The National University of Ireland

NUI MAYNOOTH

Ollscoil na hÉireann Má Nuad

Recombinative Generalisation and Psycholinguistic Grain Size: An Investigation of Reading Related Skills in Adult Readers and Children with Learning Difficulties

Thesis submitted to Department of Psychology, Faculty of Science and Engineering, in fulfilment of the requirements for the degree of Doctor of Philosophy, National University of Ireland Maynooth

Catherine Mahon

October 2010

Research Supervisor: Dr. Fiona Lyddy

Head of Department: Dr. Fiona Lyddy

Table of Contents

Acknowledgements

There are many people who I would like to sincerely thank for all their help throughout the course of this research. Firstly, I would like to thank my research supervisor, Dr Fiona Lyddy, for all her invaluable help and support, for her tremendous work and immense knowledge, and for all her kindness shown during my years at Maynooth. I am sure that I could not have had a better supervisor. I am also grateful to all the staff in the Psychology Department who have helped me, especially Professor Dermot Barnes-Holmes for his help and advice on the JABA paper, Mr Derek Walsh for his computer guidance, and Ms Anne Dooley, Ms Victoria Thompson, and Ms Caroline Edwards, for all their assistance.

This research was supported by a Postgraduate Research Scholarship from the Irish Research Council for the Humanities and Social Sciences, and a John and Pat Hume Scholarship from the National University of Ireland Maynooth. I am grateful for this funding which helped me to complete my research.

Many thanks also to Justé Koller for her assistance in collecting data, and to Christine Parsons for her advice and helpfulness.

I am extremely grateful to Ms Carmel Wynne for allowing me to come into school, for all her friendliness in making me feel welcome, and always enquiring about how I was getting on. To all the teachers too, who were very good to accommodate me in their classes. I really appreciate all their help in answering any questions that I might have had.

A great big thank you to all the wonderful children who I worked with on this research. Thank you all so much for making the research so enjoyable. Thank you also to the children's parents for allowing their children to take part.

Thank you to all the participants who took part in the adult studies.

I can never say thank you enough to my Mum, Dad, and Grandad, for all their love and encouragement. I will be forever grateful.

Publications and Presentations

Mahon, C., Lyddy, F., & Barnes-Holmes, D. (2010). A computerised procedure to support recombinative generalisation and novel word recognition. Paper submitted to The Psychological Record.

Mahon, C., Lyddy, F., & Barnes-Holmes, D. (2010). Recombinative generalisation of sub-word units using matching-to-sample. *Journal of Applied Behavior Analysis, 43, 2*, 303-307.

Mahon, C., & Lyddy, F. (2009). Supporting reading in children with learning difficulties using a matching-to-sample procedure: The role of phonological unit size. Research presentation at the Annual Conference of the Psychological Society of Ireland, November 2009.

Mahon, C., Lyddy, F., & Barnes-Holmes, D. (2008). Promoting recombinative generalisation for reading instruction: Effectiveness of a matching-to-sample protocol. Research presentation at the Annual Conference of the Psychological Society of Ireland, November 2008.

Parsons, C. E., Mahon, C., & Lyddy, F. (2008). Assessing explicit and implicit phonological awareness in typically developing children and children with learning difficulties. *Reading News,* April 2008, 16-21.

Parsons, C. E., Mahon, C., & Lyddy, F. (2008). Assessing phonological awareness in typically developing children and children with learning difficulties: Use of explicit and implicit measures. *The Irish Psychologist, 34, 8*, 232-236.

Mahon, C., Parsons, C. E., & Lyddy, F. (2008). Assessing phonological awareness and letter-sound knowledge: Examining tasks for typically developing children and children with learning difficulties. Poster presented at the Annual Conference of the British Psychological Society, April 2008.

Mahon, C., Parsons, C. E., & Lyddy, F. (2007). Assessing phonological awareness: Developing tasks for different child populations. Poster presented at the Annual Conference of the Psychological Society of Ireland, November 2007.

Mahon, C., & Lyddy, F. (2006). Understanding properties: The role of speech and gesture for children with Autism and Down Syndrome. Poster presented at the Annual Conference of the Psychological Society of Ireland, November 2006.

Abstract

In order to read proficiently we must be able to tackle printed words that have not been explicitly taught. The process of rearranging previously learned linguistic units into novel patterns is referred to as recombinative generalisation. In the case of reading, sub-word units (e.g., onsets and rimes, phonemes, syllables) of known words are recombined to form new words that can be pronounced by reference to letter–sound correspondences. Matching-to-sample (MTS) procedures have proven to be effective in promoting recombinative generalisation. The aim of the current thesis was to further develop a MTS training protocol to facilitate recombinative generalisation. Additionally, this research aimed to extend the use of such MTS procedures by exploring ways in which the training protocol could be applied to help support recognition of the wide assortment of words encountered by beginning readers of English (e.g., monosyllabic and disyllabic words, consonant blend words, regular and exception words).

Seven experiments were undertaken with literate adult participants to thoroughly test the effectiveness of the new MTS training protocol. A novel (invented) script was constructed for use with the adult participants. The findings from these experiments are reported in the first part of the thesis.

To begin the research with the adults, modifications were made to MTS procedures developed by Mueller, Olmi, and Saunders (2000) and Keaveney (2005). The adapted MTS training protocol included conditional discrimination training, explicit symmetry training, and mixed symmetry testing for onset and rime sound–symbol relations. Experiment 1 was designed to test the efficacy of the revised protocol. All participants successfully completed the new training procedures and

could accurately identify the novel recombined onset–rime and onset–rime–rime test words. To isolate the key training components within the protocol necessary for recombinative generalisation to occur, each of the training components was removed separately from the procedure in Experiment 2. The data from Experiment 2 clearly demonstrated how vital conditional discrimination training is to facilitating the recombinative generalisation effect.

For Experiment 3, a new across-unit recombinative generalisation test was incorporated within the protocol. Recognition of recombined words composed from untrained onsets and rimes (derived from the explicitly taught onsets and rimes) was examined. In a bid to improve performance on the across-unit test, an intermediate across-unit test was added to the protocol in Experiment 4. Overall, the data from Experiments 3 and 4 indicated that the MTS protocol did appear to be effective in promoting across-unit recombinative generalisation. Likewise, in Experiment 5, the protocol was found to be effective in facilitating recognition of words containing consonant blends.

In Experiment 6, variations were made to the grain size of the training unit employed to train the sound–symbol relations. Participants completed training with onsets and rimes, phonemes, or syllables (i.e., whole CVC words). The size of the training unit employed was found to have a significant effect on accuracy in recognising the recombined test words. Although there was no difference in the recombinative generalisation performance of onset and rime and phoneme trained participants, both groups of participants identified significantly more recombined words than the syllable trained participants. The final adult experiment was designed to examine if the protocol could be used to facilitate recognition of regular (rime consistent) and exception (rime inconsistent) words. One of the main findings to emerge from this experiment was that MTS training at *only* one grain size (i.e., onsets and rimes or phonemes or syllables) appeared to be insufficient to enable participants to tackle both the regular and exception words.

For the second part of the thesis, the protocol was used as a remedial tool within a classroom setting with seven children with mild learning disabilities. The aim of this phase of the research was to see if the protocol could help improve the children's word recognition and naming skills for actual words.

Baseline reading assessments were undertaken prior to the start of training to measure key reading related skills such as phonological awareness and letter–sound knowledge. A subsequent study was conducted to determine if there was an optimal sized training unit for each child (e.g., onsets and rimes, phonemes, or syllables) that appeared to best facilitate recombinative generalisation. All of the children demonstrated gains in word naming and recognition following completion of the MTS training procedures, most notably, following onset and rime training.

To try and strengthen the effectiveness of the procedure, a stimulus equivalence training component, in which the children learned to relate printed words, spoken words, and corresponding pictures, was incorporated into the protocol. The stimulus equivalence component was used in a novel way to train recognition of regular and exception words. Again, encouraging results were obtained, with all of the children showing gains in their ability to read aloud and recognise trained and untrained (recombined) words.

Implications of both the adult and child research are discussed in the final chapter of the thesis. There is a particular focus on how there is much to be potentially gained from integrating behavioural methods with cognitive theories of reading when the aim is to develop effective aids to teach components of reading.

List of Figures

List of Tables

Chapter One

General Introduction

1.1 Components of reading

It cannot be overstated that reading is one of the most important skills that can be acquired. Reading is composed of a number of related subcomponents, including decoding and comprehension. In the early stages of learning to read, children must learn how printed letters map onto, and represent, units of sound, for their particular language (Ziegler & Goswami, 2005). Writing systems vary as to the different units of spoken language (i.e., the phonological units) that are represented in print (i.e., by orthographic units). In alphabetic writing systems, such as English, Spanish, and Italian, graphemes (printed letters) map onto phonemes (individual sounds), although as we shall see, the nature of these grapheme–phoneme relations is far from straightforward in some alphabetic writing systems, most notably in English. In other orthographies, referred to as 'syllabaries', the printed symbols are associated with larger sized syllable units (e.g., Japanese Kana). In contrast, some scripts (e.g., Chinese) do not represent units of sound such as phonemes or syllables, but instead, the printed units correspond to morphemes (i.e., units associated with meaning). Collectively, such scripts are commonly known as logographic writing systems. The range of ways in which print can relate to speech has been proposed to contribute to differences in how children learn to read across languages (see Ziegler & Goswami, 2005).

Whether children are learning to read an alphabetic, syllabic, or logographic script, the pinnacle of proficient reading for all is comprehension of text. Printed words must not only be pronounced accurately, but the 'meaning' of those words needs to be understood.

Comprehension is influenced by a number of factors, including word knowledge, spoken language experience, and working memory (Kintsch & Kintsch, 2005; Oakhill & Cain, 2000). Above all of the contributing factors, the ability to recognise individual words is vital to comprehension (Samuels, 1994; Stanovich, 2000). As highlighted by Adams (1990), "unless the processes involved in individual word recognition operate properly, nothing else in the system can either" (p. 3). Readers who cannot recognise individual words quickly and accurately will be at a considerable disadvantage as they may be forced to disengage from thinking about the meaning of text to concentrate instead on processing individual words (see Ehri, 2005; O'Connor, Swanson & Geraghty, 2010; Samuels & Flor, 1997).

Individual word recognition is therefore one of the component skills of reading. It is a skill that must be acquired for proficient reading given that numerous studies have highlighted the difficulties that poor readers have in identifying isolated words in word lists and words embedded in sentences (e.g., Chapman, Tunmer, & Prochnow, 2001; Jenkins, Fuchs, van den Broek, Espin, & Deno, 2005; Rack, Snowling, & Jensen, 1992).

Acknowledging the importance of individual word recognition, the aim of the current thesis was to develop an effective training procedure to promote printed word identification, with a particular focus on facilitating recognition of novel (i.e., unfamiliar) words that have not been explicitly taught. For the first part of this thesis, findings from a series of experiments with literate adults are discussed. The second part of the thesis describes what happened when similar training procedures were used with a small group of children with learning difficulties in an attempt to support their word recognition skills.

1.2 How are printed words recognised?

Word recognition fundamentally entails translating printed words into their corresponding spoken words. There are at least two ways in which this task can be accomplished when learning to read in English.

When words are identified automatically (i.e., from memory) in their entirety as whole units, this is referred to as 'sight word reading' (Ehri, 2005). Alternatively, when knowledge of typical letter–sound mappings is employed to sound out a word, this may be referred to as 'phonological recoding' (Ehri, 1992; Share, 1995). Thus, a child learning to read in English who has learned that the letters 'h', 'a', 't', can represent the sounds /h/, /æ/, /t/, respectively, should be able to employ this knowledge of letter–sound relations to pronounce the printed word 'hat' (see Ehri, 1991; 1998).

1.2.1 Dual-route theories of word recognition

The way in which words can be identified by use of these two primary strategies (sight word reading versus phonological recoding) has often been framed within the widely cited dual-route models of word recognition (e.g., the dual-route cascaded model, Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; the connectionist dual process model, Perry, Ziegler, & Zorzi, 2007). Although there are differences between the various dual-route models, the central tenet in all is that there are two distinct, independent pathways for recognising printed words; the lexical route and the nonlexical route.

It is the lexical route that is implemented when whole words are recognised from memory by sight. As shown in Figure 1.1, the lexical route is composed of an orthographic lexicon (comparable to a mental dictionary) in which known printed words are stored, and a phonological lexicon that contains the associated spoken pronunciations for each of the printed words recorded in the orthographic lexicon. Later dual-route models (e.g., Coltheart et al., 2001) also included a semantic system, connected to both the orthographic and phonological lexicons, to account for the contribution of semantic knowledge to word recognition (see Coltheart, 2005, for further details).

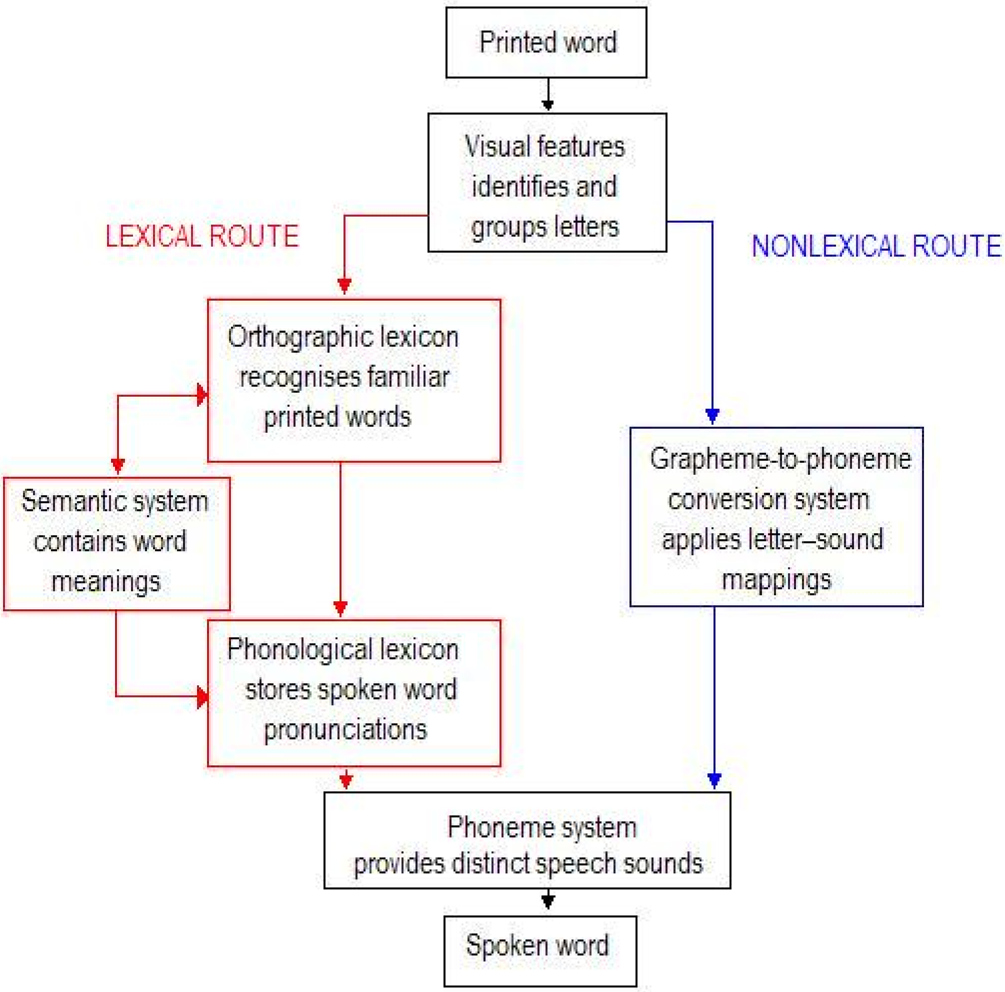


Figure 1.1 A dual-route model of printed word recognition (e.g., Coltheart et al., 2001).

Presentation of a known printed word will activate the lexical pathway. The complete sequence of letters that forms the word is matched to an entry within the orthographic lexicon which also triggers the accompanying spoken representation in the phonological lexicon. Providing that the visual and spoken form of the word is present in each lexicon, the correct pronunciation for a given printed word will be generated. Notably then, the lexical route is limited to processing actual words. Pronunciation errors may occur for nonwords (e.g., ‘flurp’, ‘smip’). However, several studies have documented how the orthographic and phonological resemblance of a nonword to an actual word (e.g., ‘dalk’ and ‘walk’, ‘fownd’ and ‘found’) may influence how the nonword is processed and pronounced (e.g., McCann, Besner, & Davelaar, 1988; Reynolds & Besner, 2004; Seidenberg, Peterson, MacDonald, & Plaut, 1996; van Orden, Johnston, & Hale, 1988; Yates, Locker, & Simpson, 2003).

To accurately read aloud such nonwords, the nonlexical route is implicated. This route functions by applying letter–sound mappings to decode words. Hence, it is this pathway that is predicted to be involved in phonological recoding. Starting with the initial letter, each of the letters contained within a printed word (e.g., ‘mat’) is related in turn to its associated sound (e.g., /m/, /æ/, /t/) so that the word can be named correctly.

As with the lexical route, there are some restrictions upon the nonlexical route. Due to the serial nature of the processing that occurs when translations are made between associated letters and sounds, the nonlexical route is slower in accessing the pronunciation for a word in comparison to the more rapid whole word retrieval of the lexical route. Furthermore, words that conform to typical letter–sound mappings, commonly referred to as regular words, be they actual words or nonwords, are accurately read aloud through the nonlexical route. However, difficulties occur when irregular words (i.e., words constructed from atypical letter–sound correspondences) are encountered. Such irregular words will be incorrectly 'regularised' by the nonlexical route (e.g., reading aloud 'pint' to rhyme with 'mint'). Instead, it is the lexical route in which the specific pronunciations for whole words are retained that is considered to be responsible for the recognition of irregular words.

1.2.2 Beginning to read: The dual-process view

Arguably, at least when attempting to explain printed word recognition in English, the dual-route models dominate the cognitive accounts (see Coltheart, 2005; Besner, O'Malley, & Robidoux, 2010). With two routes predicted to be available through which printed words can be recognised, the question of how beginning readers should be taught to read aloud words becomes a central issue. Indeed, this is a question that has formed an ongoing debate in the field of reading research (see Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001, for a review). Should sight word instructional practices be adopted, in which beginning readers learn to recognise whole words through a 'look and say' methodology? Or, are phonics based techniques a better alternative? Traditionally phonics-centred instruction concentrates on explicitly teaching children the mappings between printed letters (graphemes) and their associated individual sounds (phonemes), which, once established, can be used to sound out and decode words (see Ehri, Nunes, Stahl, & Willows, 2001; McCandliss, Beck, Sandak, & Perfetti, 2003, for further description of phonics approaches). Through whole word practices, it is largely assumed that such letter–sound knowledge is deduced incidentally during the course of whole word exposure (Ehri, 1998).

From a dual-route perspective, one proposition is that beginning readers progress from using the nonlexical route to a greater reliance on the more efficient lexical route (Barron, 1986; Van Orden & Kloos, 2005). At first, what appears to be quite a rudimentary decoding strategy (e.g., letter-by-letter sounding out) may be employed to read aloud new words (Adams, 1992; Coltheart, 2006; Ehri, 1998). Increasing exposure to a wide range of words should enable beginning readers to expand their orthographic knowledge concerning word forms, letter strings, and associated pronunciations; all of which are predicted to contribute to the more rapid and automatic identification of words through the lexical route (see Share, 1995, 1999). The implication is that novel words that are initially read through use of phonological recoding skills will eventually be recognised as whole words or 'by sight'. Thus, decoding skills help to establish a body of words in the lexicon that can be recognised quickly and efficiently. This is important, as fast and accurate word identification is one of the cornerstones of proficient reading (Snow, Burns, & Griffins, 1998). To this end, sight word reading and decoding are both essential and related components of skilled word recognition (Kirby, Desrochers, Roth, & Lai, 2008). Accordingly, instructional approaches based on these processes (e.g., whole word reading and phonics based strategies) will both contribute to successful reading development (see Rayner et al., 2001; Snow & Juel, 2005).

Having briefly touched on the importance of phonological recoding as a tool to enable beginning readers to tackle new words, it is to this issue of identifying unknown words to which we now turn in greater detail.

1.3 Novel word identification

New words will frequently be encountered during the process of learning to read. Proficient readers need to be able to tackle such unfamiliar words. Various theories have been proposed as to the different strategies that beginning readers employ to decipher novel words.

1.3.1 Reading by analogy

Goswami (1986; 1988; 1993) suggested that children attempt to read aloud unfamiliar words by use of an analogy strategy. When 'reading by analogy', knowledge concerning the pronunciation of a known word is employed to pronounce an unknown but visually similar word. As an example, a child is reading a book and comes across the word 'goat', a word that the child has never seen before. Noting that the word 'goat' closely resembles the already known word 'boat' in terms of shared letters, the child uses this similarity between the two words to correctly pronounce the untaught word 'goat'. Thus, orthographic (i.e., visual) similarity between two words is assumed to coincide with phonological (i.e., spoken) similarity, and according to Goswami, beginning readers utilise these comparisons to read new words.

