anomic aphasia. After a large amount of therapy (96 hours over 12 weeks), participants showed evidence of improved production of phonemes in isolation, but gains in spoken naming were minimal. The fact that therapy tasks did not directly target the words used in the spoken naming assessment, however, may explain the lack of any naming improvement.

4.3.1 Treatment for apraxia of speech

Given the similarities and frequent co-occurrence of phonological assembly difficulties and AOS, the AOS literature was considered a potential source of techniques that could be applied to the direct treatment of phonological assembly impairments. In this field,

most success has been reported following treatment using real, meaningful words, rather than isolated phonemes or non-words (e.g. Howard and Varley, 1995; Brendel and Ziegler, 2008) although varying methods of treatment have been employed. Wambaugh, Duffy, McNeil, Robin and Rogers (2006), in reviewing the evidence base for treatment of AOS, recommended that articulatory-kinematic treatment, which aims to improve the spatial and temporal aspects of speech production through motor practice of speech targets, had the strongest evidence base. An early example of this type of approach was the eight step continuum described by Rosenbek, Lemme, Ahern, Harris and Wertz (1973), a hierarchy of progressively decreasing cues, beginning with maximum integral stimulation (watching, listening and imitation) and working towards elicitation with minimal support. A more recent example is the sound production treatment reported by Wambaugh and colleagues (e.g. Wambaugh, Kalinyak-Fliszar, West and Doyle, 1998). In this approach, minimal contrast pairs are used with integral stimulation and articulatory placement techniques, in a hierarchy of progressively increasing cues which begin with imitation of a minimal contrast pair and give increasing assistance (e.g. provision of the written form) as required. Three participants with AOS reported by Wambaugh et al (1998) all showed improvements in the production (in imitation) of treated words and untreated words containing treated sounds after therapy, although showed minimal generalisation to words containing untreated sounds.

One disadvantage of the articulatory-kinematic treatment approach is the potential for frustration and feelings of failure because of the demands placed on spoken output, a skill which, by definition, is problematic for people with AOS. Some recent studies have tried to overcome this by targeting auditory discrimination, without overt speech production. Davis, Farias and Baynes (2009) reported a single case study with AOS who received computerised therapy involving phoneme manipulation (choosing pictures that rhymed with a spoken word or began with a spoken sound and choosing pictures from word deletion prompts e.g. “what is sheepdog without dog?”). Their client showed some gains in repetition of treated words but these were judged by visual inspection alone and were very small, given the low number of items (i.e. 10) for each of the three treated sounds. Furthermore, target words were produced during repeated probes throughout the therapy period, such that any improvements in output could not be reliably attributed to the input therapy. Fridriksson, Baker, Whiteside, Eoute, Moser, Vesselinov and Rorden (2009) used computerised spoken word to picture matching therapy to target spoken output in a group of ten people with Broca’s aphasia plus AOS.

Significant gains in spoken naming of treated items were seen after therapy for the group as a whole, but only when visual articulatory information was presented alongside the auditory word, suggesting that improved access to motor information may have been responsible for the improvements in output.

Whiteside, Inglis, Dyson, Roper, Harbottle, Ryder, Cowell and Varley (2012) reported data from a large group of people with AOS plus aphasia (n=44) who received treatment incorporating both auditory input and spoken production tasks. The self administered computer therapy was based on error reducing principles, focussing on whole words, rather than isolated phonemes, in order to encourage more automatic, fluent speech production with reduced struggle and groping. The input phase involved matching spoken words to pictures and to written words, and the output phase required participants to repeat words following auditory and visual articulatory demonstration. In both phases, the computer program provided a model before participants were required to respond, thus reducing the likelihood of errors. Following treatment, the group showed a significant reduction in the number of responses classified as demonstrating struggle behaviour, in repetition of treated, but not untreated, words. In addition, there was a significant increase in the number of responses classified as fluent, in repetition of treated and phonetically matched untreated words. No data is provided, however, regarding any change in the total number of words produced correctly after therapy, or any change in tasks other than repetition, e.g. connected speech. Furthermore, variability in individual performance was not explored, thus limiting the potential for identifying future candidates for this treatment.

4.3.2 Generalisation in treatment of apraxia of speech

Most people with AOS in the literature have not shown improvements in production of untreated words after therapy (e.g. Wambaugh et al, 1998; Whiteside et al, 2012). Generalisation of treatment effects in AOS may be most likely when therapy is based on principles of motor learning (Ballard, 2001) such that phonemes are trained in varying combinations, using a range of phonetic contexts and within different positions in a word, in order to reflect the dynamic nature of real speech. While there is a large body of evidence supporting the application of principles of motor learning to limb rehabilitation, a relatively small number of studies have investigated their role in speech motor learning (Bislick, Weir, Spencer, Kendall and Yorkston, 2012). Furthermore,

findings from some existing studies have been inconsistent. For example, Knock, Ballard, Robin and Schmidt (2000) compared blocked and random practice schedules for two people with AOS, with the latter predicted to result in greater retention and generalisation of treatment effects. Four weeks after the end of treatment, Knock et al found that, as expected, both participants showed greater retention of skills for those items treated using random practice. In contrast, the outcomes regarding generalisation were mixed. One participant showed no improvement in production of untreated items in either condition, while the second participant showed some gains in production of treated sounds in a novel stimulus following both the blocked and random practice conditions, but no improvement in production of novel responses was found. A weakness of this study, however, is that the novel stimuli used to measure generalisation were not described, and the statistical significance of the improvements was not provided. Nonetheless, Knock et al concluded that generalisation may be predicted (in some participants) for items sharing motor plans with the treated words, regardless of therapy approach. Achievement of generalisation to untreated words in treatment of AOS, therefore, may depend on a detailed understanding of the composition of speech motor plans for both treated and untreated words and syllables, rather than principles of motor learning (see also Schoor et al, 2012).

4.4 Summary and aims of study two

A second study was devised to explore the effectiveness of a novel production focussed-therapy for the treatment of phonological assembly difficulties in aphasia. The novel treatment was based on principles from the articulatory-kinematic approach to the treatment of AOS, particularly the sound production treatment of Wambaugh and colleagues, due to the large evidence base supporting this approach. Treatment would therefore involve spoken word production, focussing on whole, real words, as well as the phonemic contrasts between words, using integral stimulation and articulatory cueing. This treatment was compared with Franklin et al's (2002) auditory and monitoring therapy using a second case series of participants with phonological assembly difficulties, in order to test which approach would be most effective for which people and, through this, to scrutinize theoretical models of phonological output processing, as well as possible subgroups of people with phonological output impairments (see section 4.5, below). In addition, as Franklin et al's (2002) findings of generalised improvements after therapy were not replicated in study one, it remains

unknown whether someone with a closer linguistic profile to their original client MB, i.e., someone with a more pure phonological assembly difficulty, would achieve similar results. A further aim of study two, therefore, was to obtain additional replication data on Franklin et al's therapy with more participants, with a view to exploring the outcomes of participants who had impairments closer to those of MB.

4.5 Hypotheses

Based on the results from study one, and those of Franklin et al (2002), hypotheses were made regarding changes on the primary outcome measure of spoken naming following each of the treatments being compared in study two. Three subgroups of people with aphasia with phonological assembly difficulties were proposed.

- 1) Subgroup one: Those with pure phonological assembly difficulties, like MB, Franklin et al's original client, were predicted to show generalised improvements in naming of treated and untreated items after both the auditory discrimination and monitoring therapy, via improved phoneme encoding. This group was also predicted to show similar generalised improvements in naming after the production therapy, as it was targeted directly at the process of phonological assembly. Gains were therefore predicted to occur by the same mechanism.
- 2) Subgroup two: Those with phonological assembly difficulties additional to phonological lexical retrieval difficulties, like HS, SD and BB from study one, were predicted to show item-specific improvements in naming after both the auditory discrimination and monitoring therapy, due to improved mapping between semantics and lexical phonology. This subgroup was also predicted to show item-specific improvements in naming after the production therapy, because, like the monitoring therapy, tasks would involve seeing a picture and producing the word, thus providing similar activation of the mapping between semantics and lexical phonology. While it is theoretically possible that this subgroup could show additional gains in naming of untreated items after any therapy phase, (given the combination of lexical and post-lexical impairments, and the predictions of generalised improvement made for subgroup one, above), this was not predicted in study two given the absence of generalisation for the three participants with this profile in study one.

3) Subgroup three: Those with phonological assembly difficulties combined with AOS, like PL from study one, were not predicted to show improvements in naming following either the auditory or the monitoring therapy of Franklin et al, but improvements in naming of treated items were predicted following the production therapy, designed to target motor speech output processing as well as phonological assembly. Improvements in naming of untreated items were not predicted, based on findings of limited generalisation to untreated words in most AOS treatment studies (e.g. Wambaugh et al, 1998; Knock et al, 2000; Whiteside et al, 2012) thought to occur because treatment effects are limited to the motor plans for those words being treated. Further, the treated and untreated word sets in the current study were not sufficiently controlled for overlapping syllable structure, which may be necessary for any generalisation between shared motor plans (Schoor et al, 2012).

The design and participants in study two will be described in chapter five.

Chapter 5 Method Study Two

5.0 Aims of chapter

The aim of study two, introduced in chapter four, was to compare the effectiveness of the auditory and monitoring therapy reported by Franklin et al (2002) with a production-focussed therapy based on the articulatory kinematic approach to AOS treatment with a further case series of participants with impaired phonological assembly. This chapter will describe the design of study two and the participants.

5.1 Study design

All participants in study two received three consecutive treatment phases; Franklin et al's (2002) auditory therapy, followed by the novel production-focussed therapy, followed by Franklin et al's monitoring therapy. Details of each therapy phase are provided in section 5.8. The order of the three treatment phases was the same for all participants and, with the auditory phase always provided first, allowed optimum comparison of the outcome of the monitoring therapy in study one with that of the production therapy in study two. Furthermore, carrying out the production phase before the monitoring phase meant that data on the new treatment approach was most likely to be gathered, even if participants withdrew before completion of the study. Participants underwent language assessment on five occasions; two prior to the intervention period, one month apart, and the third, fourth and fifth carried out after each therapy phase. The addition of a third treatment phase meant that, due to time constraints, maintenance assessment was not carried out following completion of therapy in study two, which was a weakness of the study.

Spoken picture naming was the primary outcome measure and was assessed at all five assessment periods. In study one, spoken naming was assessed using the 130 words from the Nickels naming test, which incorporated items of varying phonological complexity, including consonant clusters. Assessment of spoken naming in study two was carried out with an alternative set of items to facilitate greater control over the complexity of syllabic structure, a characteristic of the new production therapy protocol (see section 5.8). A set of 100 words was devised from items in the British National Corpus lemma frequency database (Leech, Rayson and Wilson, 2001), which contained both high and low frequency items (high frequency was defined as greater than 20 words per million and low frequency less than 20 words per million) and varying

syllable structures (1 syllable CV/CVC, 2 syllable CVCV/CVCVC/CVCCVC and 3 syllable). 22 pictures were taken from the Nickels naming test and had achieved at least 90% picture naming agreement with older control subjects in an earlier study (Nickels and Howard, 1994). The remaining 78 pictures were taken from existing therapy resources and the Internet, and included eight further words from the Nickels naming test that were given a different picture. A combination of black and white and colour pictures and photographs was used. All 78 new pictures gained at least 90% naming agreement from a set of 10 adults without aphasia who were aged 60 or over. 51 high frequency and 49 low frequency words were included, and 43 x 1 syllable, 39 x 2 syllable and 18 x 3 syllable words (see appendix A). The same 100 words were used to assess spoken naming, reading aloud and repetition before therapy and after each phase of therapy.

After the first pre-therapy naming assessment, the words from the spoken naming test were randomly divided into two sets of 50, with the constraint that each contained equal numbers of items named correctly on the first attempt (not including self-corrections) and the sets were approximately matched for syllable length and word frequency. The first set of 50 comprised the treatment items for the first and second phases of therapy, and the second set of 50 remained untreated during this time. After phase 2 of therapy, the treated and untreated sets were both divided in half to create two new treated and untreated sets of 50 words for phase 3, each containing 25 words that were treated in phases 1 and 2, and 25 words that were untreated in phases 1 and 2, while still matched closely for syllable length and word frequency. This allocation was carried out to minimise ceiling effects after phase 2 masking any treatment effects in phase 3. In addition, as half the words to be treated in phase 3 had been treated previously while half had not, it would be possible to explore the impact that any gains made in phases 1 and 2 may have had on the results of phase 3.

The same battery of linguistic and cognitive assessments, as used in the first study, was administered with all participants in study two during the initial assessment period in order to gain a comprehensive picture of their abilities and to hypothesise their level, or levels, of breakdown. The written version of the TROG was again administered before and after therapy as a control task. As previously, all assessment and therapy was administered by the researcher, and the same feedback protocols were used.

5.2 Participants

Participants were recruited using the same procedure as in study one (see chapter two, section 2.2). In total, six participants were recruited to the second study; however, two participants withdrew during the course of the study, one after the initial assessment period and one after the first therapy phase. Data from these two participants will not be reported. Background information for the four participants who completed the study is shown in table 5.1. All were right-handed, monolingual English speakers. As in the first study, each participant presented with the same primary symptom of phonological errors in picture naming, word repetition and reading aloud, considered to reflect a post-lexical phonological impairment, and each had different patterns of co-occurring impairments.

	RE	CB	BCO	FY
Gender	Male	Male	Male	Female
Age	87 years	72 years	62 years	74 years
Medical history	Left middle cerebral artery infarct	Left posterior parietal infarct	Left parietal and temporal lobe intracranial haemorrhage	Left ischaemic PACS
Months post-onset	36	6	12	6

Table 5.1: Study two participant details

5.2.1 Participant *RE*

RE was retired but had previously been in the armed forces. He lived with his daughter and grandson but had little social contact outside the home. RE's spontaneous speech contained many phonological errors as well as occasions when he stopped and could not produce a word. He frequently gave up when difficulties in output arose, requiring the listener to ask questions and prompt him to have another try. He was frustrated by his communication difficulties and highly motivated for therapy.

5.2.2 Participant CB

CB was a retired taxi driver and lived with his wife and children. His mobility was not affected by the stroke and he led an active social life. CB was a highly effective communicator; despite many phonological errors in his spontaneous speech, errors were often either close enough to the target to be recognisable or they were successfully self-corrected, such that they did not significantly disrupt the flow of conversation. He was nonetheless frustrated by his errors and motivated to improve his speech.

5.2.3 Participant BCO

BCO lived at home with his wife and two daughters. He was able to walk only short distances using a walking stick and required a wheelchair for longer distances, which restricted his activities outside the home. His spontaneous speech was non fluent, often struggling to initiate any spoken output and he relied heavily on his wife to talk for him.

5.2.4 Participant FY

FY lived at home with her husband. Her mobility was only minimally affected by her stroke and she had an active social life. Her spontaneous speech was sometimes difficult to understand due to a combination of phonological errors, neologisms and word finding difficulties, as well as difficulties maintaining conversational topics. Although she did not feel that her aphasia affected her participation in social activities, she was motivated to improve her speech. Her high standards often resulted in her getting easily upset when she encountered difficulty.

5.3 Pure tone audiometry assessment

The results of each participant's pure tone audiometry test are shown in table 5.2, alongside normal data from Cruickshanks et al (1998). The normal data specifically relates to participants' gender and age, so RE's results were compared to the normal mean and standard deviation for males aged 80-92, while CB's were compared to the normal range for males aged 70-79, BCO's were compared to the normal range for males aged 60-69 and FY's to the normal range for females aged 70-79. Thresholds greater than the normal range are highlighted in table 5.2 in bold. Testing of RE, CB and BCO was carried out by the researcher using the procedure specified in the first study (see chapter two, section 2.4). Audiometric results were obtained for FY from her medical records following a recent examination at a local hospital, after she had raised

concerns over hearing difficulties since her stroke. FY had been prescribed a hearing aid at that time, although this was not received until close to the end of the study, and she preferred not to wear it. All of FY's assessments, therefore, were administered without her hearing aid, unless stated otherwise. No other participant wore a hearing aid for either the audiometry or the linguistic assessments.

As shown in table 5.2, RE had a mild hearing loss (threshold of 20- 35dB) in both ears for the lower frequencies (250-1000Hz) and a moderate to severe hearing loss (threshold of 45-85dB) in both ears for the higher frequencies (2000-8000Hz) but this was within the normal range. CB's hearing was worse in his right ear, and he had a moderate loss (threshold of 50-75dB) in both ears at the highest frequency of 8000Hz; these were within the normal range for his age. BCO had a mild hearing loss (threshold of 25-35dB) in his left ear for the lower frequencies (250 – 1000Hz) that was outside the normal range for his age, and a moderate hearing loss (threshold of 55-60 dB) in his left ear for the higher frequencies that was within the normal range. BCO had a moderate hearing loss (threshold of 65-70 dB) in his right ear for all frequencies, but this was only outside the normal range for the lower frequencies (250-2000Hz). FY showed a mild hearing loss (threshold of 20- 40dB) in both ears for the lower frequencies (250-1000Hz) that was mostly within the normal range for her age; an exception was seen with the threshold of 40dB at 1000Hz in her left ear. In addition, a moderate hearing loss (threshold of 55-65dB) was identified in both ears for the higher frequencies (2000-4000Hz), as well as a severe hearing loss (threshold of 90dB) in her left ear for the highest frequency of 8000Hz. These losses were outside normal limits for her age. The hearing loss in her right ear at 8000Hz was less severe, with a threshold of 70dB, which is within the normal range.