Goswami (1986; 1988; 1993) developed the clue word paradigm as a measure of analogy use. In a typical clue word task, children are taught to read aloud a novel printed word, referred to as the 'clue word' (e.g., 'bug'). Most often, the clue word remains present throughout the subsequent test trials, functioning primarily as a visual 'prompt'. During testing, a number of unknown words are introduced. These novel words overlap with the clue word in terms of shared onset–vowel (e.g., '*bu*n'), vowel (e.g., 'h*u*t'), or rime (e.g., 'm*ug*'). In any word, the onset is the initial consonant or consonant cluster, and the rime is the preceding vowel and any remaining consonants (e.g., 'bug' - 'b'[onset] 'ug'[rime]). The aim in the clue word task is for each child to accurately read aloud as many of the untrained words as possible.

Goswami (1993) observed that beginning readers successfully named more of the untrained novel words that featured the same rime as the clue word. Only a small number of the untrained words that shared the same onset–vowel or vowel as the clue word were named by beginning readers. Yet children with slightly more developed reading skills were able to read aloud a wider variety of the novel words, including the onset–vowel and vowel sharing words.

These findings contributed to the development of the interactive analogy model of reading by Goswami (1993). A key characteristic of this model is the relationship between analogy use and phonological awareness. Before returning to this model, it is important to review some of the key issues relating to phonological awareness.

1.3.2 Phonological awareness

There is a wealth of research supporting the critical importance of phonological awareness as a contributing factor in reading development (e.g., Bradley & Bryant, 1983; Hulme, Snowling, Caravolas, & Carroll, 2005; Stanovich, Cunningham, & Cramer, 1984; see also Goswami & Bryant, 1990; McBride-Chang, 1995; Nation, 2008, for reviews). To explain what is meant by the term 'phonological awareness' it is perhaps useful to first state that words can be analysed in terms of the distinct units of sound (i.e., phonological units) that combine to form the complete pronounced word. These phonological units vary in size. The smallest available units are phonemes which correspond to individual sounds. Larger units include rimes and syllables. Thus, the word 'map' can be partitioned into three phonemes (e.g., /m/, /æ/, /p/), an onset and rime (e.g., /m/, /æp/), or one syllable (e.g., /mæp/). It is this ability to recognise and attend to the different sounds contained within spoken words that is described as 'phonological awareness'. Deciding therefore if two words start with the same sound (e.g., /pet/ and /pip/) or if two words rhyme (e.g., /hen/ and /pen/), would be regarded as measures of phonological awareness.

The issue of how phonological awareness develops is a contentious one. In particular, researchers have disputed the size of the phonological unit that beginning readers in English are first aware of (e.g., Bowey, 2002; Duncan, Seymour, & Hill, 1997; Goswami, 2002; Hatcher, Hulme, & Snowling, 2004; Hulme, Hatcher, Nation, Brown, Adams, & Stuart, 2002). Arguably the more widespread view is that phonological awareness evolves through a large-unit-to-small-unit trajectory (e.g., Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003; Ziegler & Goswami, 2005). Initially, children are most sensitive to larger units, such as whole words and syllables. This is followed by a greater awareness of onset and rime units. Lastly, children demonstrate an increasing awareness of the more fine grained, smaller phonemes. Crucially, the ability to detect and manipulate phonemes is believed to occur only when explicit reading instruction has commenced and greater opportunities are afforded to learn about print–sound mappings (Ziegler & Goswami, 2005, but see Hulme, 2002). To support this assertion, researchers have pointed to the findings from studies with illiterate adults (e.g., Lukatela, Carello, Shankweiler, & Liberman, 1995; Morais, Carey, Alegria, & Bertelson, 1979). In the majority of these studies, the illiterate adults performed poorly on tasks indexing phoneme awareness.

Opposing the view that phonological awareness develops along a large-to-small-unit continuum, some researchers have suggested that an awareness of smaller units, such as phonemes, precedes (or at least does not occur after) awareness of larger phonological units (e.g., Duncan et al., 1997; Nation & Hulme, 1997; Muter, Hulme, Snowling, & Taylor, 1997; Savage, Blair, & Rvachew, 2006; Seymour, Duncan, & Bolik, 1999). However, questions have been raised against the findings from some studies advocating a small-to-large unit view of phonological awareness (e.g., Duncan et al., 1997), primarily on methodological grounds, such as the cognitive demands of the tasks employed (see Ziegler & Goswami, 2005). Furthermore, researchers have stressed that the type of reading instruction encountered by children learning to read impacts on their ability to detect different phonological units (see Goswami, 2002; Seymour, 2005). A child learning to read in English through whole word practices which largely avoid explicitly teaching individual grapheme–phoneme correspondences, will not be as adept at identifying phonemes within words as a child who has received phonics led instruction.

Having briefly considered some of the issues surrounding the development of phonological awareness, we resume again with Goswami's interactive analogy model. In this model, Goswami (1993) stipulated that children's use of analogies is closely intertwined with their current phonological awareness status. Beginning readers can use onset and rime analogies from known words to read unfamiliar words as these larger phonological units are the most accessible at this early stage of reading. As reading ability is enhanced with increased reading instruction, developing readers are believed to acquire greater awareness of phonemes. Consequentially, they may be able to form analogies between words based on smaller phonemic units, such as shared onset–vowel units (e.g., 'beak', 'bean').

Evidence has been gathered to support the view that beginning readers can use analogy strategies to read aloud unfamiliar words (e.g., Brown & Deavers, 1999; Savage, 1997; Savage & Stuart, 1998). Notably, however, beginning readers do not persistently rely on analogy strategies to decipher unknown words (see Bowey, Vaughn, & Hansen, 1998; Muter, Snowling & Taylor, 1994). Furthermore, there appear to be several factors that mediate the use of such analogy strategies. For instance, some knowledge of letter–sound mappings may be necessary to enable reading by analogy (see Ehri, 1995; Ehri & Robbins, 1992). Other researchers (e.g., Nation, Allen, & Hulme, 2001; Roberts & McDougall, 2003; Wood & Farrington-Flint, 2002) have questioned whether it is the orthographic similarity, but rather the phonological similarity between words that confers an advantage on performance in the clue word task. Essentially, when the experimenter pronounces the clue word this may 'prime' the participant to generate a word that rhymes with the clue word. Even when children can only hear the clue word pronounced aloud, studies have shown that some children can still name many of the untrained printed test words, despite never viewing the written clue word that visibly overlaps with the test words (see Bowey et al., 1998; Nation et al., 2001; Savage & Stuart, 1998).

Overall, there is general agreement that early readers can make use of analogies to decipher unfamiliar words, especially if they have received analogy orientated instruction (e.g., Muter et al., 1994). But if we were to evaluate the effectiveness of an analogy strategy as a tool for beginning readers to tackle novel words, there is one possible caveat. One view is that the spontaneous use of orthographic analogies is more likely to be a strategy that is used by more experienced readers (Nation et al., 2001). A more skilled reader possesses a larger bank of words from which to draw comparisons and make analogies with novel words. The beginning reader may simply not have sufficient vocabulary knowledge available to enable them to instinctively make analogies. From this position, an analogy strategy alone might not be the best approach for beginning readers at least to take.

1.3.3 Phonological recoding

An alternative way in which unfamiliar words can be read is through phonological recoding. Providing that a word contains typical letter–sound relations, knowledge of letter–sound associations can be utilised to read aloud the new word. The ability to decode novel words through the application of previously acquired letter–sound relations can also be referred to as a ‘word attack skill’ (Saunders, 2007).

Phonological recoding occupies a prominent role in the self-teaching hypothesis proposed by Share (1995). When an unfamiliar word is encountered by beginning readers, they can attempt to ‘self-teach’ and pronounce the word through use of their previously established letter–sound knowledge (Jorm & Share, 1983). Once the correct pronunciation for the new word has been deciphered, perhaps through feedback provided by a parent or teacher, the beginning reader starts to accumulate greater knowledge about the orthographic and phonological properties of that particular word (e.g., what printed letters visually form the word? how is this letter string pronounced?) which is further refined through future encounters with the word. Such repeated exposure to the word is one way in which the word can be integrated into the orthographic lexicon. Indeed, studies have shown that some beginning readers may only need to encounter a word a small number of times in order for the word to be entered into the orthographic lexicon (e.g., Manis, 1985; Nation, Angell, & Castles, 2007; Reitsma, 1983). Ultimately then, the words stored in the orthographic lexicon should be recognised quickly and accurately ‘by sight’, thereby enabling proficient reading (Ehri, 2005).

Research has shown that phonological recoding is a skill that can be used by early readers in English to identify unfamiliar words (e.g., Bowey & Muller, 2005;

Cunningham, Perry, Stanovich, & Share, 2002; Thompson, Fletcher-Finn, & Cottrell, 1999). How then can phonological recoding be achieved?

1.3.4 Acquiring phonological recoding skills

According to Ziegler and Goswami (2005) successful phonological recoding is contingent upon beginning readers finding “shared grain sizes in the symbol system (orthography) and phonology of their language that allows a straightforward and unambiguous mapping between the two domains” (p. 3). That is, beginning readers must learn how printed letters relate to sounds, but the way in which these relations are acquired (or taught) can occur at different grain sizes. Potentially, individuals can learn the associations between individual letters (graphemes) and individual sounds (phonemes); this would be learning the print–sound correspondences at a small grain size. Alternatively, larger grain sizes, such as rimes and syllables, can be used, in which combined letter strings are matched to larger spoken units.

As will be discussed further in Chapter 8, for children learning to read in English, the difficulty lies in the inconsistency of letter–sound mappings that occur in English. An identical printed letter may have several pronunciations, while the same phoneme may be represented by different letters. Other alphabetic scripts, such as German and Italian, are highly consistent and predictable in that the associations between graphemes and phonemes are largely stable, one-to-one mappings. Fortunately, greater consistency in spelling–sound relations in English can be found for many larger units such as rimes and syllables (Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). For example, the rime ‘ing’ as found in the words ‘ring’, ‘sing’, ‘wing’, ‘bring’, is always pronounced the same way across these words.

The very fact that writing systems vary in how printed letters represent spoken units, and in the case of alphabetic scripts, can be differentiated further in terms of the consistency of these mappings, provided the background for the psycholinguistic grain size theory of reading (Ziegler & Goswami, 2005). According to this theory, reading development is directly related to, and influenced by, the orthography that a child is learning to read. With differences between scripts in the consistency of grapheme–phoneme mappings, consequently, there may also be differences in the grain sizes that are used most effectively across orthographies to read words.

In consistent orthographies, such as German and Italian, smaller grain sizes (e.g., phonemes) alone can be used to decode words given the straightforward mapping between graphemes and phonemes in these languages. When learning to read in an inconsistent orthography such as English, it may be necessary to develop recoding strategies at more than one grain size (i.e., phonemes, onsets and rimes, syllables, whole words) to cope with the idiosyncrasies of this particular script. As Ziegler and Goswami (2005) noted, English contains a wide assortment of word types. There are regular words adhering to expected letter–sound patterns (e.g., 'ran', 'lot', 'hen') that can easily be decoded through use of small grapheme–phoneme mappings. Certain words share identical printed rimes which are pronounced consistently across words (e.g., 'bake', 'cake', 'lake', 'make'). For such words learning the larger rime spelling–sound mappings may be helpful. Lastly, irregular words containing atypical spellings and pronunciations (e.g., 'choir', 'knife') must be learned as whole words, each with a unique letter sequence and spoken form.

Thus, flexibility in the grain sizes that are learned and applied has been suggested to be one of the keys to facilitating successful word recognition in English (see Brown & Deavers, 1999; Ziegler & Goswami, 2005, 2006). The idea of developing recoding strategies at multiple grain sizes arguably parallels the variable nature of English. In other, more consistent, orthographies, such flexibility is not necessary, as smaller grain sizes can reliably be used.

Evidence has been gathered to support some of the central assumptions of the psycholinguistic grain size theory. In particular, the ability to read nonwords that can only be decoded correctly through the application of grapheme-to-phoneme relations has been examined. If orthographic consistency does influence the development of recoding strategies, children learning to read consistent languages through use of small grain grapheme-to-phoneme mappings, arguably, should be more proficient than children learning to read in English when attempting to decode nonwords. Several studies have reported such a difference in nonword reading performance. For example, Goswami, Gombert, and de Barrera (1998) found that English speaking children matched for reading age with French and Spanish children were noticeably poorer at reading nonwords than the children from the more consistent languages. More recently, Ellis and Hooper (2001) and Spencer and Hanley (2003) compared reading acquisition of children living in Wales who attended English speaking schools (learning to read in English) or Welsh speaking schools (learning to read in Welsh). Unlike English, Welsh is composed of more direct and reliable one-to-one mappings between its graphemes and phonemes. Throughout the experiments, the children learning to read in Welsh continually performed better than the age matched children learning to read in English on the word recognition measures (e.g., naming of regular and irregular words, and nonwords). Once more, the findings underlined how the consistency of the orthography could, on the one hand, facilitate the rapid development of word recognition skills in the case of consistent scripts, or on the other hand, at least in the early stages of reading acquisition for inconsistent scripts, potentially obstruct the ease with which word recognition skills are acquired. However, in studies where nonwords can be read aloud through use of rime analogies (e.g., ‘bicket’ – ‘ticket’), researchers have observed there is a marked improvement in nonword reading for English speaking children (e.g., Goswami, Porpodas, & Wheelwright, 1997, Brown & Deavers, 1999). Of relevance here also are the findings from the investigations in Wales (e.g., Ellis & Hooper, 2001; Spencer & Hanley, 2003) showing that the children learning to read in English were more likely to name printed words as other actual words (i.e., to make real word substitution errors). For example, reading ‘bye’ as /be/, ‘mow’ as /moon/. Conversely, the children learning to read in Welsh tended to mispronounce the actual words to produce nonwords that were phonologically similar to the target words. Ziegler and Goswami (2005) interpreted these findings as indicative that beginning readers of inconsistent scripts do use larger grain sizes such as rimes, alongside smaller grain sizes to decode unfamiliar words, whereas in more consistent orthographies, smaller sized grapheme-to-phoneme mappings, but rarely larger grain sizes, will be applied.

In this section we have reviewed some of the ways in which unfamiliar words can be tackled. Although these approaches were presented separately, beginning readers in English at least, do not simply rely on one strategy to decipher new words; they can use more than one available strategy (Brown & Deavers, 1999; Roberts & McDougall, 2003). For example, a child who has received instruction in how to make use of analogies, and who has learned about letter–sound correspondences, will very likely employ a combination of these approaches when confronted with an unfamiliar word.

1.4 Word attack skills – Recombinative generalisation

Recognition of unfamiliar words does not depend on simply possessing a well established letter–sound knowledge at various grain sizes. What is also important is how this knowledge is put to practice to decode new words. It is the ability to re-organise established letter–sound relations that is an essential component of novel word recognition. The process of re-arranging previously learned linguistic units into novel patterns is referred to as recombinative generalisation (Goldstein, 1993). In the case of reading, sub-word units of known words (e.g., syllables, rimes, phonemes) are recombined to form new words that can be pronounced by reference to known letter–sound correspondences.

As an example of recombinative generalisation, imagine that a child has learned to read aloud the words ‘pen’, ‘hot’, ‘sat’, and ‘bun’. By rearranging the known sub-word units (onsets and rimes) within these taught words, the child should also be able to read aloud the recombined novel words ‘hen’, ‘pot’, ‘bat’, and ‘sun’. In this way recombinative generalisation is an important word-attack skill for productive reading, in that it potentially enables readers to tackle unfamiliar words without the need for explicit instruction concerning how to pronounce each word.

At first glance, it appears that there are some parallels between recombinative generalisation and reading by analogy. Recall that the typical procedure for exploring the use of analogies by beginning readers often entails a new word being formally taught, followed by an examination of ability to read aloud novel words that overlap to varying degrees with the taught word.

Goswami (1993) observed that beginning readers demonstrated greater success in naming untrained words that shared the same rime unit as a taught word (e.g., reading ‘rug’ and ‘mug’ after learning to read ‘bug’). Goswami (1993) interpreted these findings as an example of reading by analogy. Alternatively, Suchowierska (2006) proposed that the performance of the children could be interpreted as a demonstration of recombinative generalisation (see also Mueller, Olmi, & Saunders, 2000).

Goswami (1993) acknowledged that the number of untaught words correctly named by the children was not particularly large and partially accounted for this finding by referring to the fact that the children had only just begun to learn to read. Closer inspection of the training procedures may further help to explain the children's performance. For each analogy test, the children were trained to name one of four printed clue words (e.g., 'bug'). The untrained test words presented shared the same rime (e.g., 'm*ug*', 'r*ug*'), onset–vowel (e.g., '*bu*n', '*bu*s'), or vowel (e.g., 'h*u*t', 'c*u*p') sequence as the clue word. At no stage during the pretests or analogy tests were the children exposed to words that also contained some of the sounds found in the test words. Perhaps if during the pretests, the participants had experienced words overlapping with elements of the test words, (e.g., words such as 'map', 'rat', 'hot', 'can', which would have shared the same onsets as the test words 'mug', 'rug', 'hut', and 'cup' respectively), it may be predicted that the number of test words accurately named may have increased.

1.4.1 Facilitating the recombinative generalisation effect

A number of studies have investigated the conditions under which recombinative generalisation is most likely to occur (see Suchowierska, 2006, for a review). Matrix training strategies, in which the shared elements of training items are emphasised prior to the presentation of the recombined test stimuli, are associated with successful recombinative generalisation (see Goldstein & Mousetis, 1989).

An example of a classic matrix training procedure would be a participant learning to name the objects ‘yellow square’, ‘yellow circle’, and ‘blue square’. Recombinative generalisation would be evident if the participant was later able to name the untrained novel object ‘blue circle’. Notice that the training objects are presented in such a way that reinforces the overlap between the items which ensures that the participant has been exposed to all of the individual components that are joined together to form the untrained object. This is a key characteristic of matrix training strategies.

1.4.2 Matching-to-sample training procedures

Matching-to-sample (MTS) procedures have also proven to be effective for within-word recombinative generalisation. In a typical MTS procedure, the participant first views a sample stimulus (e.g., the printed word ‘hat’), which is followed by the presentation of a number of comparison stimuli (e.g., the spoken words /hat/ and /hut/). The objective is for the participant to learn which of the comparisons is the correct match for the given sample stimulus. Participants can discover the associated comparison for each sample through use of a ‘trial and error’ strategy. However, some researchers prefer to use exclusion type MTS procedures (see Dixon, 1977; Ferrari, de Rose, & McIlvane, 1993, for further details). Exclusion procedures are unique in that once participants have been taught to relate a particular comparison to a certain sample, this trained (or defined) relation can be used to help the participants to learn an as yet undefined relation. In a typical exclusion trial, an undefined sample (i.e., a sample not yet related to a particular comparison) is presented with an undefined comparison (i.e., a new comparison) and a defined comparison (i.e., a comparison previously related to another sample). Exclusion trials are believed to be especially effective because participants can rule out the defined comparison on the basis that it is associated with another sample, they can then select the remaining undefined comparison, thereby quickly learning the new sample–comparison relation.

In one of the first studies to examine the use of MTS procedures to facilitate recombinative generalisation, de Rose, de Souza, and Hanna (1996) trained seven pre-reading children to name 51 printed Portuguese words. Subsequently, they tested whether the children could read non-trained words constructed from recombinations of the syllables found within the previously taught words (see also de Rose, de Souza, Rossito, & de Rose, 1992; Melchiori, de Souza, & de Rose, 2000). Whole printed words (e.g., ‘bolo’, ‘vaca’) were trained to corresponding spoken words using a MTS exclusion procedure. Syllables contained within the trained words (e.g., ‘bo’, ‘ca’) were recombined to form the untrained test words (e.g., ‘boca’). Following training, de Rose et al. (1996) found that five of the seven children could name approximately 40% of the recombined untrained words. However, two children failed to read aloud any of the test words.

1.4.3 The Mueller, Olmi, and Saunders (2000) matching-to-sample protocol

Influenced by research emphasising the saliency of onset and rime units for beginning readers of English, Mueller, Olmi, and Saunders (2000) developed an onset and rime based MTS training protocol to explore recombinative generalisation in three pre-reading children. Twenty-one words were organised into six word sets, with each set containing four training words and two generalisation test words. The six words within each word set were combinations of two onsets and three rimes. For example, the onsets /m/ and /s/ and the rimes /ug/, /ot/, and /ap/ were combined in one word set to produce the four training words /mug/, /sug/, /sot/, and /sap/, and the two generalisation test words /mot/ and /map/.