5.4 Background assessments

The results of each participant's pre-therapy assessment are set out in Table 5.3. Raw scores and proportions correct are given for each participant, as well as mean performance from normal controls where available.

		male aged 80-92		male aged 70-79		male aged 60-69		female aged 70-79	
Frequency (Hz)		RE	normal mean (standard deviation)	CB	normal mean (standard deviation)	BCO	normal mean (standard deviation)	FY	normal mean (standard deviation)
Left ear	250	20	27.4 (16.8)	10	20.6 (16.6)	30	13.4 (11.5)	25	18.8 (15.9)
	500	25	27.8 (18.1)	15	20.3 (17.1)	25	12.1 (11.6)	20	19.1 (16.5)
	1000	35	34.8 (19.5)	10	25.3 (19.4)	35	16.4 (12.8)	40	22.1 (17.6)
	2000	45	50.4 (17.7)	-5	38.8 (21.5)	35	28.6 (19.3)	60	28.3 (18.7)
	4000	70	71.3 (16.8)	30	64.6 (19.3)	55	55.1 (21.7)	65	40.9 (19.8)
	8000	75	79.7 (15.5)	50	74.1 (18.0)	60	61.2 (22.7)	90	61.6 (20.4)
Right ear	250	20	30.6 (20.3)	10	20.3 (14.1)	70	15.2 (13.3)	30	19.8 (15.8)
	500	25	31.8 (22.9)	30	18.8 (14.5)	65	12.2 (13.6)	30	19.7 (16.6)
	1000	35	38.2 (22.7)	25	23.6 (17.5)	65	15.8 (14.6)	30	22.9 (17.4)
	2000	50	52.3 (19.9)	5	35.5 (21.10)	70	26.2 (20.9)	55	27.6 (18.6)
	4000	65	70.5 (17.3)	45	62.0 (19.0)	65	54.0 (23.7)	60	39.0 (19.8)
	8000	85	81.3 (15.5)	75	71.9 (18.4)	65	59.5 (23.9)	70	60.3 (21.2)

Numbers in bold = Thresholds outside the normal range

Table 5.2: Study two participants' pure tone audiometry thresholds (dB)

	RE	CB	BCO	FY	Normal mean
PALPA 1 Auditory Discrimination of Non-Word Minimal Pairs	61/72 (.85)	67/72 (.93)	48/72 (.66)	not attempted	70/72 (.97)
PALPA 2 Auditory Discrimination of Word Minimal Pairs	61/72 (.85)	70/72 (.97)	48/72 (.66)	abandoned	70/72 (.97)
PALPA 5 Auditory Lexical Decision	146/160 (.91)	118/120 (.98)	133/160 (.83)	136/160 (.85)	155/160 (.97)
PALPA 15 Auditory Rhyme Judgment	55/58 (.95)	47/58 (.81)	50/58 (.86)	6/15 (.40) abandoned	not available
PALPA 15 Written Rhyme Judgment	36/58 (.62)	28/58 (.48)	35/58 (.60)	not attempted	53/60 (.88) (Nickels & Cole-Virtue, 2004)
PALPA 28 Homophone Decision	44/60 (.73) Regular: 18/20 Exception: 15/20 Nonword: 11/20	43/60 (.72) Regular: 15/20 Exception: 17/20 Nonword: 11/20	28/60 (.47) Regular: 8/20 Exception: 9/20 Nonword: 11/20	15/30 (.50) abandoned	54/60 (.92) Regular: 18/20 Exception: 18/20 Nonword: 18/20 (Nickels & Cole-Virtue, 2004)

Table 5.3: Study two participants' background assessment results

	RE	CB	BCO	FY	Normal Mean
PALPA 13 Digit Matching Span	5.5	5	abandoned	3	6 (Salis, personal communication)
PALPA 47 Spoken Word-Picture Match	39/40 (.98)	40/40	39/40 (.98)	37/40 (.93)	39/40 (.98)
PALPA 48 Written Word-Picture Match	38/40 (.95)	40/40	36/40 (.90)	36/40 (.90)	39/40 (.98)
Pyramids and Palm Trees (3 picture version)	48/52 (.92)	51/52 (.98)	47/52 (.90)	51/52 (.98)	51/52 (.98)
Camden Short Recognition Memory Test for Faces	20/25 (.80) (~ 17.5 th centile)	25/25 (1.00) (90 th centile)	24/25 (.96) (75 th centile)	24/25 (.96) (~ 82.5 nd centile)	see centile result
Wisconsin Card Sorting Test	1 category completed (>16 th centile); 53% error responses (53 rd centile)	0 categories completed (< 1 st centile); 69% error responses (4 th centile)	1 category completed (6-10 centile); 64% error responses (2 nd centile)	3 categories completed (>16 th centile); 32% error responses (61 st centile)	see centile result

Table 5.3 cont'd: Study two participants' background assessment results

5.4.1 Assessment of auditory input processing

As in study one, participants' auditory input processing was assessed using the real word and non-word minimal pair discrimination, and auditory lexical decision subtests of the PALPA. RE's performance on the minimal pair discrimination tasks was mildly impaired, while his score on auditory lexical decision was lower than the normal mean but higher than his minimal pair discrimination scores. CB's scores on real word minimal pair discrimination and auditory lexical decision were within normal limits, and his score on non-word minimal pair discrimination was slightly below the normal mean but still above 90%. Neither RE nor CB, therefore, had a severe auditory processing deficit. BCO's scores for minimal pair discrimination of both real words and non-words were well below the normal mean, which may indicate some auditory analysis difficulties. His auditory lexical decision score was also lower than the normal mean but, as with RE, it was higher than his minimal pair discrimination scores and above 80%, suggesting that BCO's auditory processing may not, in fact, have been impaired to a large degree.

FY was unable to perform the real word minimal pair discrimination task, and so the non-word minimal pair task was not attempted. FY did complete the auditory lexical decision task, however, and, as with BCO and RE, her score was lower than the normal mean but considerably better than chance, and better than might have been expected from her inability to perform the other auditory processing tasks. Further, FY's lexical decision score was significantly lower on real words compared to non-words (63/80 and 73/80 respectively, Fisher exact $p=0.023$ one tailed) and, with real words, low frequency items were significantly more difficult than high frequency items (27/40 and 36/40 respectively, Fisher exact $p=0.013$ one tailed). FY's better performance in lexical decision for non-words and high frequency real words, and greater difficulty in recognising low frequency real words is consistent with an impairment within or with access to the auditory input lexicon, or word form deafness (Franklin, 1989). Due, however, to her inability to complete the minimal pair assessments, an auditory analysis impairment (word sound deafness) cannot be ruled out. For the purposes of the current study, it is sufficient that FY's auditory input processing was impaired at some level.

Of the four participants in study two, BCO and FY had greatest difficulty with the minimal pair discrimination tasks, and these two clients also had hearing losses that

were outside the normal range for their ages (see table 5.2). Morris, Howard and Franklin (in preparation) demonstrated that older adults without aphasia, with moderate to severe hearing impairments, were able to perform minimal pair discrimination tasks with only slightly lower levels of accuracy than those without a hearing loss. It is unlikely, therefore, that BCO and FY's hearing loss can fully explain their difficulties on this task.

5.4.2 Assessment of phonological processing

As in study one, participants' phonological processing was assessed using PALPA auditory rhyme judgment and PALPA written homophone decision. Participants in the first study had also been assessed on picture rhyme judgment, and all four gained low scores. Interpreting this finding is not, however, straightforward as difficulties on this task could arise either due to an impaired sub-lexical link between phonological output and input, problems with lexical retrieval or with picture recognition. Written rhyme judgment was therefore assessed in the second study as lexical retrieval and picture recognition are not required for this task. Further, it was more comparable with the homophone decision task due to the similarities in format; two written words are presented and participants must decide, without reading them aloud, whether they either rhyme or sound the same respectively. The same PALPA subtest was used for both the written and auditory rhyme judgment tasks, with 58 out of the 60 items used (see chapter two, section 2.5.2).

RE and CB performed well on the auditory rhyme judgment task (see table 5.3), each scoring above 80%, demonstrating that they were familiar with the concept of rhyme. In contrast, both scored below the normal mean on homophone decision and written rhyme judgment. Scores on homophone decision were higher than on written rhyme judgment for both clients, although this difference was only significant for CB (43/60 compared with 28/58, Fisher exact one tailed $p=0.008$) and not for RE (44/60 compared with 36/58, Fisher Exact one tailed $p=0.134$). As discussed in chapter two, superior performance on homophone decision, which requires access only to output phonology, compared with written rhyme judgment, which requires access to both input and output phonological processes, could suggest a deficit in the sub-lexical rehearsal loop between phonological output and input (Nickels, Howard and Best, 1997). Furthermore, on the homophone decision task, both RE and CB scored significantly better on real words

than non-words (RE 33/40 compared with 11/20 and CB 32/40 compared with 11/20, Fisher exact one tailed $p=0.026$ and $p=0.044$ respectively). As with BB, HS and PL in study one, RE and CB were mostly able to access whole word phonological information from the lexicon for real words, but had difficulty generating a phonological plan for non-words, which do not have a lexical representation. This is supported by the finding, discussed below, that both participants also scored very poorly on non-word repetition and reading aloud. BCO scored highly on the auditory rhyme judgment task, but his scores on both homophone decision and written rhyme judgment were close to chance, with no significant difference between them (28/60 compared with 35/58, Fisher Exact one tailed $p=0.097$). BCO also showed no difference between homophone decision for real words compared with non-words (17/40 compared with 11/20, Fisher Exact one tailed $p=0.261$). These findings suggest that BCO had difficulty accessing output phonology for both words and non-words. FY struggled with both the auditory rhyme judgment and the homophone decision tasks (similar to SD in study one); both tasks had to be abandoned due to distress. As her scores were both at chance, the written rhyme judgment was not attempted.

5.4.3 Assessment of working memory

As in study one, participants' working memory was assessed using the PALPA digit matching span test, and the results are shown in table 5.3. Testing of BCO was abandoned following distress at the task. FY also found this task difficult, gaining an average span of 3, while RE and CB both scored relatively highly, with average spans of 5.5 and 5 respectively, which were just below the normal mean. RE and CB were therefore able to retain at least 10 digits at a time, demonstrating relatively good sub-vocal rehearsal.

5.4.4 Assessment of semantics and cognitive skills

In addition, participants' ability to access the semantic representations of words from spoken and written input was assessed using PALPA spoken and written word to picture matching, and their ability to access to non-verbal semantic information was assessed using the three picture version of the Pyramids and Palm Trees test. RE, CB and BCO all scored equal to or above the normal mean on the spoken word to picture matching task (see table 5.3). On the written version, CB again scored 100% correct, while RE and BCO scored slightly below the normal mean. FY scored slightly below normal on

both the spoken and written word to picture matching tasks. No participant scored below 90% on either of these tasks, however, suggesting that no participant had a serious impairment in accessing word meanings in the semantic system. On the three picture Pyramids and Palm Trees test, while RE and BCO scored below the normal mean, all four participants scored above 90%, the level given as the threshold for a significant clinical impairment. This indicated that no participant in the second study had a severe central semantic deficit.

Participants' recognition memory and problem solving skills were also assessed, as in study one, using the Camden Short Recognition Memory Test for Faces and the Wisconsin Card Sorting Test respectively. On the recognition memory test, CB, BCO and FY performed well for their age group, indicating good non-verbal working memory, while RE performed towards the lower end of the norm for his age. On the card sorting test, FY scored the highest, completing three categories correctly and producing the lowest proportion of error responses (32%). RE had some difficulty, completing only one category, but, because of his older age, his percentage of error responses (53%) was still within the normal range. CB and BCO found this task very difficult, with CB unable to complete one category, and BCO only one, and both performed towards the lower end of the norm for their ages, with a high percentage of error responses (69% and 64% respectively).

5.5 Assessment of spoken word production

The results from tests of single word spoken production for each participant at the first assessment period are shown in Table 5.4. Raw scores and proportions correct are given. The same scoring system as in study one was used and the final response correct score is shown, i.e. including self-corrections. In the first study, a high level of inter-rater reliability was established for the pre-therapy assessment data, in terms of correct and incorrect agreement (94%) (see chapter two, section 2.6). Given that study two utilised the same procedures as study one, further data on reliability of scoring was not collected.

All participants showed a deficit in producing spoken words (see table 5.4), and were impaired across all modalities to some degree. For RE, CB and FY, naming was most impaired, followed by reading aloud, with repetition the least affected. In contrast, while

BCO's scores were more similar across the three real word tasks, reading aloud was most impaired, followed by repetition, and then naming. All four were impaired on production of non-words as well as real words. Using Levelt et al's (1999) model of spoken word production, all participants showed evidence of a post-lexical impairment in phonological assembly.

		RE	CB	BCO	FY
Spoken picture naming	Total correct (n=100)	31	34	23	27
	High Frequency (n=51)	16 (.31)	19 (.37)	14 (.27)	16 (.31)
	Low Frequency (n=49)	15 (.31)	15 (.31)	9 (.18)	11 (.22)
	1 syllable (n=43)	15 (.35)	17 (.40)	15 (.35)*	14 (.33)
	2 syllable (n=39)	12 (.31)	15 (.38)	7 (.18)*	7 (.18)
	3 syllable (n=18)	4 (.22)	2 (.11)	1 (.06)*	6 (.33)
Repetition	Total correct	61	82	17	78
	High Frequency	30 (.59)	42 (.82)	7 (.13)	45 (.88)*
	Low Frequency	31 (.63)	40 (.82)	10 (.20)	33 (.67)*
	1 syllable	32 (.74)*	42 (.98)*	11 (.26)*	30 (.70)
	2 syllable	24 (.62)*	32 (.82)*	5 (.13)*	33 (.85)
	3 syllable	5 (.28)*	8 (.44)*	1 (.06)*	15 (.83)
Reading Aloud	Total correct	52	59	12	53
	High Frequency	26 (.51)	31 (.61)	5 (.10)	29 (.57)
	Low Frequency	26 (.53)	28 (.57)	7 (.14)	23 (.47)
	1 syllable	30 (.70)*	32 (.74)*	10 (.23)*	27 (.63)
	2 syllable	17 (.44)*	24 (.62)*	2 (.05)*	17 (.43)
	3 syllable	5 (.28)*	3 (.17)*	0*	8 (.44)
PALPA 8 Nonword Repetition (n=30)		5/30	5/30	0/30	1/30
PALPA 8 Nonword Reading (n=30)		0/30	1/30	0/30	0/30

* = significant difference at $p < .05$ one tailed using Fisher exact test (frequency) or Jonckheere Trend test (length)

Table 5.4: Study two participants' pre therapy assessment of spoken word production

5.5.1 Frequency and length effects

In addition to examining participants' total correct scores, table 5.4 shows participants' performance on high and low frequency words, and one, two and three syllable words, on the pre-therapy spoken word production assessments, taking the final response correct score. Pairs and triplets with a significant difference are highlighted with an asterisk. RE, CB and BCO showed no significant effect of word frequency on any task. For FY, there was no significant effect of word frequency on spoken naming or reading aloud, but this was present for repetition, with more high frequency words produced correctly (Fisher exact one tailed $p=0.012$). This may suggest that FY's auditory processing impairment was impacting on her repetition performance. On spoken naming, BCO showed a significant effect of word length, with more 1 syllable words produced correctly than 3 syllable words (Jonckheere Trend Test one tailed $p=0.006$). No other participant showed a significant word length effect on naming, although CB did show a trend towards more shorter words being produced correctly that approached significance ($p=0.060$). On both repetition and reading aloud, RE, CB and BCO all showed a significant effect of word length, with more 1 syllable words produced correctly than 3 syllable words (repetition: $p=0.001$, $p<0.001$ and $p=0.028$ respectively and reading: $p=0.001$, $p<0.001$ and $p=0.003$ respectively). FY showed no significant effect of syllable length on repetition ($p=0.081$), but there was a trend towards more shorter words being produced correctly on reading aloud that approached significance ($p=0.057$).

5.5.2. Speech errors

The profile of speech errors produced by each participant was also examined for evidence relating to the level of linguistic breakdown. Figure 5.1 shows the different types of error made by each participant pre-therapy on the three tasks of spoken naming, real word repetition and reading aloud. Participants' first responses were used for this analysis, i.e. error responses that were subsequently self-corrected were included, so that maximum information could be gained about the patterns of errors being produced. The same error classification criteria as described in chapter two (see section 2.6.2) were used.

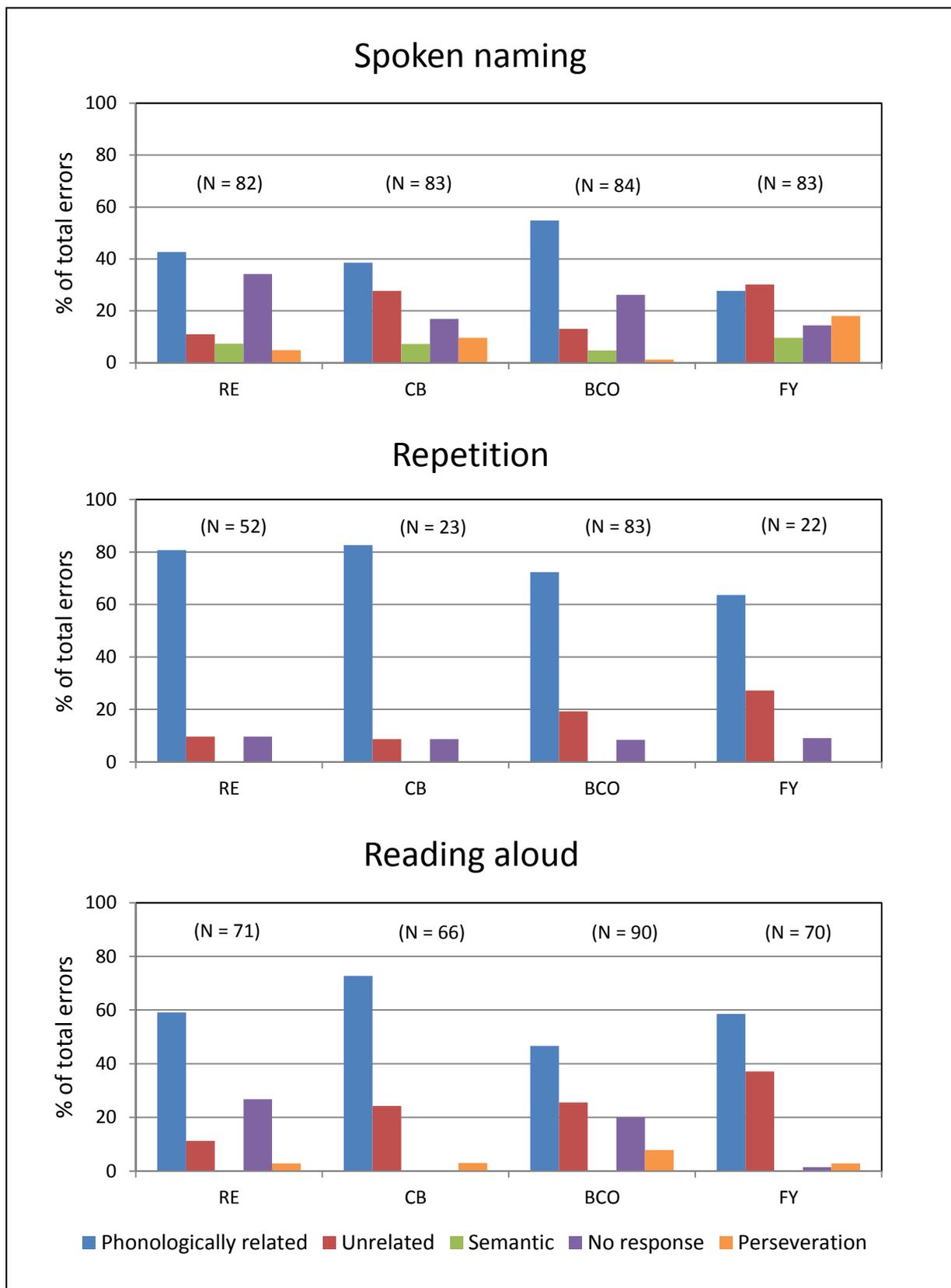


Figure 5.1: Study two participants' speech error types on pre-therapy naming, repetition and reading aloud

All four participants made large numbers of phonologically related errors on all three tasks, supporting the diagnosis of a post-lexical phonological assembly impairment. For all participants, less than ten per cent of spoken naming errors were semantically related, indicating relatively intact lexical retrieval, although FY did show some signs of an additional lexical impairment, with a high proportion of perseverations on naming. The majority of FY's perseverations were real words unrelated to the target, but four out of 15 were semantically related and one was phonologically related. As described in chapter two, only whole or obvious part word perseverations were included in the category of perseveration in the current study. According to Moses et al (2007), these are most likely to indicate an underlying lexical-semantic breakdown, in contrast to blended perseverations of phonemes, which may reflect a post-lexical phonological impairment. Further, the finding that FY produced far fewer perseverations on reading aloud, and none on repetition, supports the proposal that these errors on naming were lexical in origin. In contrast, FY produced a high proportion of unrelated errors on all three spoken output tasks, suggesting that they arose from her phonological assembly difficulty. CB also produced a high proportion of unrelated errors on both naming and reading aloud. RE and BCO both made a high proportion of no-responses on spoken naming and reading aloud. As discussed in chapter two, no-responses could occur either because of a severe lexical retrieval difficulty or because of a motor speech difficulty.

5.5.3. Errors with multiple attempts

As well as examining error types on the first response, participants' multiple attempts at the target on the tests of spoken word production were also analysed. Figure 5.2 shows the proportion of incorrect responses, that is, excluding items named correctly straight away and items with no response, which were (a) not followed by any further attempt at the target, (b) followed by at least one further incorrect attempt (including items where the first response was simply repeated) and (c) successfully self-corrected, in green, red and blue respectively.

The proportion of participants' repeated attempts that resulted in the correct target, shown by the blue areas of figure 5.2, was low for all participants across all three tasks. BCO made the fewest self corrections (4% of his total error responses over all three tasks) and RE made the most, but even for RE, this figure was only around a third (32% of his total error responses over all three tasks). The total proportion of participants'

error responses that were followed by at least one further attempt is represented by the combination of red and blue areas in figure 5.2. This combined figure is taken as an indication of monitoring ability, highlighting that participants were aware that their first response was wrong and that they needed to correct it. For RE, CB and FY, this figure was at least 70% on spoken naming and reading aloud, suggesting that, even before therapy, they had good awareness of their errors on these tasks. In addition, as in study one, further evidence of monitoring ability was demonstrated by all participants on several occasions when no further attempt at the target was made, but they showed awareness of their first response being incorrect (e.g. saying “no”). On repetition, RE had a similarly high proportion of errors followed by another attempt, but for CB the proportion was slightly lower than on the other output tasks, at 52%, and for FY the proportion was just 24%. This may have been due to FY’s auditory processing impairment impacting on her repetition ability; she may have misheard the target and thought she was correct. For BCO, the proportion of errors followed by at least one further attempt was lower than that of the other participants on all three spoken output tasks. This finding could be explained either as evidence that BCO had difficulty monitoring his errors, or that he simply “gave up” and did not feel able to try again, even though he may have had insight into his errors.

Furthermore, all participants showed evidence of a possible monitoring difficulty by failing to recognise a correct response at least once. With FY, a correct response was followed by a further incorrect response on one occasion on the repetition task (this was not included in the total produced correctly in table 5.4). There were also two instances in FY’s pre-therapy reading aloud where her first response was correct but then a further incorrect response was produced, followed by the correct response again. These items were classified as first response correct, rather than self-corrections. RE’s pre-therapy repetition and CB’s pre-therapy naming each contained one item that was self-corrected but followed by “no”. Both items were included in the total final response correct scores in table 5.4. Finally, BCO’s pre-therapy reading aloud contained two items where a further incorrect response was produced after he had self-corrected his initial error. These items were not classified as self-corrections or included in the total final response correct scores in table 5.4 because the final response was not correct.

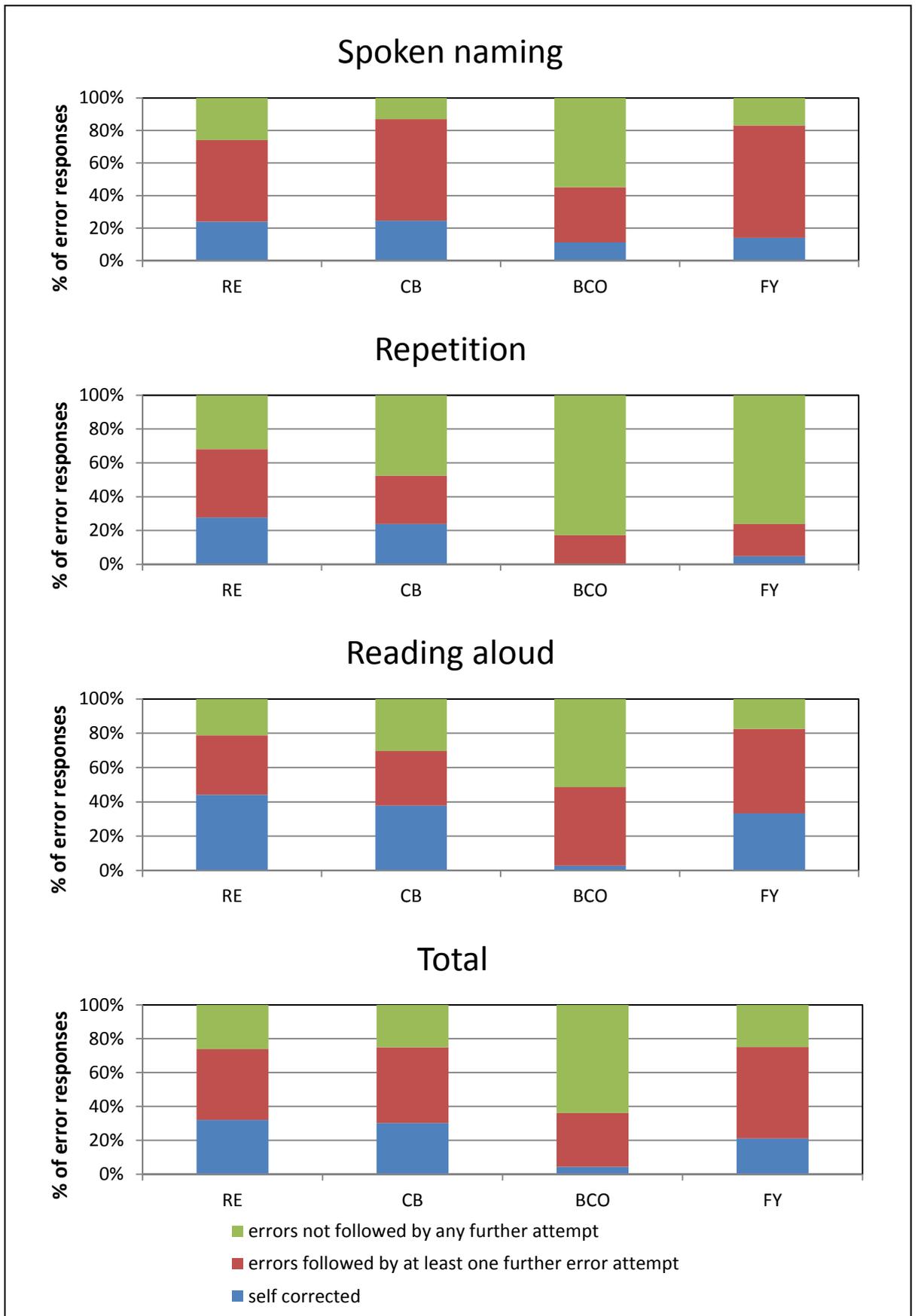


Figure 5.2: Study two participants' multiple error responses on pre therapy naming, repetition and reading aloud

5.6 Assessment of motor speech

In study one, participant PL showed evidence of apraxia of speech (AOS), which was investigated using the Apraxia Battery for Adults (Dabul, 1979) (see chapter two, section 2.6). Given that one of the therapy approaches being investigated in study two was based on an AOS treatment approach, all participants in study two were assessed for potential AOS. The Dabul Apraxia Battery was not used, however, as it was not considered to sufficiently discriminate between characteristics of AOS and phonological assembly difficulties (Nickels, 1997). For example, two of the diagnostic features of AOS in the Dabul Apraxia Battery are (a) difficulty producing words of increasing length, and (b) lengthy responses with several attempts at the target, which are both common features of phonological assembly difficulties (e.g. Gandour et al, 1994). Participants in study two, therefore, were assessed informally using a series of tasks suggested by Duffy (2005) involving repetition of single sounds, CVC words and multisyllabic words, diadochokinetic rate and automatic speech tasks. Their speech was then compared to a checklist of features, taken from Duffy (2005) and McNeil, Pratt and Fossett (2004), which are thought to occur only in AOS and not in aphasia. These features, together with their presence or absence for each participant, are shown in table 5.5.

Neither CB nor FY showed any signs of AOS. RE demonstrated some hesitancy and groping on the motor speech assessment, and his performance on the other assessments of spoken word production was marked by a high number of no-responses, but he showed none of the other diagnostic features, and his conversational speech was fluent, so AOS was not considered to be his primary impairment. BCO, however, presented with all of the AOS diagnostic features, and his spoken word production contained many no-responses and fewer attempts at self-correction than the other participants. An informal oral motor assessment was administered with BCO in order to rule out a diagnosis of dysarthria, and no sign of muscle weakness was identified. It is likely, then, that BCO had AOS in addition to his phonological assembly impairment.

	RE	CB	BCO	FY
Distorted sound substitutions	N	N	Y	N
Abnormal prosody	N	N	Y	N
Slow speech rate	N	N	Y	N
Prolonged segment and intersegment durations	N	N	Y	N
Articulatory groping	Y	N	Y	N

Table 5.5: Presence of features indicative of AOS on pre therapy motor speech assessment

5.7 Summary of linguistic impairments

All four participants showed evidence of a post-lexical phonological assembly deficit, as all spoken output modalities were impaired with phonological errors occurring in all output tasks. Further, RE, CB and BCO all found shorter words easier to produce on repetition and reading aloud, with BCO also showing a word length effect on naming. Both RE and CB presented with a relatively pure phonological assembly deficit, with the exception of some mild AOS features shown by RE. In contrast, BCO had additional AOS, shown by features such as distorted articulation and abnormal prosody. FY, meanwhile, had co-occurring lexical retrieval difficulties, shown by her perseverations on spoken naming, as well as auditory processing difficulties.

5.8 Therapy procedure

Participants were seen twice a week at home for approximately 45 minutes per session. The first phase of therapy comprised the auditory discrimination therapy tasks used by Franklin et al (2002), and was carried out in the same way as in study one, lasting three weeks (six sessions). The second phase of therapy lasted four weeks (eight sessions)

and comprised the production therapy tasks, which were broadly based on the sound production treatment reported by Wambaugh et al (1998). A progressively increasing cueing hierarchy involving production of minimal contrast pairs combined with articulatory kinematic and orthographic cueing, outlined in figure 5.3, was used. The first treatment session used only CV words, with longer syllabic structures introduced in subsequent sessions; not all of the treated word set were therefore exposed in every session. The minimal contrast words were in neither the treated or untreated set of words, and differed from the target by a single phoneme in varying word positions. For the 3 syllable words and the 2 syllable words with more complex syllable structures, where it was not possible to find a real word minimal pair, a real word sharing as many phonemes as possible at either the beginning or end was used. Following attempts at production of either the target word or a minimal contrast word, feedback on both results (whether correct or incorrect) and performance (why the production was either correct or incorrect) was given. Motor learning principles dictate that both types of feedback are needed in order to achieve long term retention, as well as short term acquisition (Ballard, Granier and Robin, 2000). While it has been suggested that frequency of feedback should be reduced during the course of treatment in order to promote generalisation (Schmidt and Lee, 1999), Wambaugh et al (1998) argued that, in a hierarchical cueing treatment such as the one used in the current study, feedback is implicit in the therapy design, meaning this would be difficult to achieve. A 100% schedule of feedback was therefore adhered to in the current study, although future research could compare this with a lower frequency schedule.

The main difference between the sound production treatment described by Wambaugh et al (1998) and the treatment reported here was in the saliency given to naming. Wambaugh et al started with production of minimal contrast pairs in imitation and stepped down to production of target words in isolation if necessary. In the current study, the first step in the hierarchy was production of the target word in isolation via picture naming, with the minimal contrast word only being introduced if the target word was produced accurately. The reasons for this were to permit direct comparisons with the monitoring therapy phase, described below, which also used picture naming as its starting point, but also because it was anticipated that participants may find production of minimal contrast pairs difficult. Production of the target in isolation was therefore the first priority. A further difference from Wambaugh et al's (1998) treatment was that, for 2 and 3 syllable words, an additional cueing strategy was used when necessary. This

involved breaking down the word into syllables and working through each syllable using the cueing hierarchy before putting the syllables together to produce the word. A similar syllable segmentation and blending technique was shown to be successful in improving naming of treated words in a client with phonological assembly difficulties reported by Morris, Cave, Coles and Waldron (2009).

The third therapy phase also lasted four weeks (eight sessions) and comprised the monitoring therapy tasks from the Franklin et al (2002) study. In study one, Franklin et al's monitoring therapy was replicated exactly, taking place over 14 sessions and incorporating all three stages. In study two, however, the monitoring therapy phase was shortened to make it the same length as the production phase. The first four sessions were unchanged compared with the first study, comprising the first stage of Franklin et al's monitoring therapy (see chapter two, section 2.8). In contrast, the final four sessions in study two were modified, based on the finding during the first study that participants preferred to judge the location of their naming errors after hearing the therapist repeat back their response, rather than using audio playback. In study two, therefore, the second and third stages of Franklin et al's therapy were combined, using a series of steps of feedback. First, participants named a picture and immediately afterwards were asked to decide whether their response was correct. If incorrect, they were asked to decide on the location of their error, without any therapist feedback, using the same written prompt sheet for beginning, middle and end, as used in the first four sessions. If they were unable, the therapist repeated back their incorrect response and asked them to decide. Following this, the same feedback as in study one was used, incorporating written cues (see chapter two, section 2.8), until either participants were able to make the error location judgment and attempt to produce the word again or the therapist gave them the information.

As in study one, all participants were given homework following each session based on the therapy tasks. For the auditory and monitoring therapy phases, homework took the same format as in study one. For the production therapy, homework tasks comprised, first, pictures of the target words plus the written word and the articulogram for the first phoneme, to practise producing the words in isolation, and second, written word lists of the target word and minimal contrast word, to practise producing the pairs of words.

5.9 Hypotheses

In chapter four, three different subgroups of people with phonological assembly difficulties were proposed, and the responses of each subgroup to the three treatment phases being tested in study two were predicted. Based on the pre-therapy assessment data from the four participants in study two, hypotheses are put forward as to which subgroup each participant belongs to, as well as predictions regarding their proposed outcomes of therapy.

The pattern of linguistic impairment for both RE and CB was more similar to that of MB, Franklin et al's (2002) original client, than any of the four participants in study one, as both showed evidence of a post-lexical phonological assembly impairment without either a concurrent lexical retrieval difficulty or severe AOS. Both RE and CB, therefore, were considered to be in subgroup one (pure phonological assembly impairment), and it was predicted that both would make improvements in naming of treated and untreated items after all three therapy phases.

FY's pre-therapy assessment profile was consistent with that of subgroup two (phonological assembly plus lexical retrieval impairment). It was predicted, therefore, that she would show item specific naming improvements following the auditory discrimination therapy phase, with possible further item specific naming improvements following both the monitoring and the production therapy phases.

BCO's pre-therapy assessment profile was most similar to that of PL in study one, placing him in subgroup three (phonological assembly plus AOS). It was predicted, therefore, that his naming would not improve after either the auditory or the monitoring therapy phases, but that naming of treated words would improve after the production therapy phase.

5.10 Summary

This chapter has described the design and the participants of study two. Four participants with aphasia were recruited; two with relatively pure phonological assembly difficulties, one with impaired phonological assembly plus apraxia of speech

and one with impaired phonological assembly plus lexical retrieval and auditory processing difficulties. All received three consecutive phases of therapy; Franklin et al's (2002) auditory therapy, followed by the novel production therapy, followed by Franklin et al's monitoring therapy. Language assessment took place twice before therapy and after each therapy phase. Chapter six will describe participants' assessment results following therapy.

Chapter 6 Results Study Two

6.0 Aims of chapter

This chapter will describe the results of therapy for the four participants in study two. As detailed in chapter five, therapy consisted of three phases; Franklin et al's (2002) auditory therapy, followed by the novel production therapy, followed by Franklin et al's monitoring therapy. Naming, repetition and reading aloud of treated and untreated items were reassessed after each therapy phase.

6.1 Control measures

No significant change was seen on the written TROG during the course of therapy for any participant (see table 6.1). In addition, three out of four participants, RE, BCO and FY, showed no significant change in spoken naming between the repeated baselines of the two pre-therapy naming assessments, taken one month apart (see table 6.2). For these three participants, therefore, any positive changes in spoken word production seen after treatment can be reliably attributed to therapy. The fourth participant, CB, improved significantly in spoken naming during the untreated baseline period, such that his results after therapy must be interpreted with caution, despite the lack of significant change in his written TROG score.