Figure 1.2 shows the four phases of the Mueller et al. (2000) MTS protocol. Initially, a pretraining phase was undertaken in which the children learned to discriminate between different onsets and rimes as presented within the context of whole words. For example, the children completed spoken-to-printed-word trials in which the comparisons differed only in terms of printed onsets (e.g., given the sample /set/, the comparisons ‘set’ and ‘met’ were presented). Spoken-word-to-picture trials were also incorporated to ensure that the children could distinguish between different spoken onsets and rimes. Two images that pictorially represented two spoken words that differed by onset (e.g., /hot/ and /pot/) or rime (e.g., /map/ and /mum/) were presented in each trial. The children were required to identify the picture associated with the sample spoken word.

Prior to the commencement of the training phase, baseline measures of the children’s accuracy in naming the 21 words used across the word sets were obtained. None of the children could name any of the 21 words. Additional tests were undertaken to assess the children’s accuracy in selecting the corresponding printed words for each of the 12 generalisation spoken word samples. Pretraining spoken-to-printed-word accuracy for the generalisation words was between 21% and 63%. As part of the MTS training, the children learned to select the correct printed word comparison for each of the four spoken word samples within each word set. Training trials were structured as six incremental steps that increased in complexity as to the number of samples and comparisons presented (e.g., gradually increasing the number of comparisons from two printed words [sharing the same rime] to four printed words [utilising three different rimes]).

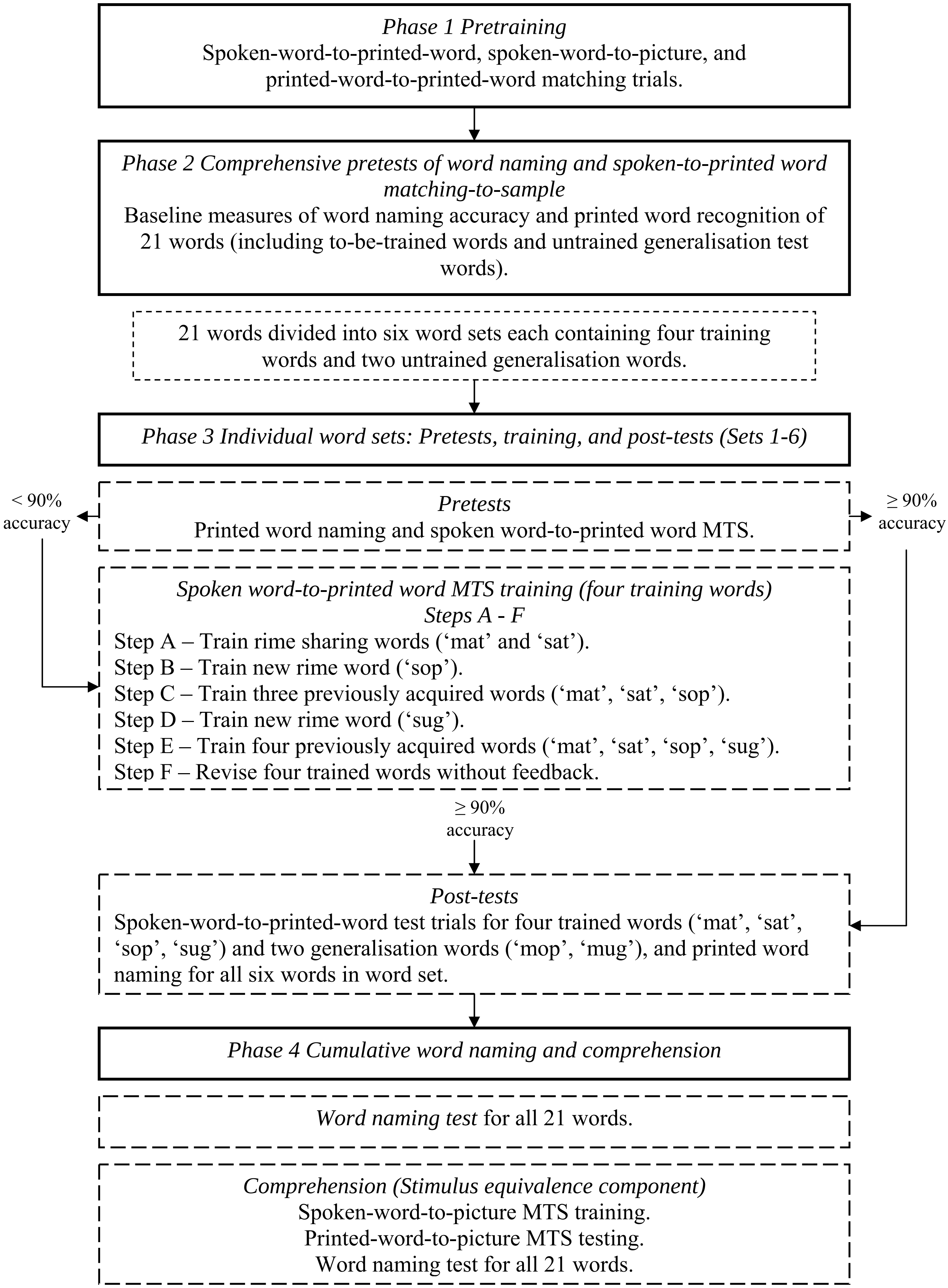


Figure 1.2 The Mueller, Olmi, and Saunders (2000) protocol.

Following training, two of the children correctly matched a high percentage of the novel printed generalisation words to the corresponding spoken words across all of the post-tests for each word set. Despite receiving the MTS training, one child demonstrated less than 20% accuracy in matching the spoken-to-printed generalisation words for the first word set. However, in the post-tests for the remaining five word sets, high accuracy in recognising the printed generalisation words was reported for this participant. There were also variations in word naming accuracy. Following the MTS training, one child could correctly read aloud 62% of the 21 set words. The other two children named very few, if any, of the presented words. Nevertheless, improved word naming was evident for these two children following the introduction of a comprehension phase. During this final phase, the children learned to match printed words, spoken words, and pictures.

In a subsequent study, Saunders, O'Donnell, Vaidya, and Williams (2003) replicated the procedure of Mueller et al. (2000) with two adults with mild mental retardation who could not read. Saunders et al. (2003) observed that while the two participants were accurate at identifying the generalisation words after completing the MTS training, additional training of printed words and spoken words to equivalent pictures was necessary before word naming increased.

The findings of Mueller et al. (2000) highlighted the effectiveness of the MTS protocol in promoting recombinative generalisation for pre-reading children. Refinements to the training procedures used by Mueller et al. (2000) might perhaps facilitate greater generalisation in terms of improving recognition and naming of the novel recombined words.

Notably in the Mueller et al. (2000) study, the children did not receive explicit training focused solely on matching the individual onset letters and sounds (e.g., /m/ -

‘m’) and rime letters and sounds (e.g., /at/ - ‘at’), although these pairings did feature in subsequent training and generalisation test words. Rather, during the pretraining phase, the children learned to discriminate between the onsets and rimes as they appeared within the context of whole words. Arguably, these word tasks did not establish the individual discriminations of the component stimulus units (i.e., onsets and rimes) from which the recombined words were composed. As highlighted by de Rose et al. (1996), if the associations between sounds and printed units are taught directly, this may facilitate the emergence of recombinative generalisation (see also Byrne & Fielding-Barnsley, 1989). Thus, perhaps a MTS protocol that trains the separate sub-word onset and rime units in isolation might be more effective in facilitating recognition of recombined words.

Furthermore, the MTS selections made by the children during the training with the individual word sets were unidirectional (i.e., selecting a printed word given a spoken word sample). Training trials in which children selected a spoken word after viewing a printed word were not included. Reversing the identity of the samples so that the trials taught both spoken-to-printed-word and printed-to-spoken-word relations would train the bidirectional, symmetrical relationship between the printed and spoken words. In light of early research by Sidman (1971) emphasising the importance of training symmetry relations between printed words and their spoken counterparts when learning to read, a MTS training procedure with letter–sound symmetry stages may facilitate the identification of novel, recombined words constructed from these letters and sounds.

1.4.4 The Keaveney (2005) matching-to-sample protocol

As part of her PhD research, Keaveney (2005) adapted the Mueller et al. (2000) procedure and devised an onset and rime based MTS training protocol that included explicit MTS training with onset and rime units, and symmetry testing. Keaveney (2005) investigated the efficacy of the revised protocol with adult participants. Abstract symbols and nonwords were used in place of letters and words to control for the pre-experimental verbal histories of the participants.

An overview of the training and test stages of the Keaveney (2005) protocol may be viewed in Table 1.1. Participants completed sound-to-symbol training (e.g., /p/ - ¿), followed by symbol-to-sound symmetry testing (e.g., ¿ - /p/) firstly for the onset sound–symbol relations, and then for the rime sound–symbol relations. Each onset and each rime sound was represented by a single abstract symbol. For the recombinative generalisation tests, the onsets and rimes were combined together to form 16 different onset–rime nonwords (e.g., /puv/). Test trials required the participants to match the recombined spoken nonwords and recombined symbols.

Keaveney (2005) found that 18 of 20 adults could accurately pair novel recombined words and sounds following one exposure to the sound-to-symbol training and symmetry testing stages. However, it was noted that over a quarter of participants did not attain the criterion for the first symmetry test.

Table 1.1 The five-stage MTS protocol developed by Keaveney (2005).

<table>
<tr><th>Five-Stage MTS Protocol</th><th>Criterion</th><th>Stimuli Examples</th></tr>
<tr><td>Stage 1a
Conditional discrimination training onset sound-to-symbol relations</td><td>Number of consecutive correct responses must equal eight.</td><td>/p/ - ¿</td></tr>
<tr><td>Stage 1b
Symmetry testing onset symbol-to-sound relations</td><td>Number of consecutive correct responses must equal eight.</td><td>¿ - /p/</td></tr>
<tr><td>Stage 2a
Conditional discrimination training rime sound-to-symbol relations</td><td>Number of consecutive correct responses must equal eight.</td><td>/uv/ - ||||</td></tr>
<tr><td>Stage 2b
Symmetry testing rime symbol-to-sound relations</td><td>Number of consecutive correct responses must equal eight.</td><td>|||| - /uv/</td></tr>
<tr><td>Stage 3a
Conditional discrimination training onset and rime sound-to-symbol relations</td><td>Number of consecutive correct responses must equal sixteen. If < 16, return to Stage 1a.</td><td>/p/ - ¿ ; /uv/ - ||||</td></tr>
<tr><td>Stage 3b
Symmetry testing onset and rime symbol-to-sound relations</td><td>Number of consecutive correct responses must equal sixteen. If < 16, return to Stage 1a.</td><td>¿ - /p/ ; |||| - /uv/</td></tr>
<tr><td>Stage 4a
Recombinative generalisation testing non-combined onset–rime words sound-to-symbol relations</td><td>Number of consecutive correct responses must be ≥ 15. If < 15, return to Stage 3a.</td><td>/p/ /uv/ - ||||
¿</td></tr>
<tr><td>Stage 4b
Recombinative generalisation symmetry testing non-combined onset–rime words symbol-to-sound relations</td><td>Number of consecutive correct responses must be ≥ 15. If < 15, return to Stage 3a.</td><td>|||| - /p/ /uv/
¿</td></tr>
<tr><td>Stage 5a
Recombinative generalisation testing combined onset–rime words sound-to-symbol relations</td><td>Number of consecutive correct responses must be ≥ 15. If < 15, return to Stage 3a.</td><td>/puv/ - ||||
¿</td></tr>
<tr><td>Stage 5b
Recombinative generalisation symmetry testing combined onset–rime words symbol-to-sound relations</td><td></td><td>|||| - /puv/
¿</td></tr>
</table>

1.5 Outline of the current research

Proficiency in recombining letter–sound correspondences is an essential skill when attempting to decode novel words. As previously discussed, investigations by Mueller et al. (2000), Saunders et al. (2003), and Keaveney (2005) have indicated the viability of MTS procedures when the aim is to aid recognition of novel recombined words. Given the importance of such word attack skills, further research into facilitating recombinative generalisation through use of MTS procedures is warranted. The current body of research was undertaken to contribute to knowledge in this area concerning the benefits of MTS training methods in the promotion of recombinative generalisation and novel word decoding.

Although the basic recombinative generalisation effect has been demonstrated in the aforementioned MTS studies, not all participants who took part in the Mueller et al. (2000) or Keaveney (2005) studies demonstrated high accuracy in recognising the recombined test words. Therefore it may be suggested that there is the potential to further modify the MTS procedures to try and improve recombinative generalisation performance.

In the current research, a computer-based protocol was developed to support recombinative generalisation of sub-word units. Over a series of experiments, initially adult participants completed training with the protocol, and their ability to read a novel (invented) script was assessed. A similar MTS protocol was also employed with a small group of children with learning difficulties.

1.5.1 Testing the revised matching-to-sample protocol with adult participants

To start the current research, modifications were made to the training protocol reported by Keaveney (2005) in her PhD dissertation. One possible limitation of the Keaveney (2005) protocol is that over a quarter of the participants who took part in Keaveney's research found it difficult to pass the symmetry test stages. In an attempt to alleviate this problem, in the amended protocol developed for this research, explicit symmetry training followed by mixed symmetry testing (i.e., testing sound-to-symbol and symbol-to-sound relations) was added to the procedure. Primarily though, these additional components were included in the modified protocol to provide a more comprehensive training process, with the aim of reinforcing the relations between the sounds and symbols from which the recombined test words were formed. Instilling a thorough knowledge of letter–sound relations has been highlighted as important for word recognition (Foy & Mann, 2006; Roberts, 2003; Share, 1995).

Many studies have investigated generalisation to recombined consonant–vowel–consonant (CVC) words consisting of one syllable (e.g., ‘sun’, ‘pot’). This focus on CVC words mirrors early reading stimuli as beginning readers typically commence with relatively short words before progressing to longer, more complex words (Snow, Scarborough, & Burns, 1999). However, the role of recombinative generalisation in progression to larger words has not to date been empirically demonstrated. To this end, a new recombinative generalisation test was added to the modified protocol to examine generalisation of established sub-word units to novel disyllabic CVCVC words. As far as is known, this was the first study in this area to investigate this issue. If participants can read these untrained CVCVC combinations following MTS training on the sub-word units, this would support a key role for recombinative generalisation in productive reading skills and further extends the potential uses and advantages of the training protocol.

In Chapter 2 the modified MTS protocol developed for the current research is described in detail. As in the Mueller et al. (2000) and Keaveney (2005) protocols, to begin with, participants were trained using onset and rime sub-word units. In later experiments the size of the training unit was varied to include phonemes and syllables. Initially the new MTS protocol was tested with literate adult participants and the results from this study are presented in Chapter 3. Through this research, the aim was to try and develop an ‘optimal’ MTS training protocol. Thus, it was necessary to assess the contribution of each of the individual training components within the protocol (e.g., symmetry training) to isolate the minimum training stages that needed to be completed by participants for recombinative generalisation to emerge. The findings from this study are reported in Mahon, Lyddy, and Barnes-Holmes (2010) and are discussed in Chapter 4.

When learning to read, letters and sounds do not have fixed functions. A letter or sound that operates as part of a rime in one word (e.g., 'ha*t*') may appear as the onset in another word (e.g., '*t*in'). Thus, letters and sounds must be interchangeable within words (see McCandliss, Beck, Sandak, & Perfetti, 2003).

According to Perfetti (1991), during reading development, it is fundamental for children to learn that the constituent letters and phonemes of words can occur in different word positions (i.e., initial, medial, final position within a word). In Chapter 5, a new across-unit recombinative generalisation test was added to the protocol to examine if the participants could recognise recombined words composed from untrained onsets and rimes that were derived from the explicitly taught onsets and rimes. As far as is known, this is the first study in this area to examine across-unit transfer within the context of a MTS training protocol. Across-unit transfer was explored further in a subsequent experiment in which participants were tested with recombined consonant blend words (Chapter 6).

Pivotal when learning to read is discovering the equivalence relations between spoken and printed units (see Rayner et al., 2001; Snow & Juel, 2005). As such, the early stages of the training protocol were designed to teach participants the sound–symbol relations from which the recombined test words were formed. In contrast, the later recombinative generalisation testing stages simulated reading of new words made up of the sounds and symbols, but arranged in different formations.

There is ample research concerned with how grain size (i.e., the size of the orthographic unit) may influence the learning of phoneme–grapheme mappings (see Ziegler & Goswami, 2005, for review). One of the aims of the current research was to determine if the size of the orthographic unit employed during MTS training (e.g., onset and rime, phoneme, syllable) had any effect on the participant's ability to recognise novel recombined words. Although previous MTS experiments have incorporated whole word or onset and rime training procedures (e.g., Mueller et al., 2000; Keaveney, 2005), to date, no other MTS study has systematically compared recombinative generalisation performance following sound–symbol training at different grain sizes. For the current thesis this study was undertaken and the findings are analysed in Chapter 7.

The final adult research chapter of the thesis (Chapter 8) examines if the MTS protocol can be used to facilitate recognition of regular and exception words; words that conform to, or deviate from, expected letter–sound mappings. Both types of words will be encountered during reading instruction and hence, to increase the ecological validity of the procedures, it was important to determine if the protocol could be suitably employed to enable recognition of the various words that beginning readers may be confronted with.

1.5.2 Supporting word recognition skills in children with learning difficulties

Somewhat surprisingly, despite the findings of Mueller et al. (2000) and Saunders et al. (2003) indicating the suitability of MTS procedures for pre-reading children and adults with mental retardation, there is little published research exploring the use of such MTS methods to promote recombinative generalisation in children with learning difficulties (LD). This research gap is unexpected, given that children from this population may be particularly at risk of experiencing reading difficulties (Saunders, 2007). What is apparent from the literature is that some of the core reading difficulties often encountered by children with LD relate to printed word recognition and phonological recoding (see Conners, Rosenquist, Sligh, Atwell, & Kiser, 2006; Gersten, Fuchs, Williams, & Baker, 2001). Potentially, the MTS training protocol could be effective in helping to facilitate recombinative generalisation and novel word recognition in children with LD.

In the current research, the modified protocol was first tested with literate adults. After establishing that the revisions to the protocol were suitable, a similar procedure was employed using actual letters and associated sounds with seven children with LD. These children were identified by their school teachers as experiencing problems in learning to read. The protocol was used as a remedial tool in accordance with the strengths of each individual child to determine if the protocol could help support their word recognition and word naming skills. The findings from the research with the children with LD are presented in Chapters 9 and 10.

To conclude the research with the children, a stimulus equivalence component was added to the training procedure to try and improve the children's word naming and recognition accuracy for regular and exception words. Findings from this study are reported in Chapter 11. In the final chapter of the thesis (Chapter 12), the key issues to emerge from the adult and child experiments are reflected upon.

Chapter Two

Methodology: Introducing the Revised Matching-to-Sample Protocol

2.1 Introduction

Building on previous research conducted by Mueller et al. (2000) and Keaveney (2005), the current research aimed to extend and develop a matching-to-sample (MTS) protocol to support recombinative generalisation of sub-word units (onsets and rimes) and to promote novel word recognition. Initially, the effectiveness of the modified protocol was tested with literate adult participants. After establishing that the revisions to the protocol did indeed appear to be effective in facilitating the recombinative generalisation effect, similar procedures were employed with a small group of children with learning difficulties. The protocol functioned as a remedial tool, designed to help support their word recognition and oral word naming skills.

The present chapter relates to the experiments conducted with the adult participants, and outlines the basic amended MTS protocol that provided the starting point for the research with the adults.

2.2 The revised matching-to-sample protocol

A basic six-stage MTS computerised protocol was developed for use in the current research. Across the adult experiments, this protocol was used with some modifications. These variations are outlined as relevant to particular experiments detailed in the forthcoming chapters. However the fundamental components of the protocol in terms of format of trials, accuracy criteria etc., remained relatively unchanged throughout the experiments.

2.2.1 Apparatus

The protocol was presented using SuperLab Pro® software. All participants completed the protocol in a quiet location (e.g., an experimental cubicle in the Psychology Department) on a laptop computer with a 2.00 GHz processor, 256 MB of RAM, and a 15” screen. Auditory stimuli were presented via headphones with volume consistent over trials. All recorded sounds were spoken by one female speaker. Recordings were normalised and presented as audio files via the computer program.

2.2.2 The invented script

Because the new protocol was first tested with literate adult participants, to control for the pre-experimental verbal histories of the adults, it was necessary to develop a novel script comprised of abstract symbols and nonwords. Abstract symbols that were acceptable for use in the invented script were those that did not have strong visual or acoustic associations with particular words or concepts. For example, currency signs were not permissible. For the auditory stimuli, consonant and vowel sounds were selected that were as distinctive as possible. This was important as the participants needed to be able to clearly differentiate between the sounds when learning the sound–symbol relations.