	RE	CB	BCO	FY
Written TROG pre therapy	39/52	46/60	14/28	40/52
Written TROG post therapy	40/52	51/60	16/28	40/52
McNemars test (one tailed)	p=0.500	p=0.113	p=0.344	p=0.605

Table 6.1 Study two participants scores pre and post therapy on written TROG

	RE	CB	BCO	FY
Naming Pre therapy 1	31	34	23	27
Naming Pre therapy 2	30	57	17	25
McNemars test (one tailed)	p=0.640	p<0.001	p=0.971	p=0.721

Table 6.2 Study two participants scores on pre-therapy spoken naming repeated baseline (n=100)

6.2 RE therapy outcomes

RE's scores in naming, repetition and reading aloud of treated and untreated items, at all assessment points during the study, are shown in figure 6.1. RE's naming of treated and untreated items showed no significant change after the first, auditory, phase of therapy, compared with his scores on the previous pre-therapy 2 assessment (McNemar's one tailed $p=0.905$ and $p=0.055$ for treated and untreated items respectively). His score on naming of untreated items showed an increase that approached significance, but this may be explained by a decrease in score between the first and second pre-therapy assessments. There was no significant difference between treated and untreated sets after the first therapy phase (Fisher exact one tailed $p=0.333$). Following the second, production, therapy phase, RE's naming of treated items improved significantly, compared with his previous score after phase one ($p=0.011$) while naming of untreated items did not improve ($p=0.090$), and there was a significant difference between treated and untreated sets ($p=0.037$). The set of words used in treatment was changed after the second phase of therapy for all participants in study two, as detailed in chapter five, such that the treated set for the third, monitoring, therapy phase contained 25 words that were treated in the preceding phases and 25 that were previously untreated. RE's score in naming of the new treated set showed a significant improvement after therapy phase three, compared with his previous score after phase two ($p=0.015$), although naming of untreated items did not improve ($p=0.696$), and there was a significant difference between treated and untreated sets ($p=0.001$). In repetition, there were no significant gains for either treated or untreated words when comparing scores after each therapy phase, although there was a significant difference between treated and untreated items

following the second therapy phase (38/50 and 29/50 respectively, $p=0.045$). RE made no significant changes on reading aloud of treated or untreated words at any stage.

6.3 CB therapy outcomes

CB's scores in naming, repetition and reading aloud of treated and untreated items, at all assessment points during the study, are shown in figure 6.2. CB made significant gains in naming of treated items following the first, auditory, therapy phase, in comparison with his previous pre-therapy 2 score ($p=0.003$) while naming of untreated items did not improve ($p=0.063$), and there was a significant difference between treated and untreated sets ($p=0.014$) after phase one of therapy. Following the second, production, therapy phase, CB's naming of treated items showed a further significant improvement compared with his score after phase one ($p=0.020$), and his naming of untreated items also improved significantly ($p=0.006$), although the difference between scores on treated and untreated sets after phase two remained significant ($p=0.016$). Following the third, monitoring, therapy phase, CB's naming of the new set of treated items improved significantly ($p=0.008$) but naming of the new untreated set did not ($p=0.773$) and the difference between scores on treated and untreated items was significant ($p=0.018$). On repetition, CB's scores did not change significantly for either treated or untreated items following the first therapy phase ($p=0.500$ and $p=0.063$ respectively) and there was no significant difference between treated and untreated sets ($p=0.380$) after phase one of therapy. Following the second therapy phase, there was a significant improvement in CB's repetition of treated words ($p=0.008$) but not in untreated words ($p=0.500$), although the difference between treated and untreated sets after phase two did not reach significance ($p=0.064$). Following the third therapy phase, there were no significant gains in CB's repetition of either the new treated or untreated word sets ($p=0.250$ and $p=0.750$ respectively), likely due to ceiling effects. On reading aloud, there were significant improvements in both treated and untreated items following the first therapy phase ($p<0.001$ and $p<0.001$ respectively) and there was no significant difference between treated and untreated sets ($p=0.082$). No further significant gains were seen in reading aloud after either the second or third therapy phases. As with his repetition scores, this may reflect ceiling effects due to the extent of the improvement after phase one.

6.4 BCO therapy outcomes

BCO's scores in naming, repetition and reading aloud of treated and untreated items, at all assessment points during the study, are shown in figure 6.3. No significant changes were seen in BCO's spoken naming over any successive tests for either treated or untreated items. Scores on treated and untreated sets did not differ significantly at any point, except after the third, monitoring, therapy phase ($p=0.018$), but this was due to a decrease in BCO's score on untreated items, rather than an increase in treated items (see figure 6.3). On repetition, BCO's scores did not change significantly for either treated or untreated items after the first, auditory, therapy phase ($p=0.656$ and 0.090 respectively) and there was no significant difference between scores on treated and untreated items after phase one ($p=0.172$). Following the second, production, therapy phase, there was a significant improvement in BCO's repetition of treated items ($p=0.003$) but not untreated items ($p=0.989$) and a significant difference between treated and untreated sets was seen ($p=0.006$). No significant improvements were seen, however, in repetition of either the new treated or untreated sets following the third therapy phase ($p=0.151$ and $p=0.726$ respectively), and scores on treated and untreated items after phase three of therapy did not differ significantly ($p=0.257$). On reading aloud, BCO showed a significant improvement in production of treated items after the first therapy phase ($p=0.004$) but reading aloud of untreated items did not improve ($p=0.984$), although the difference between scores on treated and untreated sets after phase one was not significant ($p=0.087$). Scores on reading aloud of both treated and untreated items showed no further gains after either the second therapy phase ($p=0.605$ and $p=0.773$ respectively) or the third ($p=0.194$ and $p=0.605$ respectively).

6.5 FY therapy outcomes

FY's scores in naming, repetition and reading aloud of treated and untreated items, at all assessment points during the study, are shown in figure 6.4. FY made significant gains in naming of treated items following the first, auditory, therapy phase, in comparison with her previous pre-therapy 2 score ($p=0.025$) while naming of untreated items did not improve ($p=0.500$). Following the second, production, therapy phase, FY's naming of treated items showed a further significant improvement ($p=0.001$), again with no significant change seen in untreated items ($p=0.500$). Following the third, monitoring, therapy phase, naming of the new treated set improved significantly ($p=0.003$), with no change seen in naming of the new untreated set ($p=0.685$). Significant differences were

seen between treated and untreated sets after all three therapy phases ($p=0.048$, $p<0.001$ and $p<0.001$ respectively). In addition, FY made significant gains in repetition of treated items following the first therapy phase ($p=0.011$) but not for untreated items ($p=0.363$) and scores on treated and untreated items differed significantly ($p=0.028$). No further significant improvements in repetition of treated or untreated items were seen following the second therapy phase ($p=0.813$ and $p=0.788$ respectively), although the difference between treated and untreated sets remained significant ($p=0.022$). Following the third therapy phase, there were no significant changes in repetition of the new treated or untreated sets ($p=0.500$ and $p=0.828$ respectively) and there was no significant difference between treated and untreated sets ($p=0.133$). This lack of significant change in repetition, after that seen following the first therapy phase, could have been partially due to ceiling effects. On reading aloud, significant improvements were seen following the first therapy phase for both treated and untreated items ($p=0.038$ and $p=0.004$, respectively). There was no significant difference between scores on treated and untreated items after phase one ($p=0.525$). Following the second therapy phase there was another significant improvement in reading aloud of treated items ($p=0.046$), with no further gains in untreated items ($p=0.881$), and the difference between treated and untreated sets was significant ($p=0.011$). Following the third therapy phase there were no significant improvements in reading aloud for either the new treated or untreated items ($p=0.145$ and $p=0.105$ respectively) and no significant difference was seen between treated and untreated sets ($p=0.133$).

6.6 Detailed changes in naming of treated and untreated sets

To further examine improvements seen in spoken naming after each therapy phase, participants' scores on the four sets of 25 words, created through the division of the treated set after phase two, were analysed. For each participant, of the 100 words in the spoken naming assessment, 25 were treated in phases one, two and three (set TT), 25 were treated in phases one and two but untreated in phase three (set TU), 25 were untreated in phases one and two but treated in phase three (set UT), and 25 were untreated in all three phases (UU). Naming scores on these four sets at each consecutive assessment period, for each of the four participants, are presented in figure 6.5. The first assessment point shown in figure 6.5 is the second pre-therapy naming baseline, because comparison with this score was used previously to calculate any improvements in naming following the first therapy phase.

For RE, it was reported in section 6.2 that no improvements were seen in naming after the first therapy phase, while naming of treated items improved significantly following both the second and third therapy phases. Detailed analysis confirmed that none of the four word sets improved significantly after the first therapy phase (see figure 6.5). Following the second therapy phase (when sets TT and TU were treated), set TT improved significantly (McNemar's $p=0.004$ one tailed), while set TU did not ($p=0.500$). Following the third therapy phase (when sets TT and UT were treated), set TT made no further significant improvements ($p=0.227$) but set UT improved significantly ($p=0.033$). For CB, it was reported in section 6.3 that naming of treated items improved significantly after all three therapy phase, with additional significant improvements in naming of untreated items following the second treatment phase. Detailed analysis, shown in figure 6.5, highlighted that following both the first and second therapy phases (when sets TT and TU were treated), set TU improved significantly ($p=0.020$ and $p=0.031$ respectively), while set TT did not ($p=0.125$ and $p=0.313$ respectively). Furthermore, the improvement in naming of untreated items following the second therapy phase can be seen in set UT ($p=0.031$). Following the third therapy phase (when sets TT and UT were treated), set UT continued to make further significant improvements ($p=0.031$), while set TT did not ($p=0.250$). For BCO, it was reported in section 6.4 that no improvements were seen in naming of treated or untreated items after any treatment phase. This was also reflected in no significant changes for any of the four word sets (see figure 6.5). For FY, it was reported in section 6.5 that naming of treated items improved significantly after all three therapy phase. Detailed analysis revealed that following the first therapy phase (when sets TT and TU were treated) set TT improved significantly ($p=0.001$), while set TU did not ($p=0.500$). Following the second therapy phase (when sets TT and TU were treated again), set TT continued to show improvement approaching statistical significance ($p=0.055$), but TU was the only set to show significant change ($p=0.011$). After the third therapy phase (when sets TT and UT were treated) only set UT showed significant gains ($p=0.004$), and not set TT ($p=0.313$).

This detailed analysis of treated and untreated sets demonstrates that all improvements seen following the third, monitoring, phase of therapy, in naming of treated items, came

from set UT, which had been previously untreated. For two out of three participants (RE and FY), this shows that these improvements were not simply a continuation of those made after the previous treatment but a genuine treatment effect. For CB, set UT had also shown significant improvements during the preceding treatment phase when it had been untreated, meaning the findings are less clear.

6.7 Changes in speech errors

As in study one, in addition to examining any changes in the total number of words produced correctly after therapy, participants' speech error types on spoken naming were analysed after each therapy phase for evidence of any change. Figure 6.6 shows the numbers of different error types produced by each participant in naming of treated and untreated items, as a proportion of the total number of error responses, before therapy and after phases one, two and three of therapy. Errors produced on the new treated and untreated sets were analysed after phase three. Participants' first responses were used such that errors subsequently self-corrected were included.

No participant showed any significant change in error type on spoken naming of treated items after therapy (RE chi square (12) = 12.84, $p=0.381$; CB chi square (12) = 16.58, $p=0.166$; BCO chi square (12) = 15.90, $p=0.196$; FY chi square (12) = 13.03, $p=0.367$). BCO also showed no change in error type on spoken naming of untreated items after therapy (chi square (12) = 17.74, $p=0.124$). The remaining three participants, however, all showed a significant change in error type on spoken naming of untreated items after therapy (RE chi square (12) = 24.61, $p=0.017$; CB chi square (12) = 30.19, $p=0.003$; FY chi square (12) = 27.07, $p=0.008$).

6.8 Changes in monitoring

All the results reported so far have used the final response correct score, i.e. including self-corrections. As in study one, self-correction of spoken naming errors was also studied for evidence of any change following intervention. Figure 6.7 shows the proportion of naming errors, excluding no responses, for each participant that were (a) not followed by any further attempt at the target, (b) followed by at least one further incorrect attempt and (c) successfully self-corrected, in green, red and blue respectively,

for treated and untreated items, pre-therapy, post therapy phase 1 and post therapy phase 2. Any significant changes after therapy were identified using a Jonckheere trend test (one tailed), taking the number of self-corrections as a proportion of the total number of error responses with more than one attempt (i.e. the size of the blue area, out of the combined red and blue parts of the graphs in figure 6.7).

Across the four time conditions, RE, CB and FY all showed a significant increase in the proportion of errors that were successfully self-corrected in naming of treated items ($p=0.005$, $p<0.001$ and $p<0.001$ respectively). CB showed an additional significant increase in the proportion of self corrections in naming of untreated items ($p<0.001$), whereas RE and FY showed no changes in untreated items ($p=0.492$ and $p=0.098$ respectively). BCO showed no significant change in the proportion of self-corrections in naming of either treated or untreated items across the four time conditions ($p=0.334$ and $p=0.202$ respectively).

Further information about changes in participants' ability to self-correct their naming errors, as well as which treatment phase may have brought about these changes, was gained by examining the differences between the number of correct first responses and the number of correct final responses after each therapy phase, as shown in figure 6.8. For both RE and FY, significant differences after therapy were only seen when their final response correct score was taken (see sections 6.2 and 6.5); no significant changes between consecutive assessments were found when their first response correct score was used. This indicates that both the production and the monitoring therapy (and the auditory therapy for FY) were effective through increasing these participants' self-correction ability rather than their ability to produce the word correctly straight away. For CB, both first and final response correct scores showed significant improvements in naming of treated items after the auditory therapy (McNemar's one tailed $p=0.018$ and $p=0.003$ respectively) and the monitoring therapy ($p<0.001$ and $p=0.008$ respectively). In contrast, after the production therapy, only CB's final response correct score improved significantly for naming treated items ($p=0.020$) whereas his first response correct score did not change ($p=0.584$). Furthermore, the improvement in naming of untreated items, seen after the production therapy (see section 6.3), was only evident when taking the final response correct score ($p=0.006$) and not the first response correct

score ($p=0.954$). This indicates that the production therapy phase had a generalised effect on CB's self-correction ability, whereas the auditory and monitoring therapy had an item specific effect on CB's ability to produce words correctly straight away. BCO showed no significant differences in naming of treated or untreated items on either his first or final response, after any therapy phase.

6.9 Changes in non-word production

Further information about the effect of treatment on participants' phonological output abilities was gained by examining non-word repetition and reading aloud (PALPA subtest 8) before therapy and after the third, monitoring, phase of therapy, as in study one. Figure 6.9 shows the total number of non-words produced correctly by each participant, including self-corrections, before and after therapy, as well as the mean number of correct phonemes present in the most accurate response (including correct responses).

BCO's non-word production was not reassessed after therapy. This was due to the level of distress experienced in both tasks before therapy. For CB, non-word repetition showed no significant change after therapy, despite numerical increases in both total correct and mean phonemes correct that approached significance (McNemar's one tailed $p=0.059$ and Wilcoxon matched pairs one tailed $p=0.066$ respectively). In contrast, while CB's non-word reading aloud also showed no significant change in total words produced correctly ($p=0.313$), there was a highly significant increase in the mean number of correct phonemes produced on this task after therapy ($p<0.001$). Neither RE nor FY showed any significant change in non-word production following therapy, in either total correct or mean phonemes correct (FY: non-word repetition $p=0.063$ and $p=0.426$ respectively; non-word reading $p=0.500$ and $p=0.092$ respectively. RE: non-word repetition $p=0.188$ and $p=0.197$ respectively; non-word reading $p=1$ and $p=0.096$ respectively).

6.10 Summary

This chapter has reported treatment outcomes for the four participants in study two. Treatment consisted of three phases; auditory discrimination therapy, followed by production therapy, followed by monitoring therapy. Data from participant CB was

ambiguous due to significant improvements made in naming during the untreated baseline period, suggesting that spontaneous recovery may have been partially responsible for his results. After the first treatment phase, two participants, CB and FY, improved significantly in naming of treated items, but naming of untreated words did not improve. After the second treatment phase, three participants, RE, CB and FY improved significantly in naming of treated items, and while no gains in naming of untreated items were made by RE and FY, a significant improvement in naming of untreated items was seen in CB. After the third treatment phase, the same three participants, RE, CB and FY, made further significant gains in naming of treated items, but no participant made any gains in untreated items. For RE and FY, all improvements seen in naming of treated items were evident only when taking their final response correct score, indicating that treatment had improved their self-correction ability. Improved self-correction was also responsible for the gains made by CB in naming of treated and untreated items after the production therapy. The fourth participant, BCO, showed no significant improvements in spoken naming after any treatment phase.

In repetition and reading aloud, RE showed no significant improvements on either treated or untreated words after any therapy phase. In contrast, after the first therapy phase, CB and FY both made significant gains in reading aloud of treated and untreated words, while significant improvements were also seen in FY's repetition of treated words, and BCO's reading aloud of treated words. After the second therapy phase, significant improvements were seen in CB and BCO's repetition of treated items as well as FY's reading aloud of treated items. No significant gains in repetition or reading aloud were made by any participant following the third therapy phase. CB showed a significant increase in the mean number of correct phonemes produced on non-word reading aloud after therapy, but no other significant changes in non-word production were shown by the other participants. Implications of these findings will be discussed in chapter seven.