Four consonants (/t/, /s/, /n/, /y/) were selected as the onset sounds. Four vowel–consonant (–VC) pairs were chosen as the rime sounds (/af/, /ek/, /ol/, /im/). Consonants occurring as onset sounds did not feature as part of a rime sound. Each onset sound corresponded to a single abstract symbol. A rime sound was represented by a two-symbol pair, consistent with the representation of vowels and consonants in an alphabetic script. Practice items differed from those employed in the training trials. Sounds and symbols were randomly selected to give four practice sound-to-symbol pairs, four onset sound-to-symbol pairs, and four rime sound-to-symbol pairs (dual-symbol pairs corresponding to a –VC unit). To further strengthen the novelty of the script and control for the previous reading experiences of the adults, the rime symbol pairs (and subsequent onset–rime CVC recombined test words) were presented from bottom (vowel)-to-top (consonant). The English speaking adult participants would all be proficient in reading from left-to-right, but less accustomed to reading from bottom-to-top. These steps were taken to ensure that the participants were unable to 'read' the script prior to completion of the training procedures. If after undertaking the MTS training protocol the participants were able to 'read' the recombined test words constructed from the novel script, it remains that such 'reading' can only have occurred as a result of successfully completing the training protocol.

Sound–symbol pairs were pre-tested for discriminability by ten individuals who did not participate in the later experiments. Piloting the sounds and symbols took part in two phases. Firstly, participants listened to all of the sounds presented in a random order and wrote down the letter or letters corresponding to each sound. This ensured that all of the sounds were clear and distinguishable from each other. All sounds were apparent to the participants, and thus, no changes to the sounds were required. Secondly, for the four onset sounds and then for the four rime sounds, after hearing the four sounds played consecutively, and then one at a time, participants selected one of four symbols or symbol pairs, that they thought was the correct match for a given sound. None of those tested demonstrated above chance response biases in matching a particular sound with its associated symbol. Piloting the stimuli in this way helped to further verify that participants could not read the script before training.

Table 2.1 shows the sound–symbol pairs that were trained in the basic protocol, alongside examples of how these sounds and symbols were recombined to form the novel CVC and CVCVC test words.

Table 2.1 The sound–symbol pairs trained in the protocol and examples of the recombined CVC and CVCVC test words.

Practice	*Training*		*Recombinative Generalisation Testing*	
Practice symbols and sounds	Trained onset (C) symbols and sounds	Trained rime (VC) symbols and sounds	Recombined onset–rime CVC words	Recombined onset–rime–rime CVCVC words
▽ - /h/	~ - /t/	☐ - /af/ >>	☐ - /taf/ >> ~	₪ - /tafol/ ஐ ☐ >> ~
❚❚ - /g/	* - /s/	⌖ - /ek/ ♉	⌖ - /sek/ ♉ *	⊙ - /sekim/ ⛝ ⌖ ♉ *
↺ - /w/	❖ - /y/	₪ - /ol/ ஐ	₪ - /yol/ ஐ ❖	⌖ - /yolek/ ♉ ₪ ஐ ❖
¤ - /b/	♋ - /n/	⊙ - /im/ ⛝	⊙ - /nim/ ⛝ ♋	☐ - /nimaf/ >> ⊙ ⛝ ♋

Note. All rime, onset–rime, and onset–rime–rime symbols were presented and read from bottom-to-top.

2.2.3 General procedure

There were two types of trials used in the MTS protocol, sound-to-symbol trials and symbol-to-sound trials.

In the sound-to-symbol trials, a white screen appeared to indicate the start of the trial, followed 1000 ms later by a sample sound. The on-screen instructions prompted the participants to press the spacebar once they had heard the sound. A white screen showing four comparison symbols then appeared. As shown in Figure 2.1, one symbol was located in each corner of the screen. In order to select one of the comparison symbols, a participant pressed one of four coloured responses keys on the keyboard that corresponded to the on-screen location of the comparison symbol that the participant intended to choose.

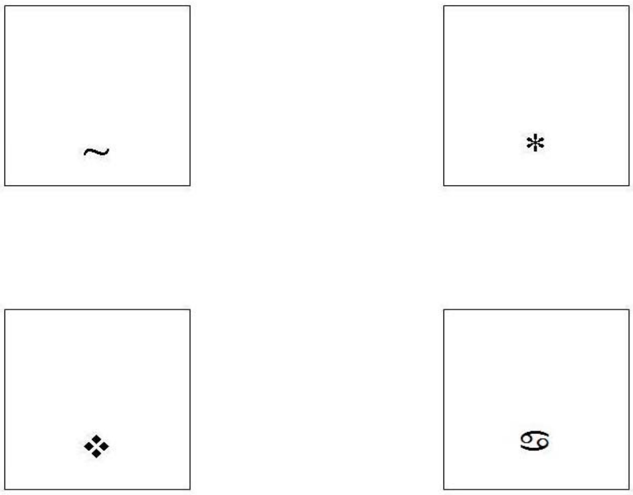


Figure 2.1 Screen shot of a sound-to-symbol trial. After a participant heard the sample sound, four comparison symbols were shown, one symbol in each corner of the screen. The participant pressed one of four coloured response keys that corresponded to the screen location of the chosen comparison symbol.

For the symbol-to-sound trials, each trial commenced with a white screen, in the centre of which was the sample symbol. The sample symbol remained in the middle of the screen throughout the trial. Below the sample symbol, the on-screen instructions reminded the participants to press the spacebar once they had seen the symbol. Pressing the spacebar activated the presentation of the four comparison sounds. Starting with the top left corner, as one of the comparison sounds was played, a blue “marker” star appeared in the top left corner of the screen for 2000 ms. A second comparison sound was then emitted as a blue star was presented in the top right corner, again for 2000 ms. A third and then a fourth sound were presented accompanied by a blue star in the bottom right and bottom left corners respectively. Once all four comparison sounds were played in sequence, beginning with the top left corner and ending with the bottom right corner, the four blue stars appeared together, one in each corner of the screen. Using the four coloured response keys, participants pressed the key that corresponded to the location on the screen of the comparison sound that they wished to select. Figure 2.2 shows a typical symbol-to-sound screen.

During the training stages, feedback to responses was provided by the computer program. When a correct comparison was chosen, a white screen with the words "well done correct", written in green, was presented for 1 s. For an incorrect response, the word "incorrect", printed in red, appeared on a white screen for 1 s. The feedback screens were followed by a 600 ms white intertrial screen before the next trial commenced.

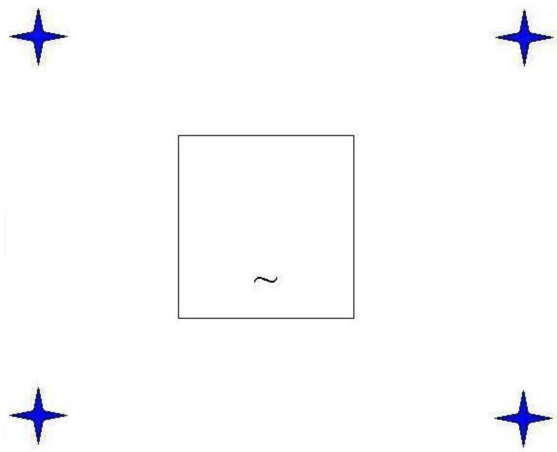


Figure 2.2 Screen shot of a symbol-to-sound trial. As each comparison sound was played, a blue "marker" star appeared in one of the corners of the screen.

The sound-to-symbol and symbol-to-sound test trials were identical to the respective sound-to-symbol or symbol-to-sound training trials, except that no feedback was provided. Instead, after a participant had made their response, the program progressed immediately to the 600 ms white intertrial screen. Prior to the start of the test trials, participants were forewarned in the on-screen instructions that feedback would be omitted during the subsequent trials.

In both sound-to-symbol and symbol-to-sound training and test trials, the position of the correct comparison was counterbalanced across the trials in each stage so that it occurred equally often in each of the four screen locations.

2.2.4 Overview of stages

Training and testing took place over six stages. Some of the stages were comprised of training and test trials, whereas other stages consisted solely of test trials. Trials in all stages were presented in a quasi-random order.

To familiarise participants with the training procedures, before commencing the first stage, all participants completed a practice session with the experimenter in which four sound-to-symbol and four symbol-to-sound practice trials were attempted.

An overview of the six-stage protocol may be seen in Figure 2.3.

Onset sound-to-symbol conditional discrimination training

Sixteen onset sound-to-symbol training trials were presented within each block. Each onset sound (/t/, /s/, /y/, /n/) was presented four times as the sample sound with its designated correct comparison. The remaining comparisons were comprised of the three other onset symbols, which were randomly allocated to the three remaining screen locations. To proceed to onset symbol-to-sound symmetry training, at least 14/16 correct responses within a single block were required. Participants continued to attempt the trial blocks until the criterion was met.

Onset symbol-to-sound symmetry training

Symbol-to-sound symmetry training trials involved the same onset pairs from the sound-to-symbol conditional discrimination training. Sixteen onset symbol-to-sound training trials were presented in each block. Each onset symbol was presented four times as the sample symbol with its associated correct sound comparison. The incorrect comparisons consisted of the remaining three onset sounds. A minimum of 14/16 correct responses within a 16-trial block were required to complete this stage. Participants who did not attain the criterion after attempting five 16-trial blocks (i.e., 80 trials) returned to onset sound-to-symbol training.

Mixed onset sound-to-symbol and symbol-to-sound testing

Sixteen test trials (eight onset sound-to-symbol and eight onset symbol-to-sound trials) were presented in this stage. Trials were identical in format to those encountered in the previous onset stages, but no feedback was provided. The criterion for passing the mixed onset test was set at 15/16 correct responses. On each attempt, participants experienced only one exposure to the 16 test trials. If a participant recorded fewer than 15 correct responses, training would recommence with the onset sound-to-symbol conditional discrimination training.

Rime sound-to-symbol conditional discrimination training.

During this stage, participants learned to relate four rime sound-to-symbol pairs. Each rime two-symbol pair, read from bottom (vowel)-to-top (consonant), corresponded to a –VC sound. Each of the four rime sounds (/af/, /ek/, /ol/, /im/) was presented four times as the sample sound across a block of 16 sound-to-symbol training trials. To proceed to rime symbol-to-sound symmetry training, a minimum of 14/16 correct responses were required within one block.

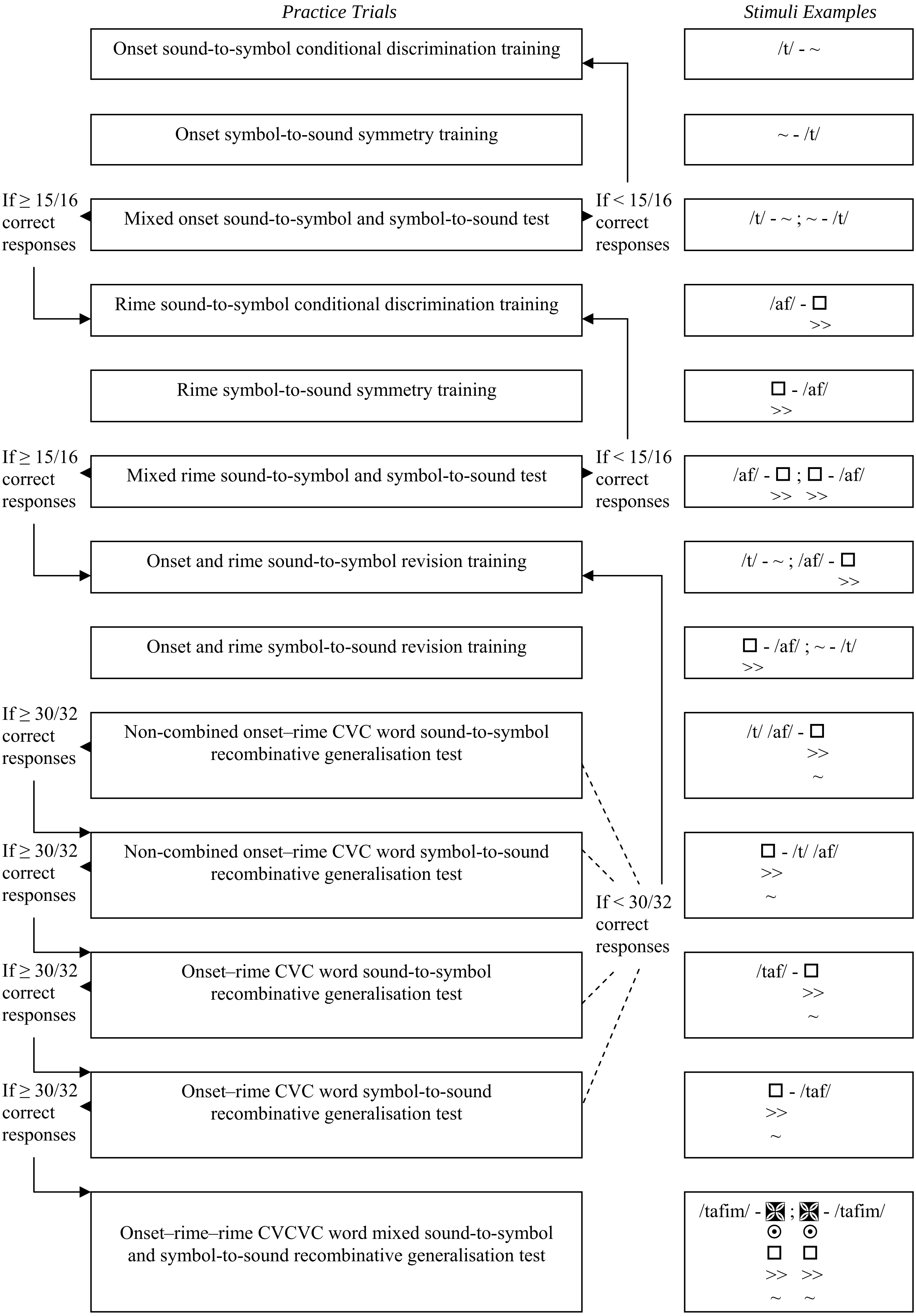


Figure 2.3 The revised six-stage MTS protocol used in the current research.

Rime symbol-to-sound symmetry training

Rime symbol-to-sound symmetry training was similar to the previous training stage, except that the four rime symbols were presented as samples and the rime sounds as comparisons. As in the rime sound-to-symbol training, participants needed to respond correctly to at least 14 training trials within a block to advance to the next stage. If after attempting five blocks, a participant failed to achieve the criterion, he or she returned to the rime sound-to-symbol conditional discrimination training.

Mixed rime sound-to-symbol and symbol-to-sound testing

The four rime sound–symbol pairs were presented in a block of 16 test trials (eight rime sound-to-symbol and eight rime symbol-to-sound test trials). Participants attempted the 16-trial test block once. Those participants who recorded at least 15 correct responses progressed to the next stage. Otherwise, a participant who responded correctly to fewer than 15 test trials, resumed training with the rime sound-to-symbol training.

Onset and rime sound-to-symbol revision training

This stage was included as a revision stage of the previously trained four onset and four rime sound-to-symbol relations. Participants completed blocks of 32 sound-to-symbol training trials (16 onset sound-to-symbol and 16 rime sound-to-symbol training trials). To proceed to the next stage, 30/32 correct responses within a single block were required. The number of blocks that a participant could attempt was limited to four blocks. If the criterion was not met within four blocks, a participant returned to the onset sound-to-symbol conditional discrimination training.

Onset and rime symbol-to-sound revision training

This stage was identical to the previous stage, except that participants completed 16 onset symbol-to-sound training trials and 16 rime symbol-to-sound training trials within each 32-trial block. Likewise, the criterion from the sound-to-symbol revision training was also applied in this stage, and again, participants who failed to fulfill the criterion cycled back to the onset sound-to-symbol conditional discrimination training.

Non-combined onset–rime CVC word sound-to-symbol recombinative generalisation test

During this stage, each of the four onset sounds (/t/, /s/, /y/, /n/) was combined with each of the four rime sounds (/af/, /ek/, /ol/, /im/) to produce 16 onset–rime CVC words. A slight pause occurred between the pronunciation of the onset and rime so that the separate onset and rime could be easily discriminated (e.g., /y/-/ek/, /t/-/af/). Three symbols corresponded to each onset–rime sound. The symbols were presented in sequence from bottom (onset) to top (rime), with no indicated break between the onset and rime.

Participants completed a block of 32 sound-to-symbol test trials. Each of the 16 non-combined CVC onset–rime sounds was presented twice as the sample sound. On each trial, the correct onset–rime comparison was presented with three incorrect onset–rime comparisons that overlapped in terms of shared onsets and rimes. Care was taken in the preparation of the comparisons so as to preclude responses based on onset or rime alone. For example, if the correct comparison was /t/-/af/, the remaining incorrect comparisons could be constructed as follows. One incorrect comparison would contain the same onset as the correct comparison but a different rime (e.g., /t/-/ek/). Another incorrect comparison would feature the same rime as the correct comparison but a different onset (e.g., /s/-/af/). The third incorrect comparison would contain the rime from the first incorrect comparison along with the onset from the second incorrect comparison (e.g., /s/-/ek/).

To proceed to the next stage, at least 30/32 correct responses were required. If the criterion was not met during the first exposure, the participant returned to the onset and rime sound-to-symbol revision training. Participants were permitted a maximum of three attempts at the non-combined CVC word sound-to-symbol test (i.e., 96 trials and reattempting the onset and rime sound-to-symbol and symbol-to-sound revision stages twice), after which debriefing would occur.

Non-combined onset–rime CVC word symbol-to-sound recombinative generalisation test

This testing stage was identical to the previous test, except that participants completed 32 symbol-to-sound test trials in which the onset–rime symbols operated as the samples and the onset–rime sounds were the comparisons.

Onset–rime CVC word sound-to-symbol recombinative generalisation test and onset–rime CVC word symbol-to-sound recombinative generalisation test

These recombinative generalisation tests were identical to the first sound-to-symbol and symbol-to-sound recombinative generalisation tests, except that the onset and rime sounds were fully blended together (i.e., there was no brief pause between the articulation of an onset and a rime). Participants completed 32 onset–rime CVC word sound-to-symbol generalisation test trials followed by 32 onset–rime CVC word symbol-to-sound generalisation test trials. The guidelines outlined under the non-combined CVC word generalisation tests for constructing the incorrect comparisons were also employed here. However, care was taken to ensure that the specific combinations of onsets and rimes that were used for incorrect comparisons differed from those employed in the non-combined onset–rime CVC word tests.

Onset–rime–rime CVCVC word mixed sound-to-symbol and symbol-to-sound recombinative generalisation test

The final recombinative generalisation test was incorporated into the protocol as an additional 'advanced' test to see how accurately participants responded to the more difficult recombined CVCVC items. For this final stage, a single block of 32 generalisation test trials (16 sound-to-symbol and 16 symbol-to-sound) were presented. All of the sample and comparison stimuli were onset–rime–rime, fully blended CVCVC items.

For these test trials, each of the four onsets was joined once to each of the rimes (e.g., /taf/, /tek/, /tol/, /tim/, /saf/, /sek/, /sol/, /sim/, etc.) to form the initial onset–rime sequence of the CVCVC word. An end rime (/af/, /ek/, /ol/, /im/) was joined to this sequence to form the complete CVCVC word (e.g., /tafek/). In total, recognition of 32 different CVCVC words was tested.

The onset–rime–rime sounds or symbols could contain the same rime (e.g., /tafaf/) or two different rimes (e.g., /tafol/).

As shown in Figure 2.4, for trials in which the onset–rime–rime sample possessed two different rimes (e.g., /tafol/), the three incorrect comparisons were devised as follows. The first contained the same initial onset–rime sequence as the correct comparison but a different end rime (e.g., /tafim/). A second included the same onset and end rime as the correct comparison but a different first rime obtained from the end rime of the first incorrect comparison (e.g., /timol/). The third incorrect comparison was a reversal of the rime–rime sequence of the correct comparison using the same onset as the correct comparison (e.g., /tolaf/).

For trials in which the same rime was used in the onset–rime–rime sample (e.g., /tafaf/), the incorrect comparisons were as follows. One comparison contained the same onset as the correct comparison but a different rime–rime sequence (e.g., /tolol/). A second comparison featured a different onset but the same rime–rime sequence as the correct comparison (e.g., /safaf/). A third comparison employed the onset from the second comparison and the rime–rime sequence from the first incorrect comparison (e.g., /solol/).

Once the single block of 32 generalisation test trials had been attempted, participation ended and debriefing occurred.

Trained onsets	/t/ - ~	/s/ - *	/y/ - ❖	/n/ - ♋
Trained rimes	/af/ - >> □	/ek/ - ♉ ⌖	/im/ - ⊙	/ol/ - ♌ ₪

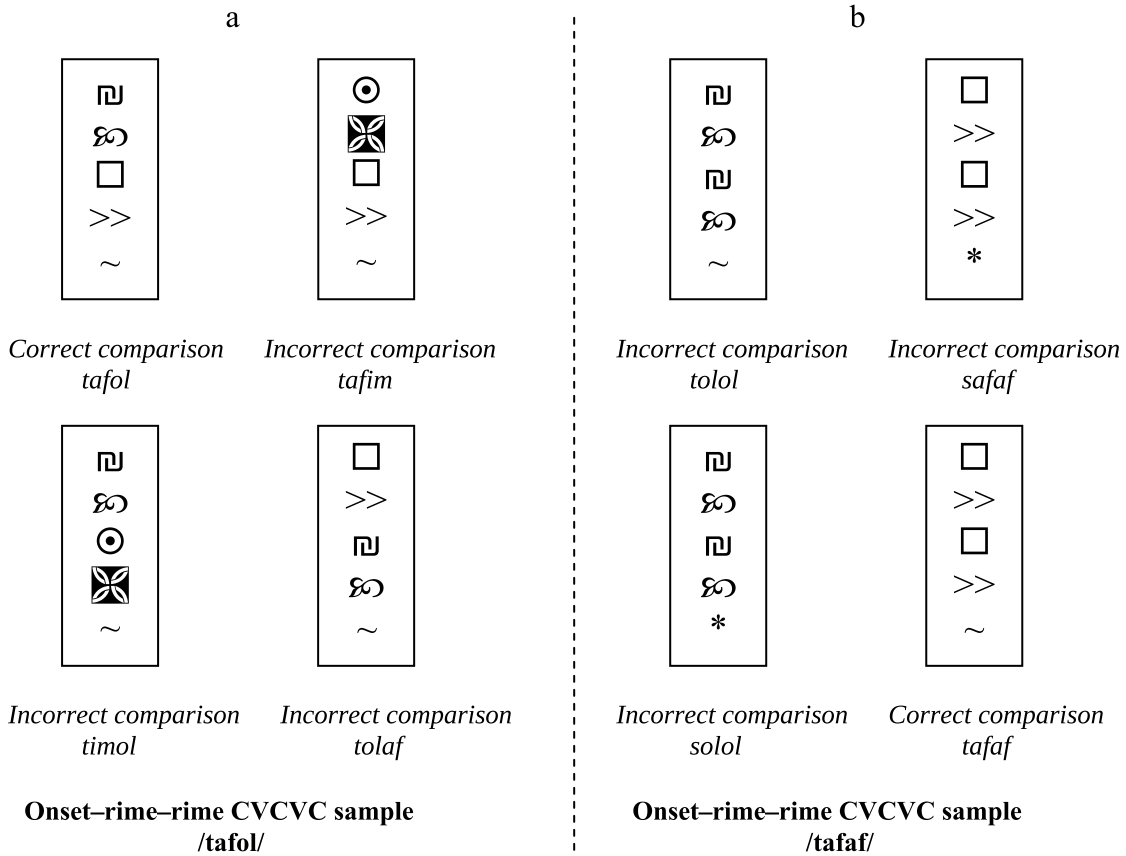


Figure 2.4 Examples of the comparisons presented in the onset–rime–rime CVCVC word generalisation test for: an onset–rime–rime sample with (a) two different rimes; (b) the same rime.

2.3 Ethical issues for the adult research

Ethical approval was granted for the current research from the University Ethics Committee.

The experimental process began with the experimenter detailing what would be expected during the course of participation. Confirmation was sought that a participant did not have any auditory or visual impairments which may have affected their ability to complete the computer presented tasks. Once a participant was happy to proceed with the experiment, a consent form was signed by each participant. A copy of the informed consent form may be seen in Appendix 1 (p. 341). Participants were told that any data collected would be anonymous, confidential, and would be securely stored at all times. Participants were reminded that they could withdraw from the experiment at any stage should they so wish, and that in such circumstances, their data would not be included in any subsequent analyses. None of the participants withdrew from the current experiments.

Participants completing the protocol were trained to criterion. As the length of time to complete the protocol often exceeded one hour, all participants were given the opportunity to take a short break at the end of each stage.

There was the possibility that some of the participants may not have been able to learn the sound–symbol relations. Measures were set in place to avoid any potential embarrassment for participants if this occurred. Before training started, all participants were reassured that the length of time taken to complete the experiment varied depending on the computer program. Additionally, the experimenter noted the time that each participant began the first training stage. If after 15 minutes a participant had not contacted the experimenter to signal the completion of the first stage, the experimenter checked with the participant how he or she was coping with the task and reviewed the procedure again. If following an additional 10 minutes of training the criterion had not been met, the experimenter accessed the data log and informed the participant that sufficient data had been collected. Debriefing followed and participants were thanked for their assistance with the research.

Once participants had completed the entire protocol, all participants were debriefed and thanked for their participation.

Chapter Three

Experiment 1: Establishing the Basic Protocol[1]

3.1 Introduction

It was essential to verify that the modified MTS protocol as described in Chapter 2 was indeed effective in facilitating recombinative generalisation. Thus, Experiment 1 was conducted to test the efficacy of the complete revised procedure in promoting recombinative generalisation of onset and rime units, and to determine if the new training sequence (incorporating symmetry training and mixed symmetry testing) was suitably sufficient to enable participants to recognise novel recombined onset–rime and onset–rime–rime words. If the revised protocol proved to be effective, this would certainly support its further development as a tool to potentially help facilitate recombinative generalisation.

3.2 Method

3.2.1 Participants

An ad-hoc sample of 20 literate adults (8 men and 12 women) participated in Experiment 1. Participants ranged in age from 18 years to 52 years (median = 24 years). When consenting to take part in the experiment, the participants confirmed by self report that they did not have any visual or auditory impairments. All participants spoke English as a first language.

3.2.2 Procedure

The training and testing protocol outlined in Chapter 2 was completed by all 20 participants.

[1] The findings from Experiment 1 have been submitted to The Psychological Record and are under consideration for publication.

To recap briefly, participants were trained to criterion in four onset sound–symbol relations (e.g., /y/ - ❖; ❖ - /y/) and four rime –VC pair sound–symbol relations (e.g., /af/ - >> □ ; >> □ - /af/). Subsequent testing examined, firstly, if the participants could accurately identify recombined onset–rime sounds and symbols (e.g., /yaf/ - ❖>> □), and secondly, if they could recognise recombined onset–rime–rime sounds and symbols (e.g., /yafim/ - ❖>> □ ⊠ ⊙).

3.3 Results

3.3.1 Training stages

All 20 participants successfully completed the three training stages (please see Table 3.1). For the onset sound-to-symbol conditional discrimination training, the mean number of training trials required to reach criterion was 58 (range, 30 to 190). One participant trained within two blocks. Twelve participants completed training within three blocks, and six participants within four blocks. Only one participant required 12 blocks to pass the first stage. All 20 participants trained successfully on their first attempt at the onset symbol-to-sound symmetry training stage. The onset mixed test was passed by all participants on their first exposure, with 16 participants achieving 100% accuracy.

On average, 41 trials were required to complete the rime sound-to-symbol conditional discrimination training (range, 30 to 110). Twelve participants completed training within two blocks, six within three blocks, and one within four blocks. One participant required seven blocks. Once a participant had passed the rime sound-to-symbol training, he or she passed the rime symbol-to-sound symmetry training and the mixed rime testing, each at the first attempt. Fifteen participants demonstrated

100% accuracy on the rime symbol-to-sound training, while 16 participants showed 100% accuracy on the mixed rime testing.

Next, the participants completed the onset and rime revision training stages. The onset and rime sound-to-symbol training was passed by all participants within one block of trials, with eight participants achieving 100% accuracy. Similarly, the onset and rime symbol-to-sound training stage was passed at the first exposure, with 14 participants showing 100% accuracy.

Table 3.1 Number of trials completed to reach criterion for the three training stages. The percentage of correct responses for each stage is shown in parentheses.

Participant	Onset sound-to-symbol training	Onset symbol-to-sound training	Onset sound-to-symbol and symbol-to-sound testing	Rime sound-to-symbol training	Rime symbol-to-sound training	Rime sound-to-symbol and symbol-to-sound testing	Onset and rime sound-to-symbol training	Onset and rime symbol-to-sound training
1	47 (72)	15 (93)	15 (100)	30 (80)	14 (100)	15 (100)	31 (97)	31 (97)
2	48 (52)	15 (93)	16 (94)	47 (72)	15 (93)	15 (100)	31 (97)	31 (97)
3	190 (59)	15 (93)	15 (100)	110 (73)	14 (100)	16 (94)	32 (94), 32 (94)	30 (100), 30 (100)
4	48 (69)	15 (93)	15 (100)	30 (73)	14 (100)	15 (100)	30 (100)	30 (100)
5	48 (67)	15 (93)	15 (100)	30 (87)	14 (100)	16 (94)	30 (100)	30 (100)
6	62 (61)	15 (93)	15 (100)	31 (87)	14 (100)	15 (100)	30 (100)	30 (100)
7	47 (74)	14 (100)	16 (94)	46 (70)	14 (100)	15 (100)	31 (97)	30 (100)
8	30 (87)	16 (88)	15 (100)	32 (59)	14 (100)	15 (100)	30 (100)	30 (100)
9	46 (65)	15 (93)	15 (100)	31 (71)	15 (93)	15 (100)	31 (97)	30 (100)
10	47 (70)	14 (100)	15 (100)	30 (83)	14 (100)	15 (100)	30 (100)	30 (100)
11	63 (65)	14 (100)	16 (94)	46 (70)	14 (100)	15 (100)	31 (97)	30 (100)
12	48 (58)	15 (93)	15 (100)	32 (69)	15 (93)	15 (100)	30 (100)	31 (97)
13	62 (61)	14 (100)	15 (100)	46 (74)	14 (100)	15 (100)	31 (97)	31 (97)
14	47 (64)	15 (93)	15 (100)	62 (58)	15 (93)	16 (94)	31 (97)	30 (100)
15	47 (74)	14 (100)	15 (100)	31 (77)	14 (100)	15 (100)	30 (100)	30 (100)
16	63 (57)	15 (93)	16 (94)	46 (67)	14 (100)	15 (100)	32 (94)	31 (97)
17	46 (80)	14 (100)	15 (100)	46 (76)	14 (100)	15 (100)	31 (97)	31 (97)
18	62 (56)	15 (93)	15 (100)	31 (68)	15 (93)	15 (100)	31 (97)	30 (100)
19	62 (66)	14 (100)	15 (100)	30 (73)	14 (100)	16 (94)	30 (100)	30 (100)
20	47 (74)	15 (93)	15 (100)	30 (70)	14 (100)	15 (100)	31 (97)	30 (100)

Note. Where there are two figures, this indicates that a participant did not meet the criterion on their first attempt at a particular stage, and retraining at an earlier stage was required.

3.3.2 Recombinative generalisation testing

The three recombinative generalisation tests were completed successfully by all 20 participants (please see Table 3.2).

Table 3.2 Number of correct responses on the recombinative generalisation tests. Percentage of correct responses is shown in parentheses.

Participant	Non-combined onset–rime CVC sound-to-symbol test correct / 32	Non-combined onset–rime CVC symbol-to-sound test correct / 32	Combined onset–rime CVC sound-to-symbol test correct / 32	Combined onset–rime CVC symbol-to-sound test correct / 32	Onset–rime–rime CVCVC sound-to-symbol and symbol-to-sound mixed test correct / 32
1	32 (100)	31 (97)	31 (97)	31 (97)	29 (91)
2	31 (97)	30 (94)	32 (100)	31 (97)	29 (91)
3	25 (78), 30 (94)	30 (94)	30 (94)	32 (100)	29 (91)
4	30 (94)	32 (100)	31 (97)	31 (97)	29 (91)
5	32 (100)	32 (100)	32 (100)	32 (100)	30 (94)
6	31 (97)	32 (100)	32 (100)	32 (100)	30 (94)
7	30 (94)	31 (97)	31 (97)	32 (100)	30 (94)
8	31 (97)	31 (97)	32 (100)	32 (100)	29 (91)
9	31 (97)	31 (97)	32 (100)	32 (100)	30 (94)
10	31 (97)	31 (97)	32 (100)	31 (97)	30 (94)
11	31 (97)	32 (100)	32 (100)	32 (100)	30 (94)
12	31 (97)	31 (97)	32 (100)	31 (97)	29 (91)
13	32 (100)	32 (100)	31 (97)	32 (100)	29 (91)
14	30 (94)	31 (97)	31 (97)	31 (97)	31 (97)
15	30 (94)	32 (100)	32 (100)	32 (100)	31 (97)
16	32 (100)	31 (97)	31 (97)	31 (97)	30 (94)
17	32 (100)	30 (94)	31 (97)	31 (97)	29 (91)
18	31 (97)	31 (97)	30 (94)	30 (94)	28 (88)
19	32 (100)	32 (100)	31 (97)	31 (97)	30 (94)
20	31 (97)	31 (97)	32 (100)	32 (100)	29 (91)

Note. The values in the final column are the number of recombined onset–rime–rime CVCVC words correctly identified.

The first recombinative generalisation test (sound-to-symbol test trials followed by symbol-to-sound test trials) examined how accurately the participants could identify non-combined onset–rime CVC words. Nineteen participants attained the criterion of at least 30/32 correct responses on their first attempt at matching the non-combined onset–rime CVC sound-to-symbol relations. One participant (Participant 3) produced 25 correct responses on the first exposure, but following re-exposure to the onset and rime sound-to-symbol and symbol-to-sound revision training, the participant passed the non-combined onset–rime CVC sound-to-symbol test successfully at the next attempt. All 20 participants passed the non-combined onset–rime CVC symbol-to-sound test at the first attempt, with seven participants demonstrating 100% accuracy.

Recognition of fully combined onset–rime CVC words was assessed in the second recombinative generalisation test. All 20 participants completed both the sound-to-symbol and symbol-to-sound generalisation test trials at the first attempt. Mean accuracy in the onset–rime CVC sound-to-symbol test trials and onset–rime CVC symbol-to-sound test trials was 98% (range, 94% to 100%), with 10 participants achieving 100% accuracy in each of these tests.

For the final recombinative generalisation test, recognition of 32 different recombined onset–rime–rime CVCVC words was examined. All 20 participants correctly identified at least 88% of the novel CVCVC words presented. The mean number of CVCVC words recognised was 30 (range, 28 to 31).

3.3.3 Summary

All 20 participants completed the revised six-stage training and testing protocol successfully. Following bi-directional training of the onset and rime sound–symbol relations, all 20 participants demonstrated at least 94% accuracy in matching sound–symbol and symbol–sound pairings of recombined onset–rime CVC words. Furthermore, for the advanced recombinative generalisation test, in which recombined onset–rime–rime CVCVC words were presented, the 20 participants performed with at least 88% accuracy.

3.4 Discussion

Experiment 1 was conducted to test the viability of the modified training and testing protocol in facilitating the emergence of recombinative generalisation. The results obtained were positive and indicated that following training of the onset and rime sound–symbol relations, all participants were able to identify recombined CVC and CVCVC words composed from the previously taught onsets and rimes.

The participants were highly accurate in recognising the recombined onset–rime CVC words. However, it is important to remember that, prior to attempting the test trials featuring the fully combined onset–rime words, the participants completed a recombinative generalisation test with non-combined onset–rime words. Perhaps the preceding test served as a critical ‘bridge’ between training with separate onset and rime units and testing with the fully combined novel words. In effect, participants were provided with some prior exposure to, or training with, partially recombined words before attempting to identify the fully combined CVC recombined units. Nevertheless, it is important to note that despite having no previous exposure to words constructed in an onset–rime–rime syllabic structure, the participants were highly accurate in recognising the more complex, untrained CVCVC words.

The current results are in line with previous research findings (e.g., Keaveney, 2005; Mueller et al., 2000; Saunders et al., 2003) that have emphasised the effectiveness and robustness of MTS procedures in facilitating recombinative generalisation. Only one participant in Experiment 1 required one additional re-exposure to an earlier training stage before passing the first recombinative generalisation test (this participant successfully completed all subsequent tests without further training). In all, the data suggested that the revised protocol was very likely an effective tool that could be used to support recombinative generalisation. With this affirmation in place, greater confidence was instilled to employ and extend the use of the protocol in further experiments.

Performance following completion of the original MTS protocol devised by Keaveney (2005) indicated that just over a quarter of participants required further retraining after they were unsuccessful in the first symmetry test. In contrast, all participants in the current study passed the symmetry training and mixed tests on the first exposure. Thus, the addition of the symmetry training stages appeared to be a useful modification in providing a more comprehensive training protocol.

One of the disadvantages for participants when undertaking the revised protocol was the amount of time required to complete all of the training and test stages. Depending on progress through the training stages, some participants required nearly two hours to reach the final recombinative generalisation test. It is possible that the high number of trials in the early training stages may have induced some fatigue and boredom and thus contributed to the length of time required to complete all stages. However, the initial training needs to be sufficiently thorough so that the participants can learn the correct sound–symbol relations. It is important, therefore, to strike a balance between the number of training stages and trials so that they are not too small as to be ineffective, or overly expansive as to produce fatigue effects which may also hamper recombinative generalisation performance.

Overall, the results from Experiment 1 established that the modified training was effective not only in facilitating the recognition of CVC words, but also in enabling participants to accurately recognise the more complex CVCVC words.

Critically, however, it remained unclear to what extent each of the training stages were needed in order to produce the observed recombinative generalisation performances. Could the current protocol be further redefined to develop an optimal training protocol incorporating only the essential training components for establishing recombinative generalisation? These issues were focused on in the next experiment reported in Chapter 4.

Chapter Four

Experiment 2: Identifying the Key Training Stages[1]

4.1 Introduction

Participants in Experiment 1 demonstrated recombinative generalisation after completing an adapted training protocol that incorporated conditional discrimination training, symmetry training, and recombinative generalisation training (in the form of presenting non-combined onset–rime words). As all of the adults could accurately identify the novel recombined CVC and CVCVC words after participating in the training, the protocol itself was deemed to be successful. Yet although the protocol in its entirety was found to be effective, it was important to isolate what training components needed to be included in the protocol for recombinative generalisation to emerge. That is, to determine the training conditions under which recombinative generalisation was most likely to occur. This was the aim of the second adult experiment.

In Experiment 2, the three core training components of the protocol (conditional discrimination training, symmetry training, and non-combined onset–rime recombinative generalisation training) were removed separately from the training procedure; thereby allowing the contribution of each individual training component to the demonstration of recombinative generalisation to be assessed.

One of the main criticisms levelled against the protocol employed in Experiment 1 was the extensive length of time needed to advance through the six stages. Therefore, in order to reduce the time taken to complete the protocol, participants in Experiment 2 attempted each recombinative generalisation test once

[1] The findings from Experiment 2 have been published as Mahon, C., Lyddy, F., & Barnes-Holmes, D. (2010). Recombinative Generalization of Subword Units Using Matching-to-Sample. *Journal of Applied Behavior Analysis, 43, 2*, 303-307.

and did not receive further retraining with earlier stages if the criterion (as established in Experiment 1) for a particular recombinative generalisation test was not met.

The script presented in Experiment 1 was modelled on an alphabetic writing system (i.e., a fixed sound-to-symbol correspondence). A spoken recombined CVC word was represented by three distinct symbols (e.g., /yaf/ was written as ❖>>□, with the symbols presented vertically and read from bottom-to-top). The results from Experiment 1 indicated that completion of the protocol facilitated recombinative generalisation of ‘words’ adhering to the characteristics of an alphabetic script (i.e., a single sound represented by a single symbol). However, there is the possibility that the effectiveness of the protocol could be influenced by different types of scripts. To determine if the efficiency of the protocol can be generalised to other writing systems, the script used in Experiment 1 was modified. For Experiment 2, a script based partly on a syllabic writing system was employed, in that each –VC rime (syllable) sound unit corresponded to a single symbol.

4.2 Method

4.2.1 Participants

Twenty-five literate adults (11 men and 14 women) aged between 18 years to 46 years (median = 21 years) took part. Predominantly, participants were sampled from a university student population. All participants reported no visual or auditory impairments, and had English as their first language.

4.2.2 Apparatus

Materials were identical to those employed in Experiment 1, with the exception of the rime stimuli. The same four rime sounds utilised in Experiment 1 were used again, but each rime sound corresponded to one abstract symbol rather than two symbols. For each rime symbol pair presented in Experiment 1 (e.g., /af/ - >> □), the first symbol was deleted (e.g., /af/ - □). Thus, for Experiment 2, the onset–rime CVC spoken words were related to two symbols (e.g., /yaf/ - ❖ □), and the onset–rime–rime CVCVC spoken words corresponded to three symbols (e.g., /yafim/ - ❖□⦿).

4.2.3 Procedure

Amendments to the protocol tested in Experiment 1 were as follows. The purpose of the non-combined onset–rime CVC sound-to-symbol and symbol-to-sound test trials that had served as the first recombinative generalisation test in Experiment 1 was changed. In Experiment 2, the trials in which the non-combined onset–rime CVC words were presented functioned as the recombinative generalisation training. For the recombinative generalisation training, participants completed a block of 32 non-combined onset–rime CVC sound-to-symbol trials, followed by a block of 32 non-combined onset–rime CVC symbol-to-sound trials. No feedback was presented.