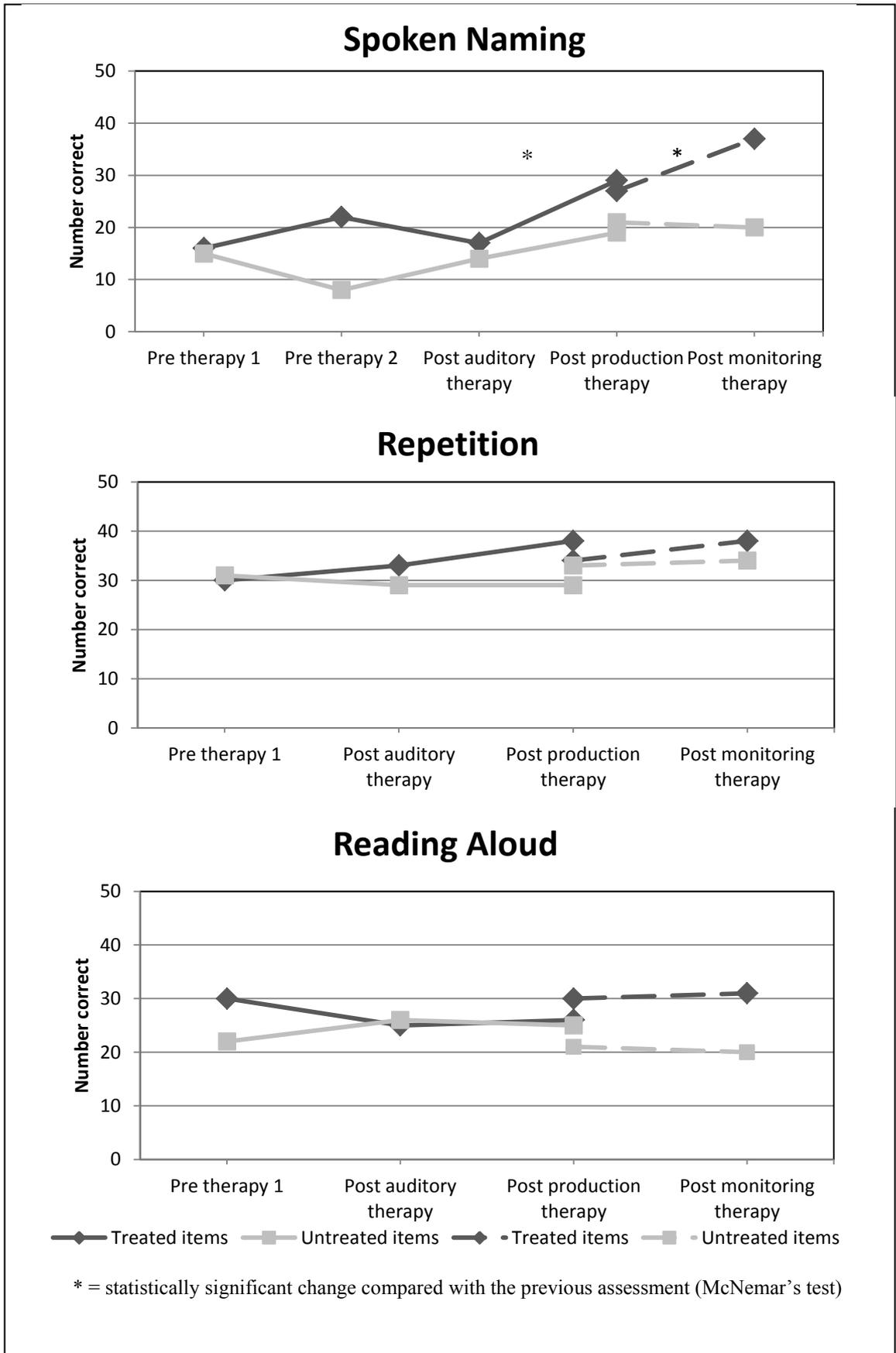


Figure 6.1 RE Spoken word production assessment results post therapy

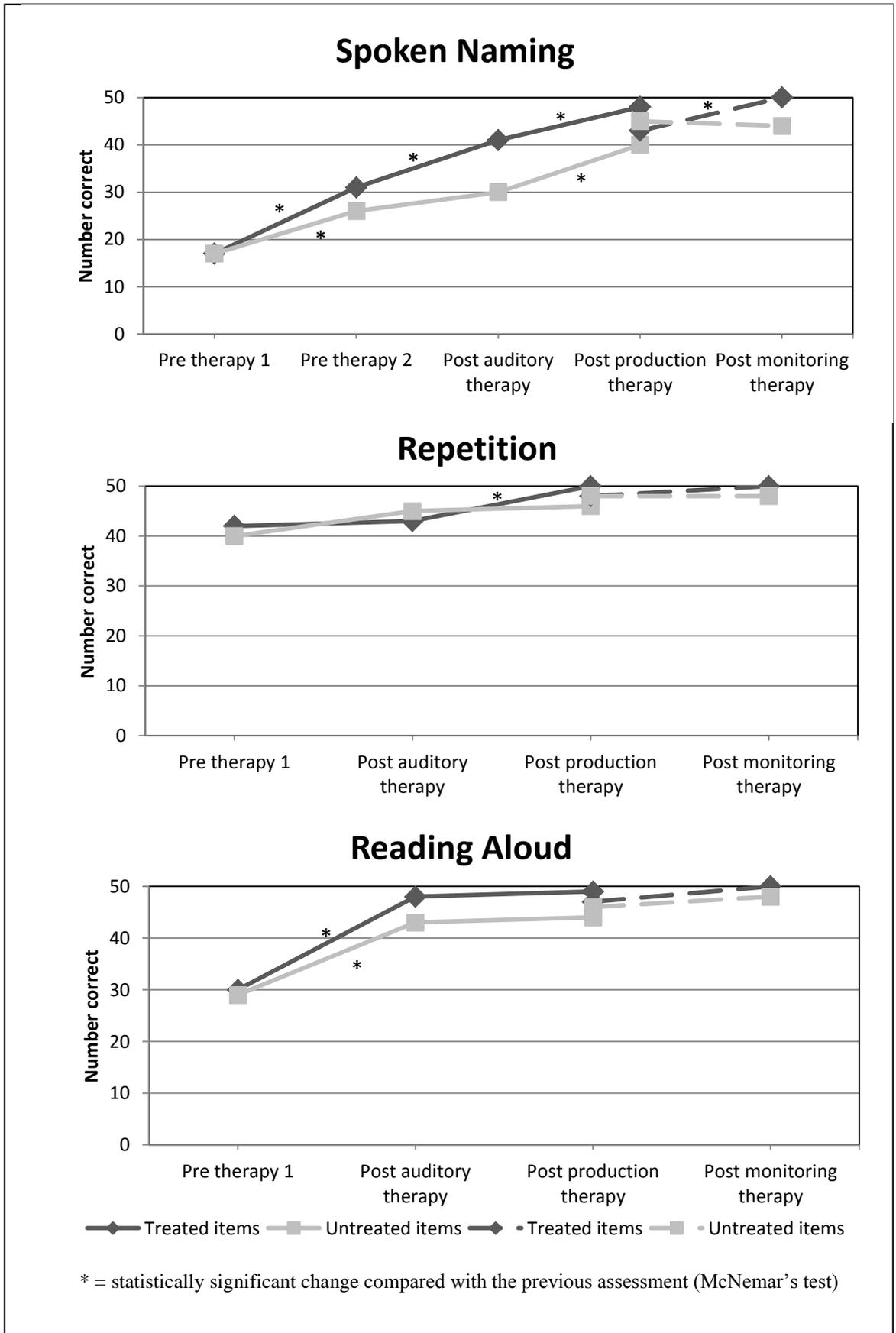


Figure 6.2 CB Spoken word production assessment results post therapy

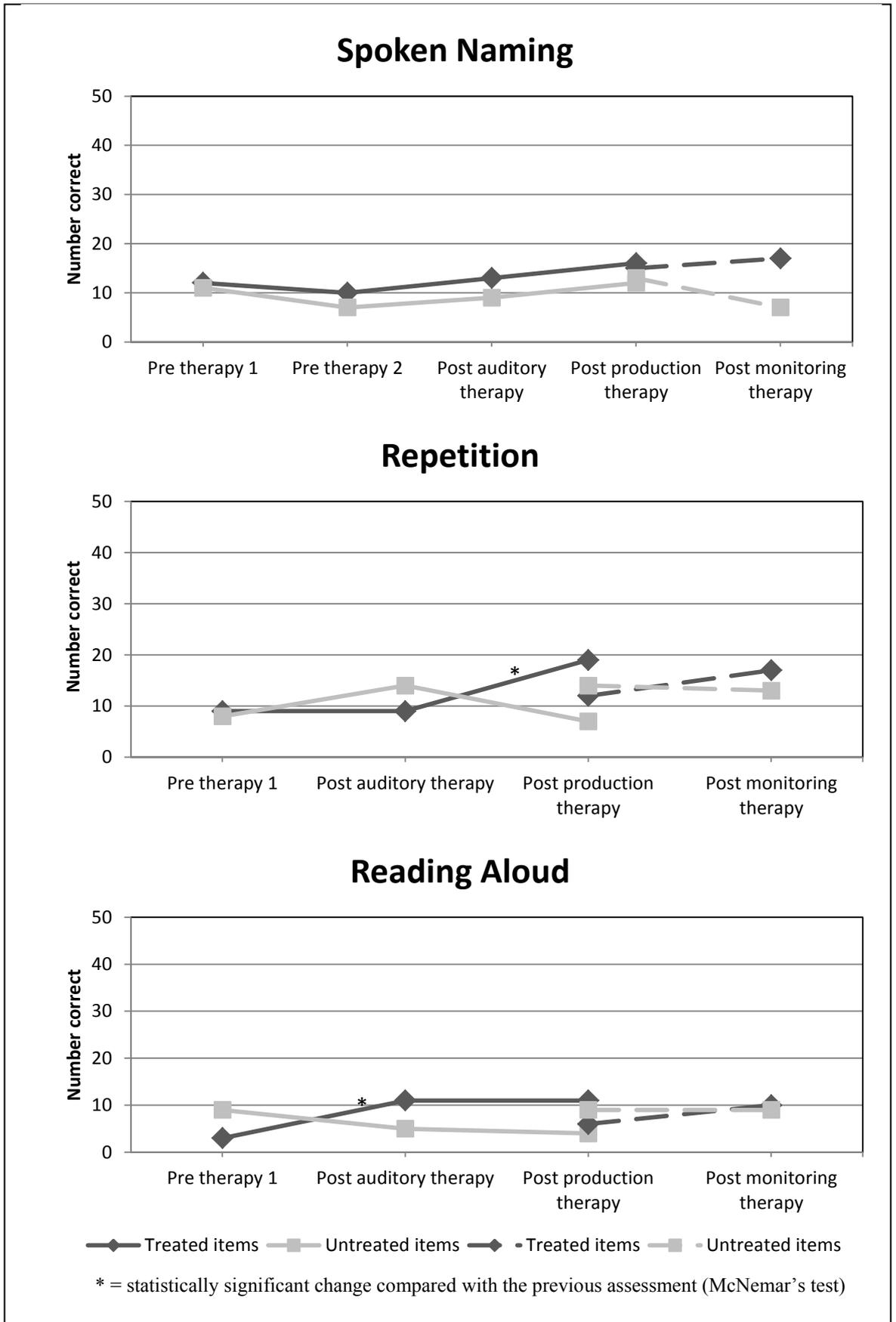


Figure 6.3 BCO Spoken word production assessment results post therapy

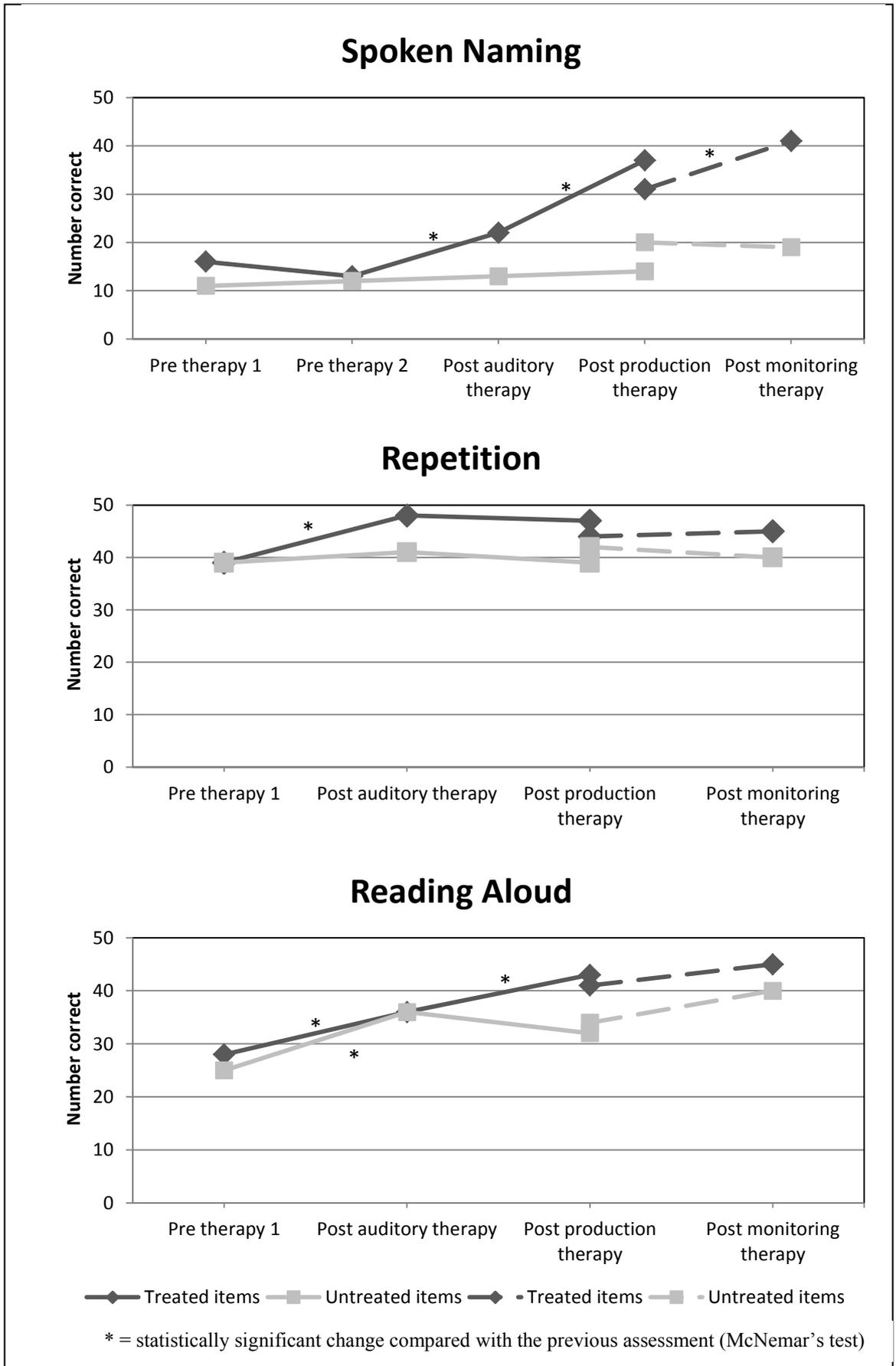


Figure 6.4 FY Spoken word production assessment results post therapy

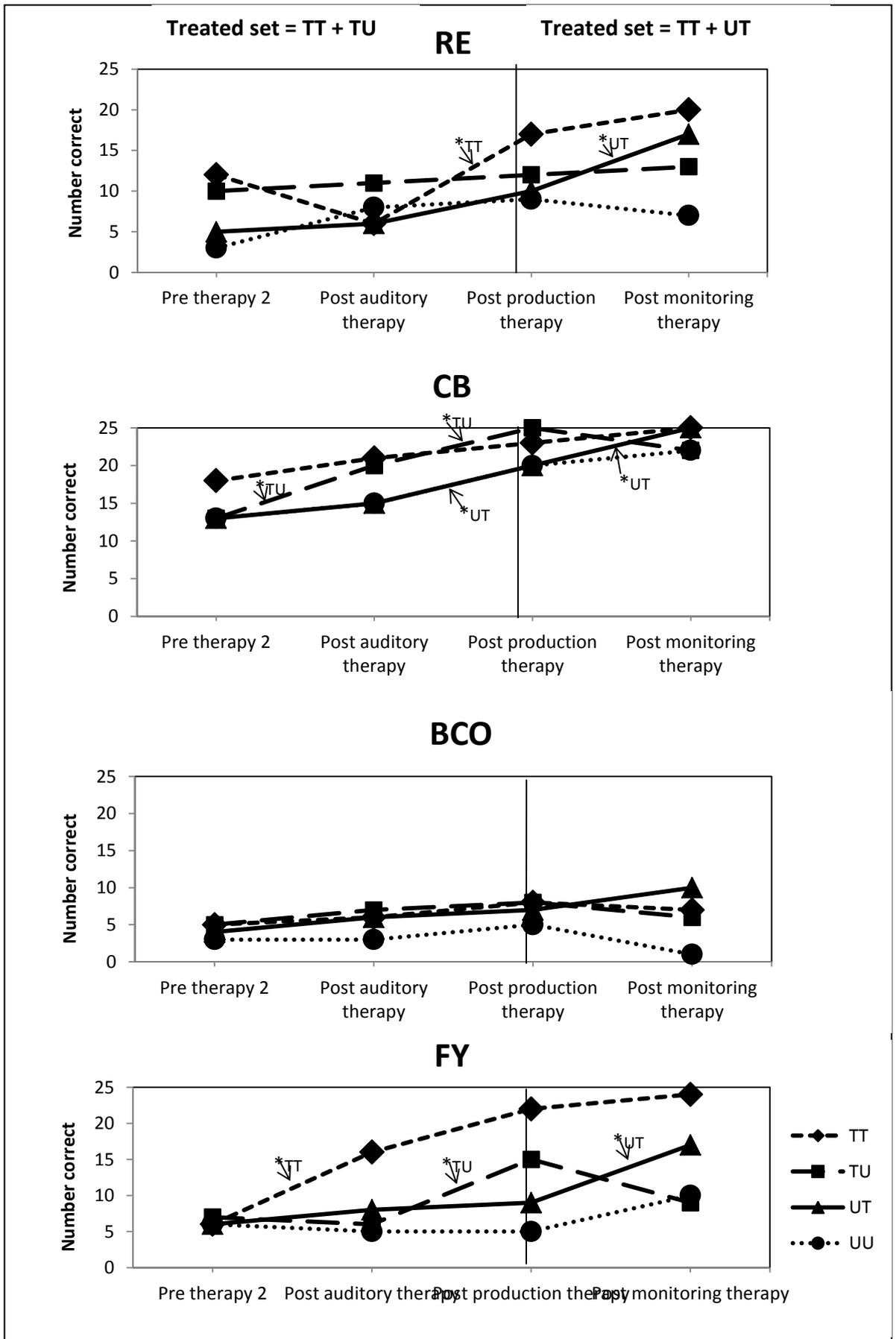


Figure 6.5 Changes in treated and untreated sets on spoken naming after therapy

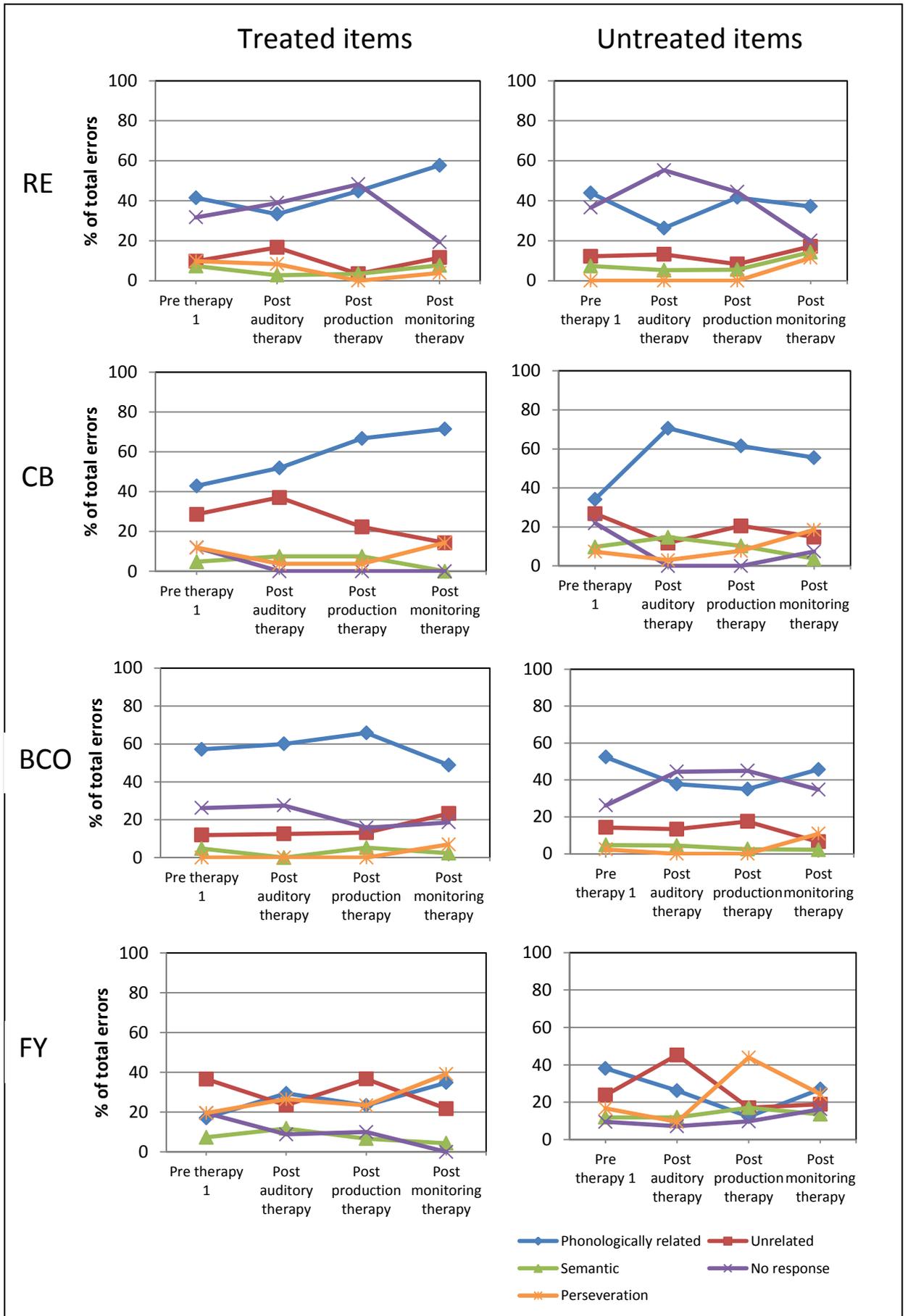


Figure 6.6: Changes in speech error types on spoken naming after therapy

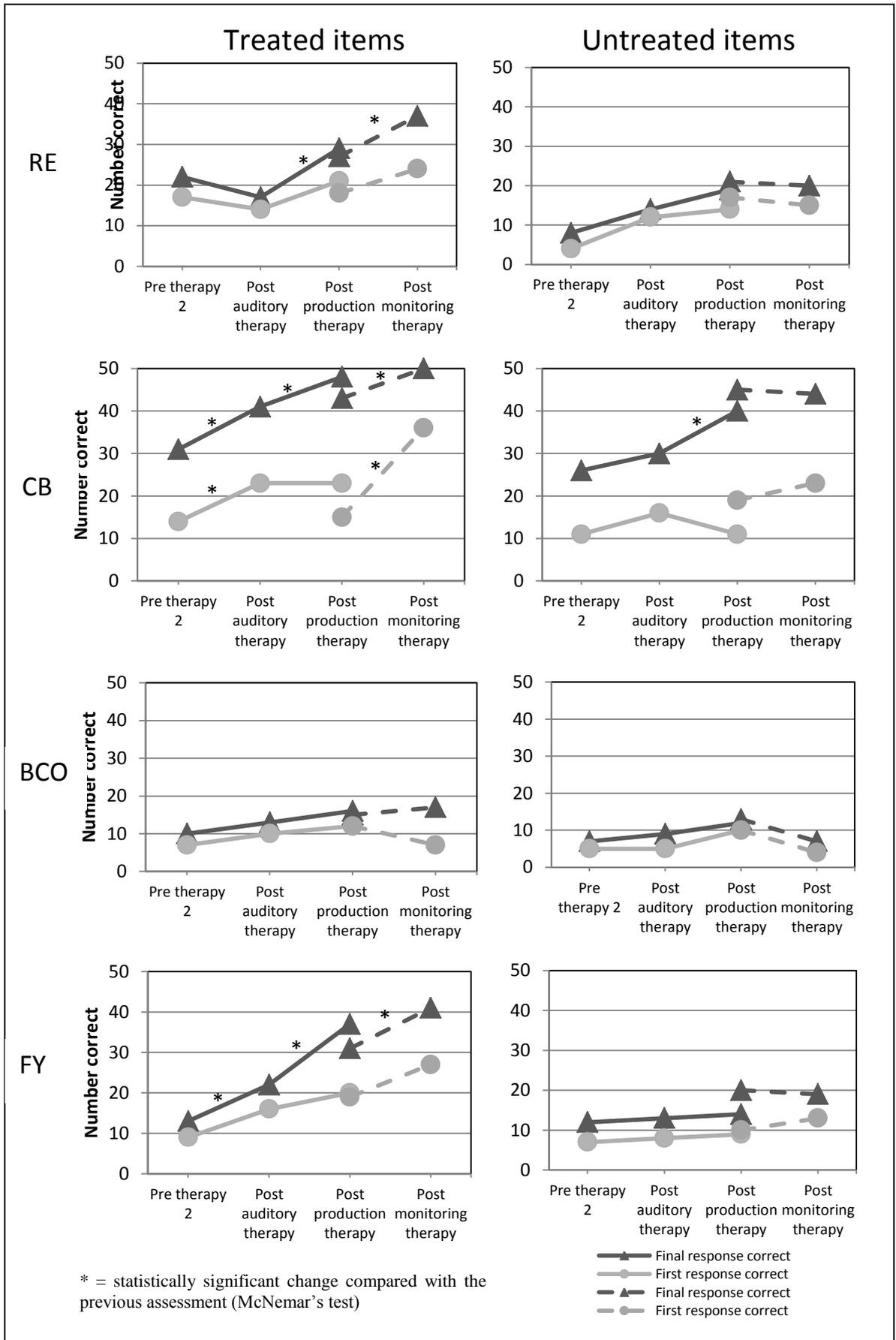


Figure 6.8 Comparison of changes on first and final response of spoken naming

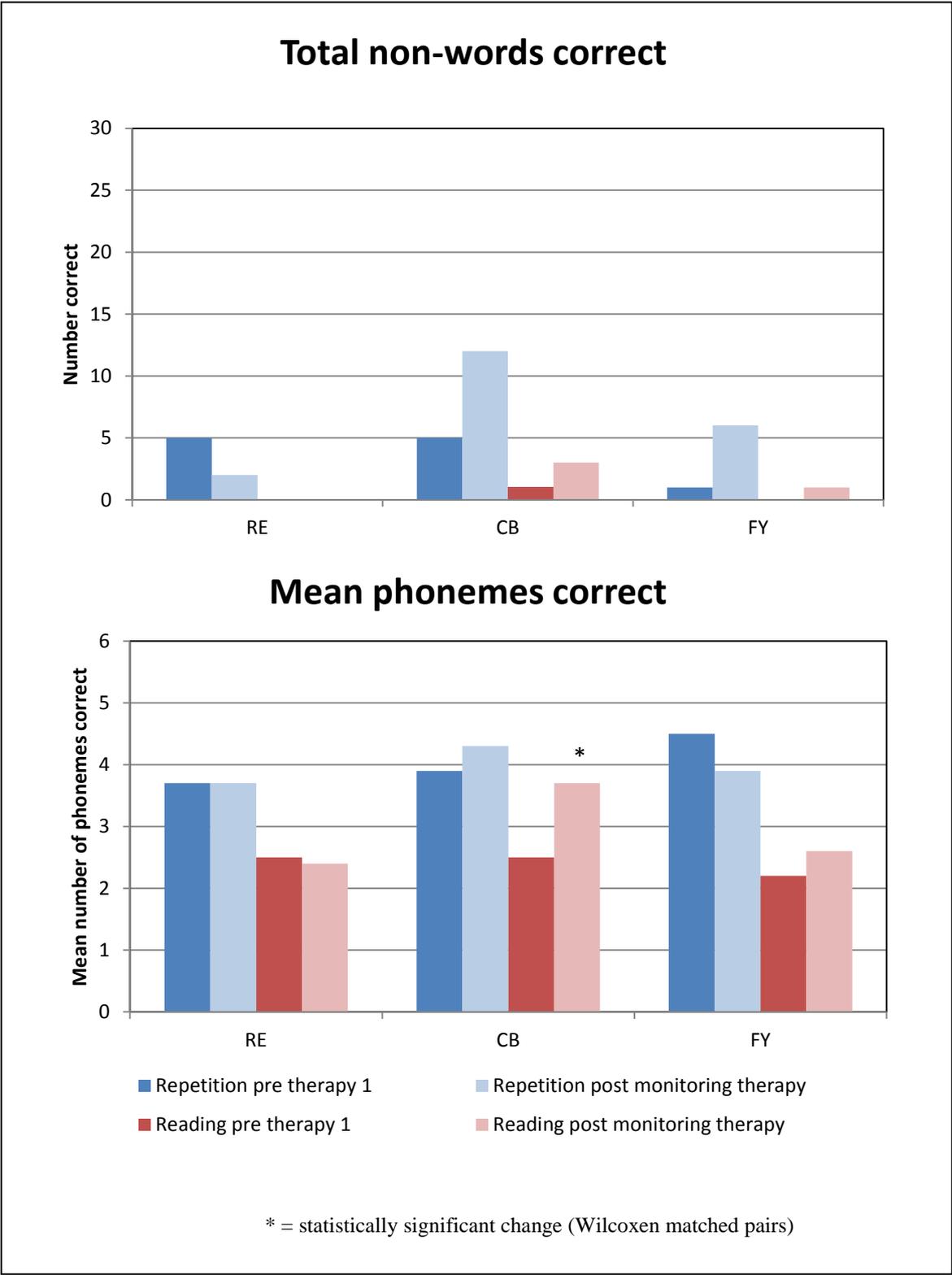


Figure 6.9 Changes in non-word repetition and reading after therapy

Chapter 7 General Discussion³

³ Parts of this chapter have been reported in Waldron, Whitworth and Howard (2011b)

7.0 Aims of chapter

This thesis set out to achieve four aims, as outlined in chapter one. These were (1) to investigate, using a case series design, whether the findings of generalised improvement reported by Franklin et al (2002) following treatment targeting auditory discrimination and monitoring are replicable with other people with aphasia whose difficulties are attributed to impaired phonological assembly, (2) to look for any differences in the outcomes for each participant with a view to identifying any factors which might suggest different language profiles will respond differentially to this therapy, (3) to explore alternative approaches to therapy for those clients who may not benefit from Franklin et al's therapy, and finally (4) to determine whether the different responses to different therapies could inform theoretical models of phonological assembly. This chapter will begin by discussing the results of study two, which aimed to build on the results of the first study by using a further case series of participants with impaired phonological assembly to gain additional replication data on Franklin et al's (2002) treatment, and to compare its effectiveness with a novel, production-focussed, approach. Discussion will focus on the hypotheses set out in chapter four proposing three subgroups of people with phonological assembly difficulties, each predicted to respond differently to the treatments being investigated. Following this, the combined results of the first and second studies are reviewed in relation to the final aim of the thesis, exploring whether the different responses to treatment can inform theoretical models of phonological assembly. The chapter concludes by evaluating some methodological issues and suggesting future research directions before summarising the clinical implications of the study.

7.1 Differences in outcomes

The results of study two (see chapter six) demonstrated that, as in study one, Franklin et al's (2002) findings of generalised improvement following therapy were not replicated, despite two of the participants, RE and CB, appearing to be more similar in linguistic impairment to MB, their original client, than any of the participants in study one. To facilitate comparison between participants in studies one and two, as well as with MB, a summary of participants' pre-therapy scores on selected key assessments, together with any changes seen in spoken naming after each therapy phase, is shown in table 7.1. While three participants in study two, RE, CB and FY, improved significantly in naming of treated items after the monitoring therapy phase, only two, CB and FY, made

significant gains in naming of treated items after the first, auditory therapy phase, and no participant improved in naming of untreated items following either of Franklin et al's treatment phases. Furthermore, while the novel production therapy phase also resulted in significant gains in spoken naming of treated words for three participants (RE, CB and FY), only one, CB, showed significant gains in spoken naming of untreated words following this treatment. In addition, no significant naming gains were shown by BCO, who had phonological assembly difficulties combined with AOS and who was predicted to benefit most from the production therapy. Of the hypotheses outlined at the end of chapter four, therefore, only one (regarding the phonological assembly combined with phonological lexical retrieval difficulties subgroup) was supported by the results of study two, with the remaining two hypotheses (regarding the pure phonological assembly difficulties and phonological assembly difficulties combined with AOS subgroups) being unsubstantiated. Possible reasons for this will now be explored via detailed analysis of participants' linguistic impairments and evaluation of the novel production therapy.

7.1.1 RE: Subgroup one?

RE was considered to be in subgroup one (pure phonological assembly impairment) because he showed evidence of a post-lexical phonological assembly impairment without either a concurrent lexical retrieval difficulty or severe AOS. It was predicted, therefore, that he would make improvements in naming of treated and untreated items after all three therapy phases. These predictions were not upheld, however, as, while RE did show significant improvements in naming of treated items after both the production and the monitoring therapy, naming of untreated items did not improve, and there were no naming improvements following the auditory therapy. These findings suggest that therapy did not cause a generalised improvement in RE's phoneme encoding processes, instead acting at a different level.

In common with RE, the three participants in study one who improved after treatment (SD, BB and HS) also made only item-specific improvements. This was explained as occurring due to the combination of lexical retrieval and phonological assembly impairments seen in these three participants, and it was proposed that therapy had acted at the level of the link between semantics and phonological lexical retrieval (see chapter