The criterion from Experiment 1 governing the combined onset–rime CVC word recombinative generalisation tests was removed (i.e., if less than 30/32 correct responses, participants returned to the onset and rime sound-to-symbol revision training). All participants in Experiment 2 simply attempted 32 onset–rime CVC word sound-to-symbol generalisation test trials, followed by 32 onset–rime CVC word symbol-to-sound generalisation test trials. All participants then proceeded directly to the final onset–rime–rime CVCVC word recombinative generalisation test.

To identify the training components conducive to producing the recombinative generalisation effect, modifications were made to the training protocol. Table 4.1 summarises the stages completed by the participants as described in the following section.

Table 4.1 Training stages for participants who completed: (i) the entire protocol; (ii) no symmetry training [sound-to-symbol trained]; (iii) no symmetry training [symbol-to-sound trained]; (iv) no recombinative generalisation training with non-combined onset–rime CVC words; (v) no conditional discrimination training.

Entire Six-Stage Protocol	*No Symmetry Training (sound-to-symbol trained)*	*No Symmetry Training (symbol-to-sound trained)*	*No Recombinative Generalisation Training with Non-Combined Onset–Rime CVC Words*	*No Conditional Discrimination Training*
Onset sound-to-symbol conditional discrimination training	✓	Onset symbol-to-sound training	✓	
Onset symbol-to-sound symmetry training			✓	
Mixed onset sound-to-symbol and symbol-to-sound test	Onset sound-to-symbol test	Onset symbol-to-sound test	✓	✓
Rime sound-to-symbol conditional discrimination training	✓	Rime symbol-to-sound training	✓	
Rime symbol-to-sound symmetry training			✓	
Mixed rime sound-to-symbol and symbol-to-sound test	Rime sound-to-symbol test	Rime symbol-to-sound test	✓	✓
Onset and rime sound-to-symbol revision training	Onset sound-to-symbol training	Onset symbol-to-sound training	✓	
Onset and rime symbol-to-sound revision training	Rime sound-to-symbol training	Rime symbol-to-sound training	✓	
Recombinative generalisation training non-combined onset–rime CVC sound-to-symbol	✓	✓		✓
Recombinative generalisation training non-combined onset–rime CVC symbol-to-sound	✓	✓		✓
Onset–rime CVC sound-to-symbol generalisation test	✓	✓	✓	✓
Onset–rime CVC symbol-to-sound generalisation test	✓	✓	✓	✓
Onset–rime–rime CVCVC word generalisation test	✓	✓	✓	✓

Note. The omitted stages are highlighted in grey. Changes are described where appropriate.

Five participants were exposed to the complete protocol as was presented in Experiment 1. Ten additional participants received no symmetry training. To control for the effects of type of training trials presented (i.e., sound-to-symbol versus symbol-to-sound), five of these participants completed sound-to-symbol training and sound-to-symbol testing for the onsets and rimes, and five participants completed symbol-to-sound training and symbol-to-sound testing for the onsets and rimes. The recombinative generalisation training with the non-combined onset–rime CVC words was omitted for an additional five participants. Five other participants had no conditional discrimination training with the onset or rime sound–symbol relations and only attempted the mixed sound-to-symbol and symbol-to-sound tests for the onsets and rimes before the recombinative generalisation tests were introduced. Progression criteria did not apply for these five participants.

4.3 Results

4.3.1 Training performance

Table 4.2 presents the number of trials completed across the training stages for the 25 participants. Participants who completed the entire protocol, or received no symmetry training (completing sound-to-symbol or symbol-to-sound trials instead) or no recombinative generalisation training, passed all of the training stages.

4.3.1.1 Complete training protocol

All five participants completed the onset sound-to-symbol conditional discrimination training within three blocks of trials, and passed the onset symbol-to-sound symmetry training and the mixed onset test within one block of trials. Similarly, only one block of trials was required for the participants to complete the rime sound-to-symbol conditional discrimination training and rime symmetry training.

Table 4.2 Number of training trials completed to reach the criterion. Percentage correct in parentheses.

Participant*	Onset sound-to-symbol training	Onset symbol-to-sound symmetry training	Mixed onset test correct/16	Rime sound-to-symbol training	Rime symbol-to-sound symmetry training	Mixed rime test correct/16	Onset and rime sound-to-symbol revision training	Onset and rime symbol-to-sound revision training
1 EP	46 (71)	14 (100)	16(100)	32 (63)	15 (94)	15(94)	32/32	32/32
2 EP	30 (81)	14 (100)	16(100)	30 (78)	14 (100)	16(100)	32/32	32/32
3 EP	31 (72)	14 (100)	16(100)	31 (72)	15 (94)	16(100)	32/32	32/32
4 EP	46 (69)	14 (100)	16(100)	30 (78)	14 (100)	16(100)	31/32	32/32
5 EP	46 (63)	14 (100)	16(100)	30 (81)	14 (100)	16(100)	32/32	32/32
6 SoSy	158(61), 15 (94), 15 (94)	----------	13 (81), 14 (88), 15 (94)	46 (67)	----------	16(100)	16/16	16/16
7 SoSy	112(74)	----------	15 (94)	46 (85)	----------	16(100)	13/16, 15/16	15/16
8 Sosy	112(52)	----------	15 (94)	62 (56)	----------	16(100)	16/16	15/16
9 SoSy	30 (81)	----------	15 (94)	30 (81)	----------	16(100)	16/16	16/16
10 SoSy	16 (88), 16 (94)	----------	9 (56), 15 (94)	30 (81)	----------	15 (94)	15/16	16/16
11 SySo	31 (66)	----------	16(100)	30 (81)	----------	16(100)	16/16	15/16
12 SySo	78 (70)	----------	16(100)	30 (81)	----------	16(100)	15/16	16/16
13 SySo	111(49)	----------	16(100)	31 (88)	----------	16(100)	16/16	16/16
14 SySo	46 (77)	----------	16(100)	30 (81)	----------	16(100)	15/16	16/16
15 SySo	62 (75)	----------	16(100)	31 (88)	----------	16(100)	16/16	16/16
16 RGT	222(44)	14 (100)	16(100)	47 (79)	14 (100)	16(100)	32/32	32/32
17 RGT	46 (69)	14 (100)	16(100)	32 (63)	32 (81)	16(100)	32/32	32/32
18 RGT	48 (46)	26 (88)	16(100)	16 (88)	15 (94)	16(100)	32/32	31/32
19 RGT	111(61)	14 (100)	16(100)	62 (61)	14 (100)	16(100)	32/32	29/32, 32/32
20 RGT	48 (65)	14 (100)	16(100)	30 (72)	14 (100)	16(100)	32/32	31/32
21 CD	----------	----------	1 (6)	----------	----------	1 (6)	----------	----------
22 CD	----------	----------	1 (6)	----------	----------	3 (19)	----------	----------
23 CD	----------	----------	3 (19)	----------	----------	1 (6)	----------	----------
24 CD	----------	----------	2 (12)	----------	----------	1 (6)	----------	----------
25 CD	----------	----------	0 (0)	----------	----------	3 (19)	----------	----------

Note. Where two values are shown, this indicates that the participant did not reach the criterion on their first attempt at the stage, and retraining at an earlier stage was required. Values listed in the mixed onset and mixed rime tests for the no conditional training participants represent the number of correct responses to the 16 test trials. Omitted stages are shown.

* Participants who completed the entire protocol (EP); received no symmetry training but sound-to-symbol training (SoSy); received no symmetry training but symbol-to-sound training (SySo); received no recombinative generalisation training (RGT); received no conditional discrimination sound-to-symbol training (CD).

The mixed rime test was also passed at the first attempt. All participants passed the two onset and rime revision training stages within one block of trials.

The mean number of correct responses produced on the non-combined onset–rime CVC sound-to-symbol training was 31 (range, 30 to 32). All five participants showed 100% accuracy on the non-combined onset–rime CVC symbol-to-sound training.

4.3.1.2 No symmetry training (sound-to-symbol training)

The number of trials required to complete the onset sound-to-symbol conditional discrimination training ranged between 16 and 158. Thereafter, participants progressed immediately to the onset sound-to-symbol testing. Three participants completed this test on their first attempt, but Participant 10 required one re-exposure and Participant 6 two re-exposures to the onset sound-to-symbol training, before successfully achieving the test criterion. For the rime sound-to-symbol conditional discrimination training, between 30 and 62 training trials were required to meet the criterion. All five participants then completed the rime sound-to-symbol testing on their first exposures. With the exception of Participant 7, who needed two exposures to the onset sound-to-symbol revision training, the remaining four participants completed the onset sound-to-symbol and rime sound-to-symbol revision training each within one block.

For the non-combined onset–rime CVC sound-to-symbol and symbol-to-sound training the mean number of correct responses in each training block was 31.

4.3.1.3 No symmetry training (symbol-to-sound trained)

Participants completed between 31 and 111 trials to pass the onset symbol-to-sound conditional discrimination training, and between 30 and 31 trials to reach criterion for the rime symbol-to-sound conditional discrimination training. All five participants achieved 100% accuracy for the onset symbol-to-sound test and the rime symbol-to-sound test. Again, all participants successfully completed the onset symbol-to-sound and rime symbol-to-sound revision training on their first exposures.

Few errors occurred in the non-combined onset–rime CVC sound-to-symbol and symbol-to-sound training blocks. The mean number of correct responses was 31 (range, 29 to 32), and 32 (range, 31 to 32), respectively.

4.3.1.4 No recombinative generalisation training

All five participants passed the onset sound-to-symbol conditional discrimination training, requiring between 46 and 222 trials. Four participants then immediately completed the onset symbol-to-sound symmetry training; Participant 18 needed two exposures to this stage. All five participants passed the mixed onset test and the rime sound-to-symbol conditional discrimination training on their first exposures. Participant 17 required two blocks to pass the rime symbol-to-sound symmetry training. Otherwise participants completed this stage within one block. All participants achieved 100% accuracy on the mixed rime test trials.

With one exception, the five participants completed the onset and rime sound-to-symbol and symbol-to-sound revision blocks on their first exposures; Participant 19 required two blocks of the onset and rime symbol-to-sound revision training.

4.3.1.5 No conditional discrimination training

As predicted, very few correct responses were produced by the five participants during the mixed onset test (mean = 9% correct) or mixed rime test (mean = 11% correct).

4.3.2 Recombinative generalisation tests

Figure 4.1 shows the mean accuracy on the recombinative generalisation tests for all participants.

4.3.2.1 Complete training protocol

Accuracy was high for the onset–rime CVC sound-to-symbol generalisation test trials. The mean accuracy was 99% (range, 97% to 100%), with four of the five participants achieving 100% accuracy and one participant demonstrating 97% accuracy. Similarly, high accuracy was shown on the onset–rime CVC symbol-to-sound generalisation test trials. Mean accuracy for these test trials was 98% (range, 94% to 100%).

Accuracy in identifying the recombined onset–rime–rime CVCVC words was high (mean = 92% accuracy). Two participants each recognised 88% and 91% of CVCVC words respectively. Three participants all showed 94% accuracy in identifying the CVCVC words.

4.3.2.2 No symmetry training (sound-to-symbol trained)

The mean accuracy for the onset–rime CVC sound-to-symbol generalisation test trials was 96%. Two participants each achieved 100% accuracy, one participant showed 97% accuracy, and two participants each reached 91% accuracy. Mean accuracy for the onset–rime CVC symbol-to-sound generalisation test trials was 96% (range, 88% to 100%), with three participants scoring 100% accuracy.

On average, participants correctly recognised 88% of the recombined onset–rime–rime CVCVC words. Three participants recorded accuracy levels of 66%, 88%, and 91% respectively. Two participants each showed 97% accuracy in recognising the onset–rime–rime CVCVC words.

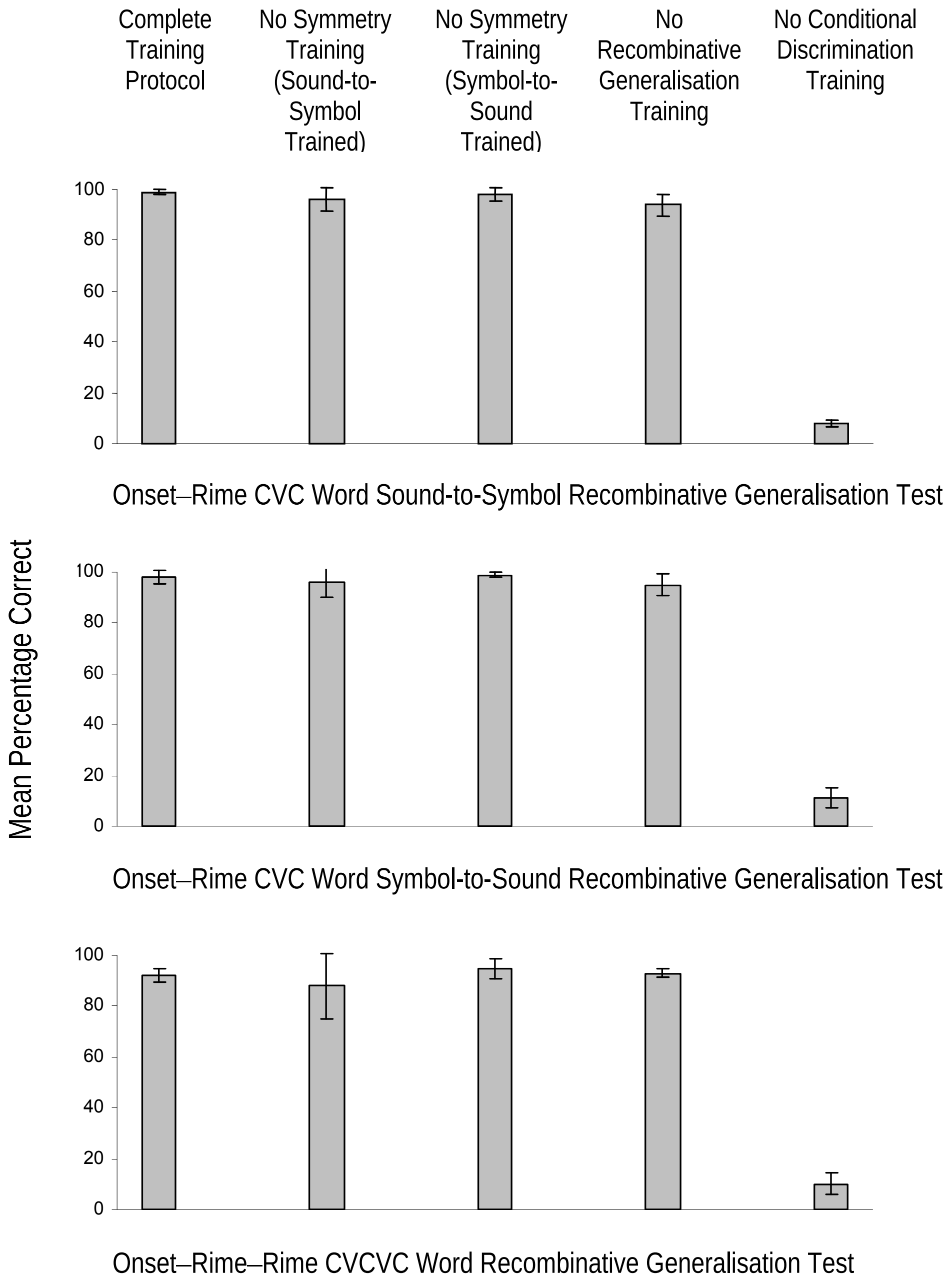


Figure 4.1 Mean percentage correct on the recombinative generalisation tests (onset–rime CVC words and onset–rime–rime CVCVC words) for participants who completed: (i) the entire protocol; (ii) no symmetry training (sound-to-symbol trained or symbol-to-sound trained); (iii) no recombinative generalisation training with non-combined onset–rime CVC words; (iv) no conditional discrimination training. Error lines representing standard deviation are shown for each bar.

4.3.2.3 No symmetry training (symbol-to-sound trained)

Mean accuracy for the onset–rime CVC sound-to-symbol generalisation test was 98%. Two participants each showed 94% and 97% accuracy respectively. The remaining three participants demonstrated 100% accuracy. Apart from one participant who achieved 97% accuracy, all participants performed at 100% accuracy on the onset–rime CVC symbol-to-sound generalisation test (mean accuracy = 99%).

Few errors occurred on the onset–rime–rime CVCVC generalisation test. Mean accuracy in recognising the CVCVC words was 95%. Two participants each achieved 88% and 94% accuracy respectively. Three participants showed 97% accuracy when responding to the CVCVC words.

4.3.2.4 No recombinative generalisation training

In general, accuracy was high for the onset–rime CVC sound-to-symbol and symbol-to-sound generalisation test trials. The mean accuracy in recognising the onset–rime CVC sound-to-symbol relations was 94%, with one participant demonstrating 88% accuracy, one participant showing 91% accuracy, and three participants scoring 97% accuracy. For the onset–rime CVC symbol-to-sound relations, the mean accuracy was 95% (range, 88% to 100%).

A mean accuracy of 93% was shown when responding to the onset–rime–rime CVCVC words. Two participants achieved 88% and 94% accuracy respectively, and three participants demonstrated 97% accuracy.

4.3.2.5 No conditional discrimination training

Response accuracy for the recombinative generalisation tests was low when the conditional discrimination training was not completed. For the onset–rime CVC sound-to-symbol generalisation test, the mean accuracy was 8%. With the exception of one participant who showed 6% accuracy, the remaining four participants all demonstrated 9% accuracy in identifying the onset–rime CVC sound-to-symbol relations. Similarly, accuracy was low for the onset–rime CVC symbol-to-sound generalisation test (mean accuracy = 11%; range, 6% to 16%).

Very few of the onset–rime–rime CVCVC words were correctly identified (mean accuracy = 10%). Two participants each recognised 6% of the CVCVC words, while three participants recognised 9%, 13%, and 16% of the CVCVC words respectively.

4.3.3 Summary

When the entire protocol was completed or when the symmetry training or recombinative generalisation training only was removed, participants demonstrated at least 94%, 88% (sound-to-symbol trained), 94% (symbol-to-sound trained), and 88% accuracy, respectively, in recognising the novel recombined onset–rime CVC words, and a mean of 92%, 88%, 95%, and 93% accuracy, respectively, in recognising the recombined onset–rime–rime words. The greatest number of errors in matching the recombined sound–symbol CVC and CVCVC words occurred when conditional discrimination training for the onset and rime sound-to-symbol relations was omitted. When the conditional discrimination training was removed, participants responded correctly to less than 16% of the CVC words, and the mean accuracy was 10% for the CVCVC words.

4.4 Discussion

The main finding to emerge from Experiment 2 was that the participants who did not receive symmetry training or recombinative generalisation training with the partly recombined onset–rime words were still able to identify a large proportion of the recombined onset–rime CVC and onset–rime–rime CVCVC words successfully. Indeed, the recombinative generalisation performance of these participants was comparable to the performance shown by participants who completed the complete protocol.

By contrast, recognition of the recombined words was not evident when participants had not undertaken conditional discrimination training. These findings support the critical importance of conditional discrimination training in facilitating the emergence of recombinative generalisation. In other words, it appears that the training established the sound–symbol relations for the onset and rimes, from which the recombined words could be recognised. These findings are thus entirely consistent with the view that learning how printed letters relate to sounds is essential for reading (Goswami, 2005; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2002; Snow & Juel, 2005).

An additional aim of Experiment 2 was to test the effectiveness of the protocol by changing the type of script used to train the sound–symbol relations. The recombinative generalisation performance of participants exposed to an alphabetic type script in Experiment 1 was very similar to the performance of the participants presented with a syllabic script in Experiment 2 (participants who completed the whole protocol, as well as participants who received no symmetry training or no recombinative generalisation training).

Overall then, the outcomes from Experiment 2 suggested that varying the type of script employed (i.e., from an alphabetic to a syllabic script) does not have a detrimental impact on recombinative generalisation.

As it remained, the data from Experiment 2 highlighted that potentially there were a number of superfluous stages in the protocol, such as the recombinative generalisation training with the non-combined onset–rime words, that could reasonably be removed from the procedure without impeding recombinative generalisation performance. For the subsequent adult experiments, the recombinative generalisation training was withdrawn from the protocol. However, the symmetry training was retained, even though the participants in Experiment 2 were capable of recognising the recombined words without symmetry training.

Why was the symmetry training maintained? Primarily because it served to provide participants with further reinforcement of the sound–symbol relations and it is this overall knowledge of such sound–symbol relations that the Experiment 2 data suggested was indispensable for successful recombinative generalisation to emerge (participants who received no conditional discrimination training recognised very few recombined words).