four, section 4.1). One explanation for RE's item-specific improvements, therefore, is that he might have had concurrent lexical retrieval difficulties, in addition to his phonological assembly impairment. RE's pre-therapy assessment data provides, however, very little support for a lexical impairment. His spoken output showed no effect of word frequency and he produced predominantly phonologically related errors. RE's good performance on real word homophone judgment also suggested intact phonological lexical retrieval. Furthermore, in contrast with SD, BB and HS in the first study, RE's spoken output did not improve after the auditory discrimination therapy phase. For these three participants, the auditory discrimination therapy tasks were thought to have worked in a similar way to the monitoring therapy tasks, i.e. by activating the semantics and the lexical phonology of the heard words. If therapy with RE was also acting at a lexical level, an improvement in naming following the auditory phase would have been expected. It is unlikely, then, that a deficit in lexical retrieval is responsible for RE's different treatment outcome.

An alternative explanation for RE's results comes from the possibility that he might have had some mild AOS in addition to his phonological assembly difficulties. Although AOS was not considered to be RE's main impairment, he did demonstrate some hesitancy and groping on the motor speech assessment pre-therapy (see chapter five, section 5.6). In addition, when he was frustrated about being unable to say words correctly, RE frequently gestured towards his mouth while saying things like "I know it but it just won't come out", indicating an articulatory or motor impairment. While such comments may also be indicative of lexical level impairment, RE's were qualitatively different, with greater emphasis on articulation. Further, his no-responses on the spoken output tasks pre therapy could also have been due to difficulty initiating speech (see chapter five, section 5.5.2). Moreover, some of RE's behaviour on therapy tasks, particularly during the production therapy phase, supported the diagnosis of an additional motor planning difficulty. RE had great difficulty with the production of minimal contrast pairs; often he could produce each word accurately in isolation, following articulatory cueing, but he would make increasing phonological errors when asked to alternate between two words. He was also highly inconsistent with his word productions during therapy, often getting a word correct but then appearing to "lose" it and go back to a phonologically related error. While he showed frequent awareness that this was happening, he lacked the motor control needed to produce the word correctly consistently.

The presence of AOS in addition to phonological assembly difficulties would explain both of the key differences between RE and MB's therapy outcomes, i.e. RE's item-specific effects and lack of improvement after the auditory discrimination phase. While some AOS treatment studies have found generalisation to untreated words containing treated sounds (e.g. Wambaugh et al, 1998; see also Maas, Barlow, Robin and Shapiro, 2002), most studies have not found improvements in production of words containing untreated sounds, that is, treatment effects are generally sound specific, if not entirely item-specific (see chapter four, section 4.3.2). This is presumably because treatment is targeting the retrieval and production of specific motor plans for specific sounds, and is consistent with Howard's (2000) suggestion that generalisation to untreated words can only be expected when either a generalised process is being targeted or a strategy taught (see chapter one, section 1.5.2). Furthermore, treatment studies using auditory input alone to target speech output in AOS have reported limited success (e.g. Davis et al, 2009; Fridriksson et al, 2009; see chapter four, section 4.3.1), perhaps unsurprisingly given that AOS is primarily a motor speech disorder.

There are difficulties, however, with the hypothesis that RE's therapy outcomes were due to an improvement at the level of motor planning. While therapy acting at this level would not be expected to achieve generalisation to untreated words, some generalisation across tasks, i.e. gains in repetition and reading aloud of treated words, might be expected as they share the same motor plans (Knock et al, 2000; Ballard, 2001). RE did not make any improvements in reading aloud after therapy, and although there was a significant improvement in the total number of words repeated correctly over the course of the whole study, there were no significant improvements in repetition of treated or untreated words taking consecutive scores after each therapy phase. Moreover, it is difficult to explain how the monitoring therapy phase may have led to an improvement in RE's motor planning. Based on Van der Merwe's (1997) model (see chapter one, section 1.2), it is relatively straightforward to see how the production therapy could have worked at this level; because RE was given specific feedback about place and manner of articulation of sounds, this may have helped with the retrieval of core motor plans. In addition, the production of minimal contrast pairs may have helped with planning sequences of movements. During the monitoring therapy phase, however,

therapist feedback was restricted to a phonological planning level. When RE named a picture incorrectly during this phase, he was encouraged to identify whether his error was at the beginning, middle or end of the word, with no further help given if he was still unable to say the word after making this decision, other than provision of a model to repeat. A further problem is raised by the finding that BCO (a further participant in study two) and PL (a participant in the first study), both of whom had a combination of phonological assembly difficulties and AOS (albeit a more severe AOS than RE), did not make any gains in spoken output following any treatment phase.