Experiments 1 and 2 indicated that the amended protocol was an effective tool in promoting recombinative generalisation skills in adult participants. In accordance with the findings from Experiment 2, the protocol was restructured slightly with the elimination of the recombinative generalisation training with the non-combined onset–rime words. Subsequently, a series of experiments to extend the use of the protocol in terms of supporting word recognition skills were carried out, the first of which is reported in Chapter 5.

Chapter Five

Experiments 3 and 4[1]: Progressing from Within-Unit Recombinative Generalisation to Across-Unit Recombinative Generalisation

5.1 Introduction

In Experiments 1 and 2 (e.g., see p. 68), the adult participants were tested with novel recombined onset–rime CVC words following explicit training with the onset and rime units. The trained consonants were always presented as the onsets at the beginning of the recombined words, and the vowel–consonant pairs trained as the rimes consistently occupied the medial and final positions of the recombined words. However, it remains to be seen if participants can extend and generalise what they have learned about the sound–symbol relations through completion of the training stages of the protocol in order to recognise recombined words assembled from derived (i.e., untaught) onsets and rimes.

Arguably this would be an important test of the effectiveness of the protocol. In early reading there are certain rimes that may occur more frequently within reading schemes. However it would be impractical, if not impossible, to directly teach beginning readers all of the rimes that they could potentially encounter. Once a subset of rimes is explicitly taught, it would be extremely advantageous if individuals could generalise their knowledge of the sound–symbol relations from the taught rimes to read novel words composed from new rimes that are essentially recombinations of the taught rimes. Demonstration of such generalisation is important as it is frequently the generalisation of responses to novel, untrained stimuli that provides an indication that an individual has

[1] Many thanks to Justé Koller for her assistance in collecting data for Experiment 4.

learned a concept - in this case, has ‘learned’ recombinative generalisation (see Sidman, Willson-Morris, & Kirk, 1986).

Experiment 3 was undertaken to explore if ‘across-unit’ recombinative generalisation was possible following training with the MTS protocol. The results from Experiments 1 and 2 highlighted that ‘within-unit’ recombinative generalisation was achievable following training with the protocol. However, it is unclear whether across-unit recombinative generalisation is possible.

An example of across-unit generalisation would be recognition of a word containing a derived onset and rime. If the onset /t/ and the rime /ap/ were directly trained, the recombined word /tap/ could potentially be identified. This would be an example of within-unit recombinative generalisation. Exchanging the /p/ from the rime /ap/ with the onset /t/ would produce the new derived rime - /at/, and the new derived onset - /p/. Recombined words may then be constructed from the derived onset and rime (e.g., /pat/) in a demonstration of across-unit recombinative generalisation.

As far as is known, Experiment 3 was one of the first studies to investigate the effectiveness of a MTS training protocol in facilitating across-unit recombinative generalisation in which the test words were not composed from explicitly taught units (i.e. trained onsets and rimes) but novel units (i.e. onsets and rimes derived from previously taught onsets and rimes). If across-unit generalisation is not evident following training and if participants cannot generalise their knowledge of sound–symbol relations to recognise recombined words, it may be that additional procedures need to be incorporated into the protocol to try and facilitate such generalisation.

As in Experiments 1 and 2, the first set of CVC words tested in Experiment 3 were formed from explicitly taught onsets (e.g., /s/, /y/) and rimes (e.g., /af/, /ek/) which were combined to form CVC words (e.g., /saf/, /yek/). This was the within-unit recombinative generalisation test.

An across-unit recombinative generalisation test was added to the protocol for Experiment 3 in which the CVC words presented were ‘derived’ words created from new untrained onsets and untrained rimes. For this test, the final consonants of the trained rimes (e.g., /f/ from /af/; /k/ from /ek/) were employed as untrained onsets (e.g., /f/, /k/), and the trained onsets (e.g., /s/, /y/) were joined to the vowels of the trained rimes (e.g., /a/ from /af/; /e/ from /ek/) to form untrained rimes (e.g., /as/, /ey/). The across-unit generalisation test entailed the presentation of CVC words constructed from the untrained onsets and untrained rimes (e.g., /kas/, /fey/).

Through altering the functions of the symbols and sounds, for example, a symbol employed as an onset now becomes part of a rime, the ‘interchangeability’ that is a key requirement of productive reading was incorporated and tested within the protocol.

5.2 Method

5.2.1 Participants

Ten literate adults (four men and six women) ranging in age from 19 to 28 years (median = 22 years) participated. Participants were generally sampled from a university student population. All participants had English as their first language, and verbally confirmed that they did not have any visual or auditory impairments.

5.2.2 Apparatus and Stimuli

All materials were identical to those employed in Experiment 1, apart from the addition of the untrained onset–untrained rime CVC words required for the across-unit recombinative generalisation test. As in Experiment 1, each consonant and each vowel sound was represented by one unique symbol.

The four onset sound–symbol pairs and four rime sound–symbol pairs trained in Experiment 1 were again employed in the conditional discrimination training stages. There was a slight modification to the onset sounds for Experiment 3, namely, the consonant sound /n/ used previously was replaced by the consonant sound /g/. All other consonant sounds (/t/, /s/, and /y/) remained unchanged. Thus, four trained onsets (/t/, /s/, /g/, /y/) and four trained rimes (/af/, /ek/, /im/, /ol/) were presented in Experiment 3.

Four new untrained onsets and four new untrained rimes were derived from the trained onsets and trained rimes for the across-unit recombinative generalisation test. Specifically, each of the final consonants from the trained rimes was employed as an untrained onset (/f/, /m/, /l/, /k/). Each of the trained onsets (/t/, /s/, /g/, /y/) was joined to one of the vowels contained within the trained rimes (/a/, /e/, /i/, /o/) to produce four untrained rimes (/as/, /ey/, /ig/, /ot/). Connecting the untrained onsets and untrained rimes yields untrained onset–untrained rime CVC words (e.g., /fas/, /mig/). The onset and rime sound–symbol pairs (trained and untrained) and examples of the recombined words presented in the within-unit and across-unit recombinative generalisation tests are shown in Table 5.1.

Table 5.1 The four trained onsets and rimes that were recombined to form the onset–rime CVC words presented in the within-unit recombinative generalisation test. Also shown, are the four untrained (derived) onsets and four untrained rimes that were recombined to form the untrained onset–untrained rime CVC words presented in the across-unit recombinative generalisation test.

		Within-unit recombinative generalisation test			Across-unit recombinative generalisation test
Trained onset symbol–sound pairs	Trained rime symbol–sound pairs	Recombined trained onset–trained rime CVC words	Untrained onset symbol–sound pairs	Untrained rime symbol–sound pairs	Recombined untrained onset–untrained rime CVC words
~ - /t/	□ » - /af/	□ » - /taf/ ~	□ - /f/	~ ♌ - /ot/	~ ♌ - /fot/ □
* - /s/	⌖ ♉ - /ek/	⌖ ♉ - /sek/ *	⌖ - /k/	* » - /as/	* » - /kas/ ⌖
❖ - /y/	₪ ♌ - /ol/	₪ ♌ - /yol/ ❖	₪ - /l/	❖ ♉ - /ey/	❖ ♉ - /ley/ ₪
♋ - /g/	⊙ ⊠ - /im/	⊙ ⊠ - /gim/ ♋	⊙ - /m/	♋ ⊠ - /ig/	♋ ⊠ - /mig/ ⊙

Note. All rime and onset–rime symbols were presented and read from bottom-to-top.

5.2.3 General Procedure

Participants completed the six-stage MTS protocol developed in Experiment 1 with some modifications made to the protocol. The order of stages, number and type of trials, and training criterion levels established for Experiment 1 remained the same.

Table 5.2 summarises the six-stage protocol completed in Experiment 3.

Table 5.2 The revised MTS protocol completed in Experiment 3. Examples of training and test stimuli are provided.

Revised MTS Protocol	*Stimuli Examples*
Onset sound-to-symbol conditional discrimination training	Four trained onsets /t/ - ~
Onset symbol-to-sound symmetry training	Four trained onsets ~ - /t/
Onset sound-to-symbol and symbol-to-sound mixed test	Four trained onsets /t/ - ~; ~ - /t/
Rime sound-to-symbol conditional discrimination training	Four trained rimes /af/ - □ »
Rime symbol-to-sound symmetry training	Four trained rimes □ - /af/ »
Rime sound-to-symbol and symbol-to-sound mixed test	Four trained rimes /af/ - □ ; □ - /af/ » »
Onset and rime sound-to-symbol revision training	Four trained onsets and four trained rimes /t/ - ~ ; /af/ - □ »
Onset and rime symbol-to-sound revision training	Four trained onsets and four trained rimes ~ - /t/ ; □ - /af/ »
Trained onset–trained rime CVC word sound-to-symbol recombinative generalisation test (within-unit recombinative generalisation test)	16 trained onset–trained rime words /taf/ - □ » ~
Trained onset–trained rime CVC word symbol-to-sound recombinative generalisation test (within-unit recombinative generalisation test)	16 trained onset–trained rime words □ - /taf/ » ~
Trained onset–trained rime–trained rime CVCVC word sound-to-symbol and symbol-to-sound recombinative generalisation test (within-unit recombinative generalisation test)	32 trained onset–trained rime–trained rime words ₪ - /tafol/ ♌ □ » ~
Untrained onset–untrained rime CVC word sound-to-symbol and symbol-to-sound recombinative generalisation test (across-unit recombinative generalisation test)	13 untrained onset–untrained rime words ~ - /fot/ ; /lig/ - ♋ ♌ ⊠ □ ₪

Alterations to the protocol were as follows. Firstly, based on the results from Experiment 2, the recombinative generalisation training in which participants were presented with partly recombined onset–rime CVC words prior to testing with fully combined onset–rime CVC words was removed from the protocol. One of the advantages of eliminating the recombinative generalisation training was that it reduced the length of time taken by participants to complete the protocol; thus potentially curtailing any fatigue effects. Despite the symmetry training also being identified as a redundant training component, the symmetry training was retained within the protocol in an attempt to instill and promote a thorough knowledge of the sound–symbol relations from which the recombined words were created.

Secondly, the final stage of the protocol was the newly added across-unit recombinative generalisation test. After completing the onset–rime–rime CVCVC word generalisation test, recognition of recombined untrained onset–untrained rime CVC words constructed from the four untrained onsets and four untrained rimes was examined in the across-unit recombinative generalisation test.

For the across-unit test, the four untrained onsets (/f/, /m/, /l/, /k/) were joined to each of the four untrained rimes (/as/, /ey/, /ig/, /ot/) to form 16 untrained onset–untrained rime CVC words (e.g., /mas/, /mey/, /mig/, /mot/, /fas/, /fey/ etc.,). Of the 16 possible untrained onset–untrained rime words, three of the combinations were actual words (/key/, /fig/, /lot/). These three words were deleted from the potential test words. Recognition of each of the remaining 13 untrained onset–untrained rime CVC words was tested in the final across-unit recombinative generalisation test. In total, 16 generalisation test trials were presented in a quasi-random order; eight sound-to-symbol and eight symbol-to-sound test trials. Of the available 13 untrained onset–untrained rime CVC words, three of the words appeared twice as samples, once in the sound-to-symbol test trials, and once in the symbol-to-sound test trials. The other ten untrained onset–untrained rime words were randomly assigned to appear as samples in either the sound-to-symbol test trials or the symbol-to-sound test trials.

In each test trial, the three distractor comparison sounds or symbols were constructed as in Experiment 1 (please see Chapter 2, p. 43). Once participants had completed the single block of 16 generalisation test trials, the end of experiment screen was displayed on screen and debriefing followed.

5.3 Results

5.3.1 Training stages

Table 5.3 presents the number of trials completed to reach criterion across the training stages. As shown in Table 5.3, all ten participants successfully completed the three training stages. For the onset sound-to-symbol conditional discrimination training, the mean number of trials completed before achieving the criterion was 52 (range, 30 to 78). Eight participants passed the onset symbol-to-sound symmetry training within one block of trials. Two participants required two blocks and three blocks respectively, to complete the onset symbol-to-sound symmetry training. All ten participants passed the mixed onset test trials at their first attempt.

On average, 43 training trials were completed to reach criterion for the rime sound-to-symbol conditional discrimination training (range, 30 to 78). All ten participants passed the rime symbol-to-sound symmetry training and mixed rime test trials within one block of trials. Likewise, the onset and rime revision training stages were passed at the first attempt.

Table 5.3 Number of trials completed to reach criterion across the three training stages. The percentage of correct responses for each stage is shown in parentheses.

Participant	Onset sound-to-symbol training	Onset symbol-to-sound training	Onset mixed test	Rime sound-to-symbol training	Rime symbol-to-sound training	Rime mixed test	Onset and rime sound-to-symbol training	Onset and rime symbol-to-sound training
1	48 (69)	14(100)	16(100)	78 (65)	14(100)	16(100)	31 (97)	30(100)
2	64 (66)	30 (91)	15 (94)	30(72)	15 (94)	16(100)	30(100)	30(100)
3	30 (88)	14(100)	16(100)	30 (78)	14(100)	16(100)	30(100)	30(100)
4	48 (52)	14(100)	16(100)	46 (63)	14(100)	16(100)	30(100)	30(100)
5	48 (48)	15 (94)	16(100)	62 (67)	16 (88)	16(100)	30(100)	30(100)
6	48 (58)	47 (69)	16(100)	46 (65)	14(100)	16(100)	30(100)	32 (94)
7	78 (53)	14(100)	16(100)	32 (81)	14(100)	16(100)	30(100)	30(100)
8	46 (75)	14(100)	16(100)	32 (72)	14(100)	16(100)	31 (97)	30(100)
9	62 (67)	15 (94)	16(100)	46 (69)	14(100)	16(100)	30(100)	30(100)
10	46 (71)	14(100)	16(100)	32 (69)	14(100)	16(100)	30(100)	31 (97)

5.3.2 Recombinative generalisation tests

Table 5.4 shows the number of correct responses for the within-unit and across-unit recombinative generalisation tests for each participant.

5.3.2.1 Within-unit recombinative generalisation tests

The within-unit test examined how accurately the participants could recognise CVC words composed from trained onsets and trained rimes. For the trained onset–trained rime CVC word sound-to-symbol test, mean accuracy was 97% (range, 88% to 100%). As shown in Table 5.4, four of the ten participants demonstrated 100% accuracy in matching the trained onset–trained rime CVC sounds to the corresponding symbols.

Table 5.4 Number of correct responses on the recombinative generalisation tests. Percentage of correct responses is shown in parentheses.

	Within-unit recombinative generalisation test			Across-unit recombinative generalisation test
Participant	Trained onset–trained rime CVC word sound-to-symbol test correct / 32	Trained onset–trained rime CVC word symbol-to-sound test correct / 32	Trained onset–trained rime–trained rime CVCVC word sound-to-symbol and symbol-to-sound test correct / 32	Untrained onset–untrained rime CVC word sound-to-symbol and symbol-to-sound test correct / 13
1	32 (100)	32 (100)	32 (100)	8 (62)
2	30 (94)	32 (100)	32 (100)	6 (46)
3	32 (100)	32 (100)	32 (100)	11 (85)
4	32 (100)	32 (100)	32 (100)	12 (92)
5	31 (97)	31 (97)	31 (97)	12 (92)
6	28 (88)	32 (100)	31 (97)	8 (62)
7	32 (100)	32 (100)	32 (100)	13 (100)
8	31 (97)	32 (100)	31 (97)	8 (62)
9	31 (97)	31 (97)	30 (94)	10 (77)
10	31 (97)	32 (100)	32 (100)	11 (85)

Note. The values listed for the trained onset–trained rime–trained rime test are the number of recombined CVCVC words correctly identified. Likewise, the values in the untrained onset–untrained rime test are the number of untrained onset–untrained rime CVC words correctly identified.

Mean accuracy was 99% (range, 97% to 100%) for the trained onset–trained rime CVC word symbol-to-sound test. Apart from two participants who demonstrated 97% accuracy, all of the participants responded correctly to all 32 test trials, and could successfully match all of the trained onset–trained rime symbol sequences presented to their associated CVC sounds.

For the final within-unit recombinative generalisation test, participants were tested with the more complex trained onset–trained rime–trained rime CVCVC words. Mean accuracy in recognising the CVCVC words was 99% (range, 94% to 100%). Generally, the participants were highly accurate in matching the CVCVC sounds and symbols, with six participants correctly identifying all of the trained onset–trained rime–trained rime words presented.

5.3.2.2 Across-unit recombinative generalisation test

The across-unit test was the new test incorporated into the protocol to assess whether participants could recognise recombined words created from derived (i.e., untrained) as opposed to explicitly trained onsets and rimes. In the training stages, participants learned four onset and four rime sound–symbol relations. These trained onsets and rimes were combined to form CVC and CVCVC words for the first within-unit recombinative generalisation tests. However, for the final recombinative generalisation test, recognition of recombined CVC words constructed from new untrained onsets and new untrained rimes was examined as a test of across-unit recombinative generalisation.

As can be seen from Table 5.4, most of the participants were generally accurate in recognising the untrained onset–untrained rime CVC words. The mean accuracy was 76%, (range, 46% to 100%). Of the 13 untrained onset–untrained rime CVC words presented, on average, participants correctly identified 10 of the 13 CVC words.

5.3.3 Summary

Figure 5.1 shows the mean accuracy on the within-unit and across-unit recombinative generalisation tests.

The ten participants all passed the three training stages and no retraining was necessary for any of the participants.

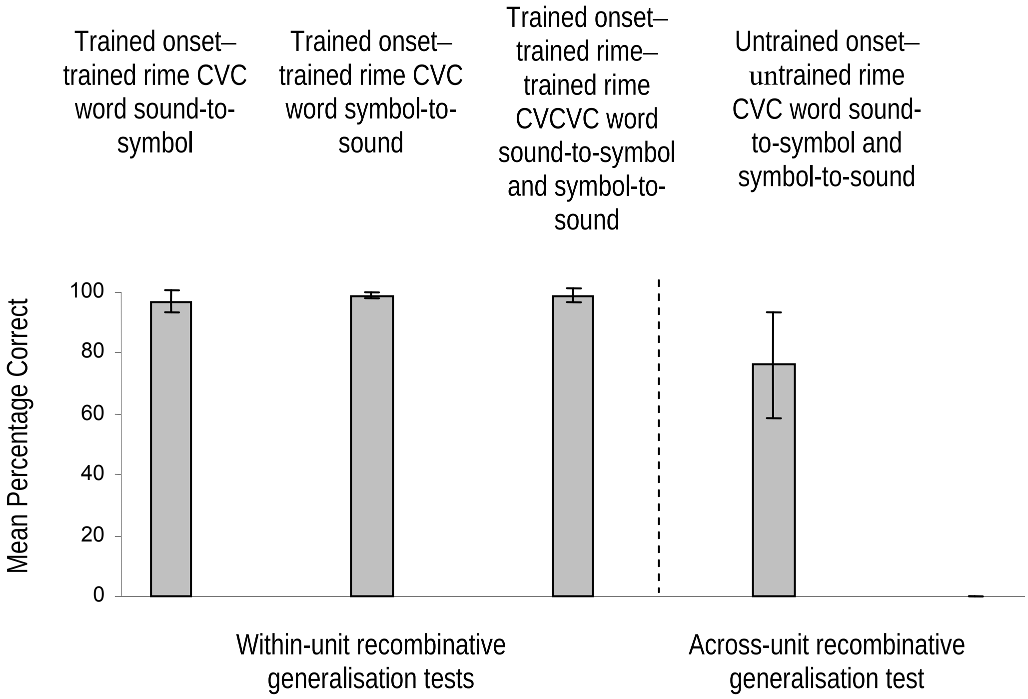


Figure 5.1 Mean percentage correct for the within-unit and across-unit recombinative generalisation tests. Error lines representing standard deviation are shown for each bar.

Participants were highly accurate in matching the associated sounds and symbols for the recombined CVC words composed from trained onsets and trained rimes. On average, participants responded correctly to 97% and 99% of the test trials in the trained onset–trained rime CVC word sound-to-symbol test and trained onset–trained rime CVC word symbol-to-sound test, respectively. Additionally, the participants were capable of recognising at least 94% of the trained onset–trained rime–trained rime CVCVC words, with six participants demonstrating 100% accuracy. These results highlight the effectiveness of the MTS protocol in facilitating within-unit recombinative generalisation.

The participants were less accurate in recognising the novel CVC words formed from derived, untrained onsets and untrained rimes. The mean accuracy for the across-unit recombinative generalisation test was 76%. In all, at least 62% accuracy was shown by the participants when responding to the untrained onset–untrained rime CVC words, with the exception of one participant who demonstrated 46% accuracy.