In summary, two alternative explanations have been discussed for why RE did not respond to therapy as predicted. First, RE may have had a lexical retrieval difficulty in addition to his phonological assembly impairment, where therapy may have worked by improving the link between semantics and lexical phonology in a similar way to three of the participants in study one; and second, RE may have had mild AOS in addition to his phonological assembly difficulties, where therapy may have worked by improving his motor planning abilities. Neither of these hypotheses, however, fully account for all of RE's results. A final factor to consider when examining the differences between RE and MB's therapy outcomes is the time post-onset. MB was only four months post-stroke at the start of the Franklin et al (2002) study, whereas RE's stroke was three years before the current study. Their histories were otherwise similar; both were over 80 years old (RE was 87, MB was 83) and both had suffered left middle cerebral artery infarcts. There is evidence to support the effectiveness of aphasia therapy up to at least six years post onset (e.g. Broida, 1977) so RE was not necessarily disadvantaged because of the time since his stroke, but MB may have benefitted from being within the critical early stages of brain recovery, during which neural connections are most likely to re-form (Robertson and Murre, 1999). Although Franklin et al reported stable baseline data demonstrating that MB was not spontaneously recovering, it is possible that the timing of her treatment, rather than level of impairment, may have been responsible for her generalised improvements.

7.1.2 CB: Subgroup one?

In common with RE, CB was also considered to be in subgroup one (pure phonological assembly impairment), and similarly, CB did not make the predicted improvements in

naming of treated and untreated items after all three therapy phases. While CB did improve significantly in naming of treated items after all three therapy phases, as well as in naming of untreated items after the production therapy, there were no improvements in naming of untreated items following either the auditory or the monitoring therapy phases. One possible explanation for CB's item-specific naming improvements following the auditory and monitoring therapy phases is that, as with RE, treatment may have improved his lexical retrieval. CB's results were more consistent than RE's with those of SD, BB and HS in study one, because his naming of treated items improved following the auditory therapy phase. However, CB's pre-therapy assessment data also lacks support for a lexical impairment. In common with RE, CB's real word homophone judgment was good, his spoken output showed no effect of word frequency, and he produced predominantly phonologically related errors. There is indeed no evidence that either CB or RE's lexical retrieval was any more impaired than MB's, Franklin et al's (2002) original client, who was thought to have a relatively pure phonological assembly difficulty. While a lexical component may have been present in that all three clients gained lower scores on spoken naming than on repetition or reading pre-therapy, a finding that could suggest a lexical impairment, and all three produced some naming errors that could have a lexical source (e.g. CB made some unrelated errors, RE made many no-responses and MB made some semantic errors), any contribution from a lexical level was considered comparable. Furthermore, unlike RE, CB showed no signs of AOS on the pre-therapy motor speech assessment (see chapter five, section 5.6). The reasons why CB did not replicate the generalised improvements of MB as predicted, therefore, are unknown, especially as, unlike RE, CB was similar to MB in time post-stroke, i.e. six months post-onset at the start of the study.

In contrast, CB did respond as predicted to the novel production therapy, showing significant improvements in naming of treated and untreated items. The different treatments, therefore, may have acted in different ways. This is supported by the finding that CB's item-specific improvements after the auditory and monitoring therapy phases came from an increase in pictures named correctly straight away, whereas the generalised naming improvements after the production therapy phase came from an increase in self-correction (see chapter six, section 6.8). Data from CB must be interpreted with caution, however, due to the presence of significant naming improvements during the untreated baseline period. Despite this caveat, the finding that

naming of untreated items only improved following the production therapy phase suggests that this treatment did impact positively on CB's phoneme encoding processes.

7.1.3 FY: Subgroup two?

FY's pre-therapy assessment profile was consistent with a phonological assembly impairment combined with lexical retrieval difficulty, i.e. that of subgroup two, due to the relatively large number of perseverative errors, as well as phonologically related errors, on her pre-therapy spoken naming. It was predicted, therefore, that she would show item-specific naming improvements following the auditory discrimination therapy phase, with possible further item-specific naming improvements following both the monitoring and the production therapy phases. This hypothesis was supported as FY showed significant improvements in naming of treated items following all three therapy phases, with no gains in naming untreated items. All three therapy phases, therefore, are proposed to have acted via improved mapping between semantics and lexical phonology, in the same way as participants SD, BB and HS in study one, with the production therapy also activating this level through the combination of seeing a picture and producing the word.

Both FY and RE improved significantly in the proportion of naming errors that were successfully self-corrected on treated items after therapy, such that their significant naming improvements were reflected only by the final response correct score (see chapter six, section 6.8). This demonstrates that their self-correction ability was improved by treatment, more than their ability to produce the word correctly straight away. A similar increase in self-correction ability was observed in HS, who showed the greatest improvement after therapy in study one, and was attributed to HS having a stronger idea of the phonology of the target that he was aiming for due to his improved lexical retrieval. This explanation can also be applied to FY and RE, with the item-specific nature of the improvements supporting a lexical locus.

		Franklin et al (2002)	Study one participants				Study two participants			
		MB	SD	BB	HS	PL	RE	CB	BCO	FY
Pre therapy assessment scores (proportion correct)	Spoken naming	.45	.25	.37	.62	.03	.31	.34	.23	.27
	Repetition	.54	.33	.61	.85	.13	.61	.82	.17	.78
	Reading Aloud	.63	.43	.53	.82	.09	.52	.59	.12	.53
	PALPA 2 Word Minimal Pair Discrimination	unknown	.53	.85	1.00	.86	.85	.97	.66	abandoned
	PALPA 15 Auditory Rhyme Judgment	.68	.64	.67	.98	.95	.95	.81	.86	.40
	PALPA 28 Homophone Decision	unknown	.50	.78	.68	.72	.73	.72	.47	.50
Significant spoken naming results after therapy	Auditory therapy	Improved treated and untreated	Improved treated only	Improved treated only	Improved treated only	Did not improve	Did not improve	Improved treated only	Did not improve	Improved treated only
	Production Therapy	n/a	n/a	n/a	n/a	n/a	Improved treated only	Improved treated and untreated	Did not improve	Improved treated only
	Monitoring Therapy	Improved treated and untreated	Did not improve	Did not improve	Improved treated only	Did not improve	Improved treated only	Improved treated only	Did not improve	Improved treated only
Proposed subgroup		Pure phon assembly	Phon assembly + lexical retrieval	Phon assembly + lexical retrieval	Phon assembly + lexical retrieval	Phon assembly plus AOS	Pure phon assembly	Pure phon assembly	Phon assembly plus AOS	Phon assembly + lexical retrieval

Table 7.1: Comparison of results across studies one and two

7.1.4 BCO: Subgroup three?

BCO's pre-therapy assessment profile was most similar to that of PL in study one, due to the presence of AOS in addition to phonological assembly difficulties, placing him in subgroup three. It was predicted, therefore, that his naming would not improve after either the auditory or the monitoring therapy phases, but that naming of treated words would improve after the production therapy phase. This hypothesis was not supported, however, as BCO made no significant naming improvements after any treatment phase. His repetition of treated words, however, did improve significantly after the production therapy phase, suggesting his phonological (or phonetic) output processing was, in fact, enhanced by the production therapy, but the higher linguistic processing demands of picture naming prevented the improvements being seen on this task. The finding that BCO performed at chance on written homophone judgment pre-therapy (see chapter five, section 5.4.2) supports the view that his impairment was not purely post-lexical, although why treatment did not cause improvements at the lexical level, in a similar way to FY, is unknown. Furthermore, BCO showed significant improvements in reading aloud of treated items following the first, auditory, therapy phase, as did PL in study one, indicating that the auditory discrimination therapy tasks also had some impact on the phonological output processing of these participants.

7.1.5 Evaluation of proposed subgroups and comparison of all participants

While all participants in the current study showed evidence of a primary impairment in post-lexical phonological assembly (i.e. all modalities of spoken output were impaired and phonologically related errors were seen on all tasks), some showed additional evidence of either lexical retrieval or motor speech difficulties, leading to the proposal, in chapter four, of three subgroups of participants, each predicted to respond differently to the treatments being investigated. Lexical retrieval difficulties were indicated by a greater range of error types present on spoken naming compared with repetition or reading, as well as high numbers of either semantically related or whole word perseverative errors on spoken naming, whereas features such as articulatory groping, distorted sound substitutions and abnormal prosody suggested motor speech difficulties. When the pre-therapy assessment scores from all eight participants in the current study are directly compared, however, both with each other and with MB, Franklin et al's original client (see table 7.1) there are very few similarities, even between participants placed in the same subgroup, such that the allocation of participants to subgroups in this

way may be viewed as too simplistic. PL and BCO, for example, were both in the phonological assembly difficulties plus AOS subgroup, yet BCO's pre-therapy spoken naming score was considerably higher than PL's, and he had greater impairments in auditory and phonological processing. Similarly, FY and HS were both in the phonological assembly plus lexical retrieval subgroup, yet FY's pre-therapy spoken naming score was considerably lower than HS's, and her auditory and phonological processing skills were more severely impaired. Furthermore, RE and CB, the two participants considered to have pure phonological assembly impairments, and therefore the most similar language profile to MB, both showed a greater difference between naming and repetition scores than MB as well as gaining higher scores than MB on the auditory processing task. The question of how to differentiate between people with aphasia in order to generate predictions regarding which therapy approach is most likely to be successful for whom should, therefore, be the subject of future research.

7.1.6 Self-correction and executive skills

In addition to the hypotheses set out at the end of chapter four setting out possible subgroups of people with phonological assembly impairments, proposals were also made, following the first study, regarding the possible influences of self-correction and executive skills in predicting which clients may benefit most from Franklin et al's treatment, particularly the second, monitoring, phase (see chapter four, section 4.2). This was motivated by the performance of HS, who was the only participant in study one to show significant naming improvements after the monitoring therapy phase. He also made the greatest proportion of self-corrections pre-therapy (self-correcting 27% of his errors across the three tasks of naming, repetition and reading aloud pre-therapy) as well as gaining the highest score on the Wisconsin Card Sorting Test (WCST) pre-therapy (completing three categories correctly).

In study two, three participants showed significant naming gains following Franklin et al's monitoring therapy phase (RE, CB and FY). Of these, RE and CB presented with similar self-correction skills to HS, with RE successfully self-correcting 32% of his errors across the three spoken production tasks pre-therapy, while for CB this figure was 30% (see chapter five, section 5.5.3). FY self-corrected 21% of her errors across the three tasks of naming, repetition and reading aloud pre-therapy, meaning her success

rate was lower than that of RE, CB and HS, but higher than either SD, BB or PL in study one, or BCO in study two, none of whom made significant naming improvements after the monitoring therapy phase. They self-corrected just 13%, 14%, 2% and 4% of their errors across the three spoken production tasks pre-therapy respectively. The results of study two, therefore, provide some support for the suggestion that partially retained self-correction abilities may be a prerequisite for Franklin et al's monitoring therapy phase. In contrast, the results of study two did not support the proposal that high scores on the WCST, indicating good executive skills, are necessary to benefit from Franklin et al's monitoring therapy phase. Of the three participants who showed significant naming gains following this treatment, RE and FY scored relatively well for their ages on the WCST, whereas CB scored very poorly, with no categories completed correctly and a high proportion of error responses (see chapter five, section 5.4.4). CB's low scores on the WCST were unexpected, given that improvements after therapy have been linked to good executive skills by several earlier studies (e.g. Fillingham et al, 2005; Lambon Ralph et al, 2010). The value of self-correction and executive skills as predictors of the success of Franklin et al's therapy, therefore, requires further investigation.

7.1.7 Evaluation of production therapy

As well as considering each participant's language profile, the design of the novel production therapy phase must also be evaluated, in order to explore all possible reasons why two participants in study two, RE and BCO, did not respond as predicted to this treatment. The production therapy was based on the articulatory-kinematic approach to AOS treatment, drawing on principles from the sound production treatment of Wambaugh and colleagues (see chapter four, section 4.3.1). In contrast with the studies by Wambaugh et al (e.g. 1998; 1999; 2010), however, which used a relatively small number of target words, containing a restricted set of target phonemes, the current study used 50 treated words, containing a wide range of phonemes. If the treated word set in the current study had been smaller, and only contained words beginning with a few selected phonemes, the production therapy may have been more successful, particularly for BCO, who presented with more features of AOS than the other participants in study two. Furthermore, despite a large body of evidence supporting this approach for the remediation of AOS, some have argued against it. For example, Varley (2011) proposed that therapy focussing on raising conscious awareness of the place and manner of

articulation of phonemes was unlikely to achieve improvements in automatic speech production, given the different neural mechanisms used for conscious and unconscious actions. Similarly, Brendel and Ziegler (2008) compared treatment targeting articulation with treatment focussing on dynamic, rhythmical cues for ten people with AOS. They found that while both resulted in significant reductions in segmental errors in sentence repetition, the rhythmical treatment had greater impact on suprasegmental aspects of speech, such as increased speed and fluency. An alternative approach to the treatment of AOS, therefore, may have resulted in greater improvements for BCO. The goal of the production therapy in the current study, however, was not to treat participants' motor speech processing, but rather to use principles of AOS treatment to target the level of phoneme assembly, such that a focus on the phonemic level, and the use of a wide range of words, was justified.

As with all the treatment protocols reported in this thesis, the production therapy was administered via twice weekly sessions lasting approximately 45 minutes, i.e. one and a half hours per week in total, thus replicating Franklin et al's (2002) original treatment procedure, and representing a level of input typical of that offered by many NHS Speech and Language Therapy services in the United Kingdom. A growing body of literature suggests that twice weekly therapy is sufficiently intensive to achieve significant improvements in speech production in people with aphasia (e.g. Sage, Snell and Lambon Ralph, 2011; Fisher, Wilshire and Ponsford, 2009; Kiran, Thompson, and Hashimoto, 2001). A review by Boghal, Teasell, Foley, and Speechley (2003), however, recommended that more intensive aphasia therapy input is likely to be more effective. Furthermore, the literature on treatment of motor speech disorders suggests that greater intensity of input is required to stimulate neural motor pathways (Varley, 2011; Whiteside et al, 2012). If the production therapy, therefore, had been delivered more intensively, the effects may have been greater.

Despite the weaknesses reported above, the novel production therapy phase resulted in significant gains in spoken naming of treated words for three out of four participants (RE, CB and FY), in common with Franklin et al's (2002) monitoring therapy phase. Furthermore, following the production therapy, spoken naming of untreated words improved significantly for CB, and repetition of treated words improved significantly for BCO, who made no naming gains after therapy. The effectiveness of the novel

production therapy in targeting both lexical (FY) and post lexical (CB) phonological processing has therefore been demonstrated, making it a potentially valuable tool for clinicians working with this client group. Indeed, several advantages of the production-focussed approach presented themselves. First, it was easier for participants to understand why they were doing the production therapy, being more transparently related to the goal of working on speech accuracy than either the auditory or the monitoring therapy. The second advantage related to homework, which was given to participants during all three therapy phases, but was often completed less consistently during the auditory and monitoring phases because the assistance of another person was required (to provide a stimulus by e.g. reading aloud target words while participants either chose the initial or final letter, or decided whether the word was right or wrong for the picture). In contrast, participants were able to carry out the production therapy homework independently, resulting in it being more frequently completed. A further advantage related to the provision of feedback following the production of a phonological error. During the monitoring therapy, participants often became frustrated by the lack of help given by the therapist, whereas during the production therapy, specific feedback regarding how to say the sounds correctly was provided. The final advantage, particularly for FY who had concomitant auditory processing difficulties, was the lesser demands placed on participants' auditory skills by the production therapy. The value of participant preference in achieving long term engagement with therapy was emphasised by Conroy, Sage and Lambon Ralph (2009). Conroy et al (2009) compared decreasing and increasing cueing therapies (errorless and errorful respectively) and found that while no difference in spoken naming outcome was seen, participants with more severe naming difficulties preferred the decreasing cue therapy as it made success more likely, whereas those with milder naming difficulties preferred the increasing cue therapy as it maintained a degree of challenge, thus sustaining motivation. Similarly, although spoken naming outcomes in the current study were comparable between the production therapy and the monitoring therapy, the increased preference of participants for the production therapy may aid treatment decisions with future clients.

7.2 Implications for theoretical models

Through investigation of the outcomes of contrasting therapies, the final aim of this thesis was to explore whether participants' differing responses to therapy could inform

theoretical models of phonological output. Nickels et al (2010) proposed that treatment studies are an important, but often neglected, methodological tool that can be used to evaluate cognitive neuropsychological theories (see chapter one, section 1.6). One way in which treatment studies can be used for this purpose is by exploring patterns of generalisation, from treated items to untreated items or tasks, suggesting shared representations or processes. Results can then be compared to the predictions made by one or more theoretical models (Nickels et al, 2010). The first and second studies in this thesis will now be considered together to discuss the implications for two main areas of theoretical interest, i.e. the number of phonological processing levels and the relationship between speech comprehension and production.

7.2.1 One or two levels of phonological processing?

As discussed in chapter one, the two most widely used cognitive neuropsychological models of single word phonological processing are those of Levelt et al (1999) and Dell et al (1997). A key difference between these two models surrounds whether there are two levels of phonological processing (lexical and post-lexical), as in Levelt et al's model, or a single, lexical level, as in Dell et al's model (see chapter one, section 1.1). Using Levelt et al's model, treatment acting at a phonological lexical level would not be expected to cause generalisation to untreated items, because lexical representations respond in an item-specific way. Generalisation to untreated items would be predicted, however, following treatment acting at a post-lexical phonological level because these encoding processes are thought to be shared by all spoken words. Dell et al's model has rarely been used to explain generalisation patterns, such that the predictions made by this model are unclear (see chapter one, section 1.5.2).

In the current study, a distinction between lexical and post-lexical phonological processing levels was supported by the pre-therapy linguistic assessment results. While all eight participants presented with predominantly phonologically related errors on all spoken production tasks, four (SD, BB, HS and FY) additionally presented with large numbers of either semantically related or perseverative errors on spoken naming. This suggested that these four participants had a phonological lexical retrieval deficit combined with a phonological assembly impairment. Further support for the distinction between lexical and post-lexical levels of impairment came from the finding that all

spoken naming improvements made by these four participants following therapy were item-specific, suggesting therapy had acted at a lexical level. In contrast, MB, the client originally studied by Franklin et al (2002), showed no signs of additional lexical impairment and made generalised improvements in naming of treated and untreated items following therapy. Similarly, one participant in the current study (CB) presented with a pre-therapy linguistic profile most consistent with a pure phonological assembly deficit, and he was the only participant to show generalisation to naming of untreated items following the production therapy phase, indicating therapy had acted at a post-lexical level. It is difficult to see how a model such as that of Dell et al (1997), with only one level of phonological processing, would explain these varying patterns of generalisation following therapy, unless a post-lexical phonological encoding stage is assumed to occur after the phoneme level of lexical processing, as proposed by Goldrick and Rapp (2002) (see chapter one, section 1.5.2). The results of the current study, therefore, provide support for Levelt et al's (1999) model, although the distinction between lexical and post-lexical phonological impairments cannot explain all the different outcomes, e.g. why neither CB nor RE showed generalised naming improvements following the monitoring therapy when neither presented with a lexical deficit. It is also unclear why therapy could not act at both a lexical and a post-lexical level, thus resulting in generalisation to untreated items despite the presence of a lexical impairment.

7.2.2 Links between speech comprehension and production

The close relationship in cognitive neuropsychological models between speech comprehension and production processes was also introduced earlier (see chapter one, section 1.4). The finding that five out of eight participants in the current study (SD, BB, HS, CB and FY) improved significantly in spoken naming of treated items following therapy targeting auditory input alone provides further support for this, building on previous studies where treating input (e.g. via word to picture matching tasks) has improved spoken output for people with anomia (e.g. Howard, Hickin, Redmond, Clark and Best, 2006). This is particularly encouraging, clinically, given that three out of these five participants (SD, BB and FY) had some degree of auditory processing impairment prior to therapy. Less positive, clinically, was the discovery that auditory input treatment did not lead to spoken output gains for the two participants with AOS in addition to phonological assembly difficulties (PL and BCO). This would imply that the

links between speech comprehension and production are stronger at the lexical-semantic and phonological encoding levels than at the phonetic encoding stage. The findings by Davis et al (2009) and Fridriksson et al (2009), of improved spoken output following auditory input treatment for people with AOS (see chapter four, section 4.3.1), were not replicated therefore, thus supporting the claim, made in chapter four, that the improvements reported in these studies were either not robust or were attributable to motor aspects of treatment.

7.2.3 Summary of theoretical implications

The results reported in this thesis have contributed to our understanding of theoretical models of spoken word production and comprehension by examining participants' differing responses to different therapies and exploring their pre-therapy profiles of impairment. First, through a comparison of patterns of generalisation from treated to untreated words, the results have provided support for a distinction between lexical and post-lexical levels of phonological processing, as proposed by Levelt et al (1999). Second, through a comparison of the language profiles of those participants who improved in spoken naming after auditory input therapy with those who did not, support has been provided for a model that incorporates separate, albeit closely linked, speech perception and production mechanisms, particularly at a lexical-semantic level (e.g. Monsell, 1987; Nickels et al, 1997; Jacquemot et al, 2007).

7.3 Methodological evaluation and future research

Several possible limitations in the study design will now be discussed, together with some interesting aspects of the data, which may be followed up in future research.

7.3.1 Order of treatment phases

Order effects in treatment are an issue to consider in this study. In both studies, all participants underwent either two or three treatment phases in the same order, such that there may have been carryover of effects from one treatment phase to the next.

Although, in study two, the treated and untreated word sets were divided after the second treatment phase, thus allowing an examination of any carryover of treatment effects into the third phase, the same set of words was treated in phases one and two in

both studies. Therefore, any improvements seen after the second treatment phase (monitoring therapy in study one and production therapy in study two) may have been influenced by the treatment received in the first phase (auditory therapy in both studies), even if no spoken output improvements were seen after the first phase, as with RE. The question of whether the auditory discrimination therapy is a necessary precursor to both the monitoring and the production therapy could be addressed in future research.

7.3.2 Method of analysing phonologically related errors

The method in which speech errors were defined as phonologically related also warrants evaluation. During the pre-therapy assessment of spoken word production in both studies, participants' error responses in spoken naming, repetition and reading aloud were classified as either phonologically related, unrelated, semantically related, no response or perseveration, with errors classified as phonologically related if they shared 50% or more of their phonemes with the target in any order, and unrelated if they shared less than 50% of their phonemes with the target (see chapter two, section 2.6.2). This method of classifying phonological errors is consistent with that used in previous studies (e.g. Olsen, Romani and Halloran, 2007). A weakness of the current study, however, was the lack of evaluation of inter-rater reliability of error coding, as all errors were categorised only by the researcher. This could be addressed more rigorously in future research.

In addition, these criteria may not have been specific enough for the purposes of this study, as they allowed the inclusion of a wide range of errors within the phonologically related category, from a single phoneme substitution (e.g. /bæθlu:m/ for "bathroom") to errors bearing a more distant relationship to the target, despite sharing more than 50% of phonemes (e.g. /lɪŋæt/ for "skeleton"). More stringent criteria, e.g. specifying 50% or more phonemes to be shared with the target *in the correct order*, may have aided diagnosis of participants' underlying phonological impairment. Alternatively, additional aspects of phonology could be incorporated, e.g. number of syllables or metrical stress. Consideration of phonological similarity in terms of syllable rather than phoneme structure could provide valuable diagnostic information in distinguishing lexical and post-lexical phonological impairments. In Levelt et al's (1999) model of speech production, the stored phonological lexical representation contains information about the number of syllables and metrical stress pattern. A phonological error containing the

correct syllable number and metrical stress, therefore, is most likely to reflect a post-lexical impairment. Alternatively, the correct metrical stress pattern could occur by chance, with around 80% of two-syllable words in English being stressed on the first syllable (Howard and Smith, 2002). In order to evaluate, in the current study, whether a different method of error classification would alter the overall pattern of error type, thereby revealing additional information about the level of impairment, the pre-therapy spoken naming responses of one participant, RE, were examined in detail. RE was selected for this additional level of analysis due to informal observations of an apparently high number of errors classified as unrelated despite sharing the correct syllable structure, thereby warranting further investigation.

Of the 35 spoken naming errors originally classified as phonologically related in RE's pre-therapy assessment, seven were the first syllable of the target word and, of these, six were subsequently self-corrected (e.g. /kɒf/ /kɒfi:/). Of the remaining 28, 21 had the correct number of syllables and metrical stress, as well as a broadly correct phonemic structure, with either a single phonemic error or a combination. The remaining seven errors in this category had an incorrect number of syllables and, although at least 50% of their phonemes were shared with the target, they were often in an incorrect order (e.g. /æsk/ for "carrot"). Of the nine spoken naming errors originally classified as unrelated, four actually had the correct number of syllables and metrical stress, albeit with mostly incorrect phonemes (e.g. /mait/ for mouse). Judging RE's errors using similarity of syllable structure, therefore, would result in 32 (rather than 35) being classified as phonologically related (7+21+4) and 12 (rather than 9) as unrelated (7+5). This would not alter RE's overall speech error pattern, however, as phonologically related errors would remain the greatest category. For RE, therefore, the proportion of phonologically related errors actually unrelated in syllable structure, and the proportion of unrelated errors actually phonologically related in syllable structure, was comparable. Other people with aphasia may, however, present with a particularly high number of either one of these error types, in which case this method of analysis could be explored in greater depth.

7.3.3 Method of analysing perseverative errors

As the data presented for discussion in this thesis has been restricted to that which is pertinent to the research questions outlined at the beginning of this chapter, certain

elements of the data, such as participants' perseverative errors, could be re-analysed in more depth in future. In the pre-therapy analysis of participants' speech errors, whole word perseverations were included but blended perseverations were not. This decision was taken due to the difficulties in coding such errors, which could arise due to chance, as well as the potential for subjective decisions, as all analysis was performed by the researcher. Moses et al (2007), however, proposed that blended perseverations are particularly common in people with phonological assembly impairments. Spoken output data from the current study could, therefore, be re-analysed to examine the presence of this type of perseveration in this client group further. This might be achieved by categorising errors first into either semantic or phonological and then categorising them all as either perseverative or non-perseverative (e.g. Ackerman and Ellis, 2007), rather than using perseveration as a separate category. Furthermore, as recommended by Moses et al (2007), a detailed examination of any changes in both whole word perseveration and blended perseverations after each type of therapy could help to reveal the level at which therapy was having its effect.

7.3.4 Analysis of multiple attempts

In considering participants' multiple attempts at the target during the spoken word production assessments, this thesis focussed only on participants' first and final attempts, but this approach does not always capture the important elements of the response. For example, it does not address the reasons for repeated responses (i.e. whether the person repeats the word as confirmation that they think it is correct, or in order to listen to it back, indicating uncertainty) or final responses (i.e. whether the person stops talking because they think they are correct or because they do not think they can get any closer to the target word). This method also fails to allow an exploration of the possibility that participants may get phonologically closer to the target in the middle of the repeated attempts but then get further away again. In future, a more detailed analysis of participants' "conduite d'approche" sequences could be performed.

7.3.5 Measuring real life change

Methods of measuring real life change following therapy will now be considered. All therapy outcomes reported in this thesis have focussed on single word spoken

production, reflecting the stance taken by the small volume of literature to date addressing treatment of phonological assembly difficulties in aphasia, where therapy effectiveness is viewed as initially needing to be established at a single word level. It is also important, however, to consider ways of measuring the impact of improvements in spoken word production on both connected speech and real life communication (e.g. Herbert, Hickin, Howard, Osborne and Best, 2008; Kagan, Simmons-Mackie, Rowland, Huijbregts, Shumway, McEwen, Threats and Sharp, 2008). To address this, several additional outcome measures were trialled in study one, to evaluate any changes beyond the single word. These were naming pictures in sentences (administered with all four participants), conversation, and participant self-report, with the latter two methods trialled with only one participant each, due to the considerable time investment. None of these real life measures were included in the protocol for study two because they were not directly related to the research questions of the thesis. Nevertheless, the impact of therapy for phonological assembly impairments on real life communication should be evaluated in greater depth in future research.

In Franklin et al's (2002) original study, client MB's ability to name target words in sentences, as well as in isolation, was assessed before and after therapy, using composite pictures containing items from the Nickels naming test. MB showed significant improvements on this task for both treated and untreated items. All participants in study one, therefore, were assessed using a similar naming in sentences task before and after therapy. In the current study, however, this was not a successful measure of connected speech, as the target sentence was rarely produced, with participants instead listing each item that was present, such that the data could not be analysed meaningfully.

Real life change after therapy may also be captured using a conversation analysis framework (e.g. Carragher, Conroy, Sage and Wilkinson, 2012; Booth and Perkins, 1999), although the qualitative nature and inherent variability of conversation raises questions over reliability across samples (Hesketh, Long, Patchick, Lee and Bowen, 2008; Manochioping, Sheard and Reed, 1992). In order to explore this possibility, one participant in study one (SD) was videoed, before and after therapy, engaged in a 10-minute conversation with her husband. The researcher was not present during either conversation, to reduce any observer paradox. Both conversations were transcribed

using conversation analysis conventions, and the numbers of speech production errors in each were calculated. Further, the resulting impact of each speech production error on the conversation was classified as either (a) conversation partner (CP) understood what SD meant without needing the error to be repaired; (b) CP successfully repaired the error for SD; (c) CP needed to ask SD to repair the error; or (d) SD successfully repaired the error herself. In the post-therapy conversation, SD made fewer speech production errors than pre-therapy (11 compared with 25) but the proportions of each repair type were broadly similar, with SD's husband able to understand her on most occasions both before and after therapy. This single example, therefore, indicates that conversation analysis holds some promise for capturing a reduction in speech production errors in conversation following therapy (see also Greenwood et al, 2010, for similar findings). The degree of variability in conversational topic, however, means that a repeated baseline pre-therapy would be recommended if this were to be used as an outcome measure in future studies (Carragher et al, 2012).

The final measure of real life change explored in study one was participant self report. One of the few aphasia therapy studies to report on participants' views following treatment is a case series by Best, Greenwood, Grassly and Hickin (2008) who used the Communication Disability Profile (CDP) (Swinburn with Byng, 2006) as a measure of change following cued naming therapy. The CDP allows people with aphasia to express their views about the impact of their aphasia on everyday life using an interview structured around the four areas of activity, participation, external influences and emotions. The activity section requires participants to rate their ability to perform tasks related to talking, understanding, reading and writing, while in the subsequent sections participants are asked to rate the impact of their aphasia on day to day situations, to reflect on what helps or hinders their communication, and to rate the degree to which their aphasia causes them to feel various emotions. Responses are elicited using a pictorial scale corresponding to a numerical score between 0 and 4, with zero indicating no problem and four extreme difficulties. Significant improvements in self ratings in the activity section of the CDP were reported after therapy for all eight participants studied by Best et al (2008), as well as significant gains in naming of treated items, indicating the potential of this measure for capturing the impact of single word treatment on real life. Furthermore, Chue, Rose and Swinburn (2010) administered the CDP with 16 people with chronic aphasia on two occasions and reported a high level of test-retest reliability for the activity section, lending additional support for its use as an outcome

measure. In the current study, the CDP was administered before and after therapy with BB, a participant in study one. BB's responses in the activity section translated into a score of 34 before therapy (out of a maximum 64) and 36 after therapy, indicating no significant difference (Wilcoxon signed rank test $p=0.608$ two tailed). Therefore, despite significant improvements in BB's spoken naming of treated items following the auditory therapy phase, these gains appear to have made no impact on her perception of her day to day communicative ability. This may be explained in part by the timing of the post-therapy CDP, which was only re-administered following the final, monitoring therapy phase, during which no further naming gains were made by BB. Alternatively, it may reflect the impersonal nature of the target vocabulary used in treatment, taken from the Nickels naming test, rather than a functional vocabulary selected by BB. It is also possible, however, that the CDP is not a sufficiently sensitive measure of real life change, with more studies needed to investigate its use for this purpose.

7.4 Concluding remarks

In this thesis, cognitive neuropsychological theory has been used to underpin a detailed examination of the differences between participant's linguistic impairments and to explore the underlying mechanisms for participants' different responses to therapy, in order to provide clinicians with a greater understanding of which therapy is likely to work for whom, and why. This study has added to the evidence base of therapy studies for people with aphasia with phonological assembly difficulties by replicating a successful single case study by Franklin et al (2002) with a case series of eight participants, as well as gathering data on a new method of treatment with four of the eight participants. Results demonstrated that people with phonological assembly difficulties respond to the therapy reported by Franklin et al (2002) in a variety of different ways. All naming improvements seen in the current study following Franklin et al's treatment were item-specific; the generalised improvements in spoken output reported by Franklin et al (2002) are still yet to be replicated. In addition, there was variability regarding the success of each of Franklin et al's two treatment phases, with only three participants (HS, CB and FY) demonstrating improved naming following both phases. In contrast, two participants made naming improvements only after Franklin et al's auditory therapy (SD and BB), and one only after the monitoring therapy phase (RE). Furthermore, the novel production therapy, based on the articulatory-kinematic approach to AOS treatment, focussed on improving participant's

phonological output impairment directly, and achieved significant improvements in spoken naming for three out of four participants (CB, RE and FY), although only one showed generalisation to naming of untreated items (CB). While further studies are needed to investigate the effectiveness of this production-based approach with a larger sample of clients, it nonetheless provides a valuable additional clinical tool.

Many differences between participants have been identified, both in their pre-therapy pattern of linguistic deficit and in their response to therapy, demonstrating that this group of clients is far from homogenous, and that the question of identifying which treatment is effective for whom is complex, especially as the same therapy was effective at different levels for different individuals, and did not always produce the outcomes predicted. Franklin et al's (2002) original treatment was devised with the aim of teaching a self-monitoring strategy but instead, MB, who had a relatively pure post-lexical phonological impairment, showed a generalised improvement in phonological assembly. In contrast, four of the participants in the current study whose speech improved following therapy (SD, BB, HS and FY) had a combination of lexical and post-lexical phonological impairments and showed item-specific improvements in the mapping between semantics and phonological lexical retrieval. Furthermore, two participants (RE and CB) appeared to have a relatively pure phonological assembly disorder but also showed only item-specific improvements following Franklin et al's therapy, for reasons that remain unidentified.

In conclusion, the investigation of the outcomes of different therapies for people with phonological assembly difficulties set out in this thesis have highlighted the reciprocity between theory and therapy; cognitive neuropsychological theory has driven interpretation of the results while the results of therapy have been used to evaluate cognitive neuropsychological theories. Due to the individual linguistic profiles of the participants recruited to this study, the impact of co-occurring deficits (either lexical or motor) has been the main focus, rather than a detailed examination of the phonological assembly process itself. The findings have, nonetheless, implications for theoretical models of spoken word production, e.g. providing support for Levelt et al's (1999) distinction between lexical and post-lexical levels of phonological processing. Further treatment studies are clearly needed in order to better understand this challenging client group, and to provide further insights into the nature of phonological output processing.

Appendix A: Words used for assessment of naming, repetition and reading aloud in study two

1 syllable CV High Frequency	1. Fire 2. Car 3. Chair 4. Door 5. Tie 6. Key 7. Sea 8. Shoe 9. Hair	2 syllable CVCV Low Frequency	51. Feather 52. Fairy 53. Holly 54. Honey 55. Ladder 56. Pepper 57. Shower 58. Tiger 59. Hammer
1 syllable CV Low Frequency	10. Bear 11. Bee 12. Bow 13. Jar 14. Pier 15. Pie 16. Toe 17. Deer	2 syllable CVCVC High Frequency	60. Bottle 61. Button 62. Rabbit 63. Pocket 64. Rubbish 65. Muscle 66. Table
1 syllable CVC High Frequency	18. Bus 19. Pipe 20. Ring 21. Cat 22. Cheese 23. Dog 24. Fish 25. Gun 26. Gate 27. Map 28. Hat 29. Watch 30. Mouse 31. Tongue 32. Wheel 33. Horse	2 syllable CVCVC Low Frequency	67. Bacon 68. Balloon 69. Garlic 70. Towel 71. Kettle 72. Lemon 73. Medal 74. Rocket 75. Coffin 76. Carrot
		2 syllable CVCCVC High Frequency	77. Bathroom 78. Mountain 79. Bedroom
		2 syllable CVCCVC Low Frequency	80. Biscuit 81. Candle 82. Mushroom
		3 syllable High Frequency	83. Potato 84. Newspaper 85. Chocolate 86. Computer 87. Medicine 88. Cigarette 89. Library 90. Camera 91. Radio
1 syllable CVC Low Frequency	34. Doll 35. Duck 36. Fork 37. Goat 38. Nun 39. Pin 40. Juice 41. Lamb 42. Sock 43. Kite	3 syllable Low Frequency	92. Banana 93. Caravan 94. Calendar 95. Tomato 96. Skeleton 97. Umbrella 98. Onion 99. Butterfly 100. Elephant
2 syllable CVCV High Frequency	44. Money 45. Coffee 46. Dinner 47. Letter 48. River 49. Mirror 50. Baby		

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