5.4 Discussion

As in Experiments 1 and 2, after successfully completing the training stages, all of the participants were proficient in recognising the recombined words composed from the trained onsets and rimes. These results, therefore, provided further evidence in support of the effectiveness of the MTS protocol in facilitating within-unit recombinative generalisation. Essentially, when the novel words are 'direct' combinations of specifically taught onsets and rimes (i.e., separately trained onsets are joined to separately trained rimes to form the test words), participants are highly accurate in recognising this particular type of word.

Unique to Experiment 3 was the inclusion of an across-unit recombinative generalisation test. After presenting participants with CVC words that could be directly linked back to the previous onset and rime training (i.e., explicitly trained onset–trained rime CVC words), participants encountered recombined words composed from entirely new onsets and rimes. These onsets and rimes were untrained, but were derived from the previously trained onsets and rimes. Despite receiving no training or exposure to the new onsets and rimes, the participants were able to recognise some of the untrained onset–untrained rime CVC words, with some participants more accurate in recognising these words than others.

Although the participants were less accurate in recognising the untrained onset–untrained rime CVC words compared to the trained onset–trained rime CVC words, it is nonetheless impressive that the participants could correctly identify a proportion of these derived words containing unfamiliar onsets and rimes.

As far as is known, this was one of the first experiments to examine across-unit recombinative generalisation within the context of an MTS protocol. The findings from this study were promising as it appeared that across-unit recombinative generalisation did seem to be possible following completion of the training stages. It seems that the participants in Experiment 3 were able to use their knowledge of the sound–symbol relations established in the training stages to recognise novel words that still contained these sounds and symbols but in different sequences to those that were initially trained. Such ‘interchangeability’ between letters and sounds, and the ability to recognise letters and sounds in different positions or sequences across words, is an important aspect of reading (see Perfetti, 1991).

Participants in Experiment 3 completed the within-unit tests and proceeded immediately to the across-unit test. Perhaps the transition from presentation of words that stemmed directly from previous training (i.e., words that were direct combinations of taught onsets and rimes) to words that were far removed from the training in terms of utilising unknown onsets and rimes was too unusual and difficult for the participants. Consequentially, this may have affected their performance by reducing accuracy in recognising the untrained onset–untrained rime words. Hence, this raised the question as to whether the protocol could be modified to facilitate performance on the across-unit test and to improve recognition of the untrained onset–untrained rime words. To address this issue, Experiment 4 was undertaken with the aim of enhancing recognition of the derived, across-unit words.

Experiment 4: Facilitating Across-Unit Recombinative Generalisation Performance

5.5 Introduction

The results from Experiment 3 highlighted that the six-stage MTS protocol seemed to be extremely effective in promoting within-unit recombinative generalisation. Although the participants were capable of recognising some of the across-unit derived words, it would be advantageous if recognition of such derived words could be enhanced without the need for explicit training with each of the derived onset and rime units. Such additional training would be problematic, firstly, as it would considerably lengthen the time taken by participants to complete the protocol. Secondly, any specific training with the derived onsets and rimes would prevent assessing if participants can generalise and extend their sound–symbol knowledge to identify words containing these sounds and symbols arranged in different combinations. Furthermore, based on the performance of participants in Experiments 1 and 2, it is highly likely that given conditional discrimination training with the derived onsets and rimes, the participants would encounter little difficulties in accurately identifying the untrained onset–untrained rime words.

One suggestion introduced earlier was that the participants may have found the progression from recombined words, the sub-word components of which could be traced back to their training, to recombined words containing new sub-word components, too challenging. Perhaps what is needed is an intermediate stage between testing with previously trained onsets and rimes and testing with derived onsets and rimes.

For the across-unit test in Experiment 3, the recombined words utilised new onsets (the final consonants of the trained rimes functioned as the untrained onsets) and new rimes (the previously trained onsets were joined to the vowel sounds to produce the untrained rimes). A simpler test of across-unit recombinative generalisation would be to test recognition of recombined words that employ new onsets *or* new rimes, rather than new onsets *and* new rimes. Such a test would still examine if the participants can extend their sound–symbol knowledge to recognise derived words, and would model the 'interchangeability' of letters and sounds within words. It was anticipated that the addition of the intermediate stage would make the transition from within-unit testing to across-unit testing a more logical advancement through gradually increasing the complexity of testing.

For Experiment 4, such an intermediate across-unit test was added to the protocol. After the within-unit tests, an intermediate across-unit test was attempted in which participants were presented with partly derived CVC words formed from trained onsets joined to new untrained rimes. The untrained rimes were ascertained by changing the final consonants across the trained rimes. Following completion of the intermediate across-unit test, the participants attempted the more advanced across-unit test with untrained onsets and rimes developed in Experiment 3.

Thus, Experiment 4 sought to determine if prior exposure to recombined words constructed from partly derived onsets and rimes was of any benefit to recognition performance when presented with fully derived untrained onset–untrained rime CVC words.

5.6 Method

5.6.1 Participants

Ten literate adults who had not participated in the previous experiment volunteered to take part. The five men and five women ranged in age from 18 years to 26 years (median = 19 years). All participants spoke English as their first language and verified that they had no visual or auditory impairments.

5.6.2 Apparatus and Stimuli

Apart from the new test stimuli required for the intermediate across-unit test stage, the materials required for Experiment 4 were identical to those described in Experiment 3 (please refer to section 5.2.2). The four consonant trained onset sounds (/t/, /s/, /g/, /y/), and the four trained rime sounds (/af/, /ek/, /im/, /ol/), that were separately trained and joined together for the within-unit tests to form the trained onset–trained rime CVC and CVCVC words remained the same. Note that the four trained rime units employed for the within-unit tests were fixed; each vowel sound was always joined to one particular end consonant sound.

Likewise, the untrained onsets (/f/, /m/, /l/, /k/) and untrained rimes (/as/, /ey/, /ig/, /ot/) that were combined to create the untrained onset–untrained rime CVC words (e.g. /kig/, /las/) for the final across-unit test were unchanged.

For the preceding intermediate across-unit test, the recombined CVC words were formed from the trained onsets (/t/, /s/, /g/, /y/) but new rimes. These new rimes were derived from the four trained rime units (/af/, /ek/, /im/, /ol/). The four final consonants of these four trained rimes (/f/, /k/, /l/, /m/) were each joined to the four vowels (/a/, /e/, /i/, /o/) to form new rime combinations (e.g., /ak/, /al/, /am/). The new rimes were blended with each of the four trained onsets to provide the partly derived trained onset–untrained rime CVC words for the intermediate across-unit test (e.g., /gak/, /yal/, /tam/).

Table 5.5 provides examples of the training and test stimuli employed throughout Experiment 4.

Table 5.5 The four trained onsets and four trained rimes used to form the recombined CVC and CVCVC words presented in the within-unit recombinative generalisation tests. Examples of the untrained rimes used to form the trained onset–untrained rime CVC words presented in the intermediate across-unit test are also shown, alongside examples of the untrained onset–untrained rime CVC words tested in the advanced across-unit test.

		Within-unit recombinative generalisation test		Intermediate across-unit recombinative generalisation test	Advanced across-unit recombinative generalisation test
Trained onset symbol–sound pairs	Trained rime symbol–sound pairs	Recombined trained onset–trained rime CVC words	Untrained partly derived rime symbol–sound pairs	Recombined partly derived trained onset–untrained rime CVC words	Recombined untrained onset–untrained rime CVC words
∼ - /t/	□ » - /af/	□ » - /taf/ ∼	⊙ » - /am/	⊙ » - /tam/ ∼	∼ ஐ - /fot/ □
* - /s/	⌖ ♉ - /ek/	⌖ ♉ - /sek/ *	□ ♉ - /ef/	□ ♉ - /sef/ *	* » - /kas/ ⌖
❖ - /y/	₪ ஐ - /ol/	₪ ஐ - /yol/ ❖	⌖ ஐ - /ok/	⌖ ஐ - /gok/ ♋	❖ ♉ - /ley/ ₪
♋ - /g/	⊙ ⌘ - /im/	⊙ ⌘ - /gim/ ♋	₪ ⌘ - /il/	₪ ⌘ - /yil/ ❖	♋ ⌘ - /mig/ ⊙

Note. All rime and onset–rime symbols were presented and read from bottom-to-top.

5.6.3 General Procedure

For Experiment 4, the intermediate across-unit test was added to the MTS protocol completed in Experiment 3. Aside from the inclusion of the intermediate across-unit test, the number and format of the trials, criterion levels to progress to the next stage of the protocol etc., remained unchanged from Experiment 3. The revised protocol completed in Experiment 4 may be viewed in Table 5.6.

Table 5.6 The MTS protocol completed in Experiment 4.

Revised MTS Protocol	*Stimuli*	*Examples*
Onset sound-to-symbol conditional discrimination training	Four trained onsets	/t/ - ~
Onset symbol-to-sound symmetry training	Four trained onsets	~ - /t/
Onset sound-to-symbol and symbol-to-sound mixed test	Four trained onsets	/t/ - ~ ; ~ - /t/
Rime sound-to-symbol conditional discrimination training	Four trained rimes	/af/ - □ »
Rime symbol-to-sound symmetry training	Four trained rimes	□ - /af/ »
Rime sound-to-symbol and symbol-to-sound mixed test	Four trained rimes	/af/ - □ ; □ - /af/ » »
Onset and rime sound-to-symbol revision training	Four trained onsets and trained rimes	/t/ - ~ ; /af/ - □ »
Onset and rime symbol-to-sound revision training	Four trained onsets and trained rimes	~ - /t/ ; □ - /af/ »
Trained onset–trained rime CVC word sound-to-symbol recombinative generalisation test (within-unit recombinative generalisation test)	16 trained onset–trained rime words	/taf/ - □ » ~
Trained onset–trained rime CVC word symbol-to-sound recombinative generalisation test (within-unit recombinative generalisation test)	16 trained onset–trained rime words	□ - /taf/ » ~
Trained onset–trained rime–trained rime CVCVC word sound-to-symbol and symbol-to-sound recombinative generalisation test (within-unit recombinative generalisation test)	32 trained onset–trained rime–trained rime words	₪ - /tafol/ ꝏ □ » ~
Trained onset–partly derived rime CVC word sound-to-symbol recombinative generalisation test (intermediate across-unit recombinative generalisation test)	22 trained onset–partly derived rime CVC words	/tef/ - □ ♉ ~
Trained onset–partly derived rime CVC word symbol-to-sound recombinative generalisation test (intermediate across-unit recombinative generalisation test)	22 trained onset–partly derived rime CVC words	□ - /sef/ ♉ *
Untrained onset–untrained rime CVC word sound-to-symbol and symbol-to-sound recombinative generalisation test (advanced across-unit recombinative generalisation test)	13 untrained onset–untrained rime CVC words	~ - /fot/; /lig/ - ♋ ꝏ ⊠ □ ₪

After completing the within-unit trained onset–trained rime–trained rime CVCVC word recombinative generalisation test, participants proceeded to the intermediate across- unit test which consisted of testing with the partly derived, trained onset–untrained rime CVC words, prior to testing with the untrained onset–untrained rime CVC words.

The partly derived trained onset–untrained rime words were formed as follows. Each of the trained onsets (/t/, /s/, /g/, /y/) was joined to each of the following vowel sounds (/a/, /e/, /i/, /o/) to form the initial trained onset–vowel sequence of the test words (e.g., /ta/, /te/, /ti/, /to/, /sa/, /se/, /si/, /so/, etc.,). The four final consonant sounds taken from the four trained rimes (/af/-/f/, /ek/-/k/, /ol/-/l/, /im/-/m/) were each joined to the initial trained onset–vowel sequences (e.g., /taf/, /tak/, /tal/, /tam/, /tef/, /tek/, /tel/, /tem/ etc.,). Eliminating the four trained rimes (e.g., /af/, /ek/, /im/, /ol/) from the word set, there were twelve untrained rimes, each of which was joined to each of the four trained onsets. In total, there were 48 possible trained onset–untrained rime CVC words. Excluding any test items that were actual words (e.g., /gal/, /yam/), 44 test words remained.

For the intermediate across-unit test, participants completed 22 sound-to-symbol test trials, followed by 22 symbol-to-sound test trials, testing recognition of all 44 trained onset–untrained rime CVC words. Trials were presented in a quasi-random order. On- screen instructions presented at the start of each 22-trial test block reminded the participants to try and remember all of the sounds and symbols previously trained.

As far as possible, the four available recombined words for each untrained rime (e.g., /tef/, /sef/, /gef/, /yef/) were evenly split between the sound-to-symbol and the symbol-to-sound 22-trial test blocks. For example, the words /tef/ and /yef/ appeared as the samples in the sound-to-symbol test trials, while the words /sef/ and /gef/ were presented as samples in the symbol-to-sound test trials. Similarly, care was taken in the organisation of test trials to ensure that approximately a quarter of the test trials utilised sample words that began with each of the four trained onsets.

Formulation of the incorrect comparisons for each trained onset–untrained rime CVC word sample was slightly different from previous experiments. All three incorrect comparisons shared the same onset as the sample (e.g., /sel/). One incorrect comparison shared the same vowel as the sample but a different end consonant (e.g., /sef/). Another incorrect comparison shared the same end consonant as the sample but a different vowel (e.g., /sil/). A third incorrect comparison was a combination of the vowel and final consonant obtained from the other two incorrect comparisons (e.g., /sif).

Once participants had completed the trained onset–untrained rime CVC word symbol-to-sound generalisation test, they advanced to the final across-unit test with the untrained onset–untrained rime CVC words.

5.7 Results

5.7.1 Training stages

As shown in Table 5.7, none of the participants encountered any difficulties in passing the three training stages. The mean number of training trials completed to reach criterion in the onset sound-to-symbol conditional discrimination training was 77, (range, 16 to 176). All participants passed the onset symbol-to-sound symmetry training within one block of trials. All ten participants showed 100% accuracy to pass the mixed onset test at their first attempt.

Table 5.7 Number of trials completed by participants in Experiment 4 to reach criterion across the training stages. The percentage of correct responses for each stage is shown in parentheses.

Participant	Onset sound-to-symbol training	Onset symbol-to-sound training	Onset mixed test correct/16	Rime sound-to-symbol training	Rime symbol-to-sound training	Rime mixed test correct/16	Onset and rime sound-to-symbol revision	Onset and rime symbol-to-sound revision
11	48 (81)	15 (94)	16 (100)	30(72)	14 (100)	16 (100)	30(100)	30(100)
12	78 (64)	14(100)	16 (100)	32 (88)	16 (88)	16 (100)	32 (97)	32 (97)
13	48 (77)	14(100)	16 (100)	32 (81)	14 (100)	16 (100	32 (97)	30(100)
14	158(53)	15 (94)	16 (100)	80 (68)	14 (100)	16 (100)	32 (97)	32 (97)
15	16 (88)	14(100)	16 (100)	30 (84)	14 (100)	16 (100)	30(100)	30(100)
16	94 (64)	15 (94)	16 (100)	16 (88)	14 (100)	16 (100)	31 (97)	30(100)
17	176(50)	14(100)	16 (100)	32(75), 15 (94)	14(100), 14(100)	13 (81), 16 (100)	31 (97)	30(100)
18	48 (73)	14(100)	16 (100)	32 (75)	15 (94)	16 (100)	30(100)	31 (97)
19	62 (70)	14(100)	16 (100)	30 (84)	14 (100)	16 (100)	31 (97)	30(100)
20	46 (83)	14(100)	16 (100)	32 (78)	14 (100)	16 (100)	30(100)	30(100)

Note. Where two values are listed and separated by commas, this indicates that retraining was required.

On average, 35 training trials were required to fulfill the criterion for the rime sound-to-symbol training (range, 16 to 80). The rime symbol-to-sound training was passed by all participants within one block. As can be seen from Table 5.7, apart from Participant 17 who required retraining with the rime sound–symbol relations, the other participants all demonstrated 100% accuracy to pass the mixed rime test.

All ten participants passed the two onset and rime revision training stages, each within one block of trials.

5.7.2 Recombinative generalisation tests

Table 5.8 presents the number of test trials correctly responded to, and percentage accuracy for each participant for all of the recombinative generalisation tests.

Table 5.8 Number of correct responses on the recombinative generalisation tests. Percentage of correct responses is shown in parentheses.

	Within-unit recombinative generalisation tests			Intermediate across-unit recombinative generalisation test		Advanced across-unit recombinative generalisation test
Participant	Trained onset–trained rime CVC word sound-to-symbol correct/32	Trained onset–trained rime CVC word symbol-to-sound correct/32	Trained onset–trained rime–trained rime CVCVC mixed test correct/32	Trained onset–untrained rime CVC word sound-to-symbol correct/22	Trained onset–untrained rime CVC word symbol-to-sound correct/22	Untrained onset–untrained rime CVC word sound-to-symbol and symbol-to-sound correct/13
11	30 (94)	30 (94)	28 (88)	15 (68)	16 (73)	11 (85)
12	30 (94)	32 (100)	31 (97)	17 (77)	18 (82)	11 (85)
13	31 (97)	32 (100)	31 (97)	22 (100)	22 (100)	13 (100)
14	31 (97)	30 (94)	31 (97)	15 (68)	14 (64)	13 (100)
15	32 (100)	32 (100)	32 (100)	17 (77)	20 (91)	11 (85)
16	25 (78)	30 (94)	23 (72)	3 (14)	11 (50)	1 (7)
17	32 (100)	31 (97)	31 (97)	20 (91)	16 (73)	11 (85)
18	32 (100)	32 (100)	31 (97)	18 (82)	20 (91)	11 (85)
19	31 (97)	32 (100)	32 (100)	21 (96)	21 (96)	12 (92)
20	31 (97)	31 (97)	31 (97)	19 (87)	20 (91)	12 (92)

Note. The values in the third column are the number of trained onset–trained rime–trained rime CVCVC words correctly identified. The values in the fourth and fifth columns are the number of recombined partly derived trained onset–untrained rime CVC words correctly identified. The values in the final column are the number of untrained onset–untrained rime CVC words correctly recognised.

5.7.2.1 Within-unit recombinative generalisation tests

As shown in Table 5.8, accuracy was high in both the trained onset–trained rime CVC word sound-to-symbol and symbol-to-sound tests. Mean accuracy was 95% (range, 78% to 100%), and 98% (range, 94% to 100%) for these tests respectively.

Overall, the participants were also highly accurate in identifying the trained onset–trained rime–trained rime CVCVC words. A mean accuracy of 94% (range, 72% to 100%) was shown in matching the CVCVC recombined sounds and symbols.

5.7.2.2 Across-unit recombinative generalisation tests

5.7.2.2.1 Intermediate across-unit test

Recognition of 44 different trained onset–untrained rime CVC words was examined. Of the 22 trained onset–untrained rime CVC words presented in each test block, the mean number of trained onset–untrained rime CVC words correctly identified was 17 in the sound-to-symbol test (range, 3 to 22), and 18 in the symbol-to-sound test (range, 11 to 22). Noticeably, the range of words recognised in the sound-to-symbol test is large. One participant (Participant 16) recognised just three trained onset–untrained rime CVC words in the sound-to-symbol test. However, as shown in Table 5.8, Participant 16 identified the smallest number of recombined words in all of the recombinative generalisation tests.

In all, accuracy in recognising the trained onset–untrained rime CVC words was generally high. The mean accuracy was 76% (range, 14% to 100%) in the sound-to-symbol test trials, and 81% (range, 50% to 100%) in the symbol-to-sound test trials. Thus, with the exception of Participant 16, all participants successfully recognised at least 68% (sound-to-symbol test) and 64% (symbol-to-sound test) of the trained onset–untrained rime CVC words presented in the two intermediate across-unit tests.

5.7.2.2.2 Advanced across-unit test

Most of the participants successfully identified a high number of the 13 untrained onset–untrained rime CVC words. Nine participants accurately recognised between 11 and 13 of the untrained onset–untrained rime CVC words presented (mean = 11 words). The smallest number of untrained onset–untrained rime CVC words recognised was one word (Participant 16).

Overall, the mean accuracy shown by participants for the advanced across-unit test was 82%. When matching the untrained onset–untrained rime sounds and symbols, one participant recorded 7% accuracy, five participants achieved 85% accuracy, two participants showed 92% accuracy, and two participants demonstrated 100% accuracy.

5.7.3 Summary

All participants completed the training stages and were highly accurate in recognising the within-unit trained onset–trained rime CVC words. For the across-unit tests, on average, the participants accurately recognised 79% of the partly derived trained onset–untrained rime CVC words presented in the intermediate across-unit tests, and recognised an average of 82% of the fully derived untrained onset–untrained rime CVC words presented in the advanced across-unit test.

When comparing the advanced across-unit test performance of participants in Expeirments 3 and 4, it is evident that the participants in Experiment 4 who completed the intermediate across-unit tests were slightly more accurate in recognising the recombined untrained onset–untrained rime CVC words (mean accuracy = 82%) than participants in Experiment 3 who did not complete the intermediate across-unit tests (mean accuracy = 76%).

Figure 5.2 shows the recombinative generalisation test performance of the participants from Experiments 3 and 4.

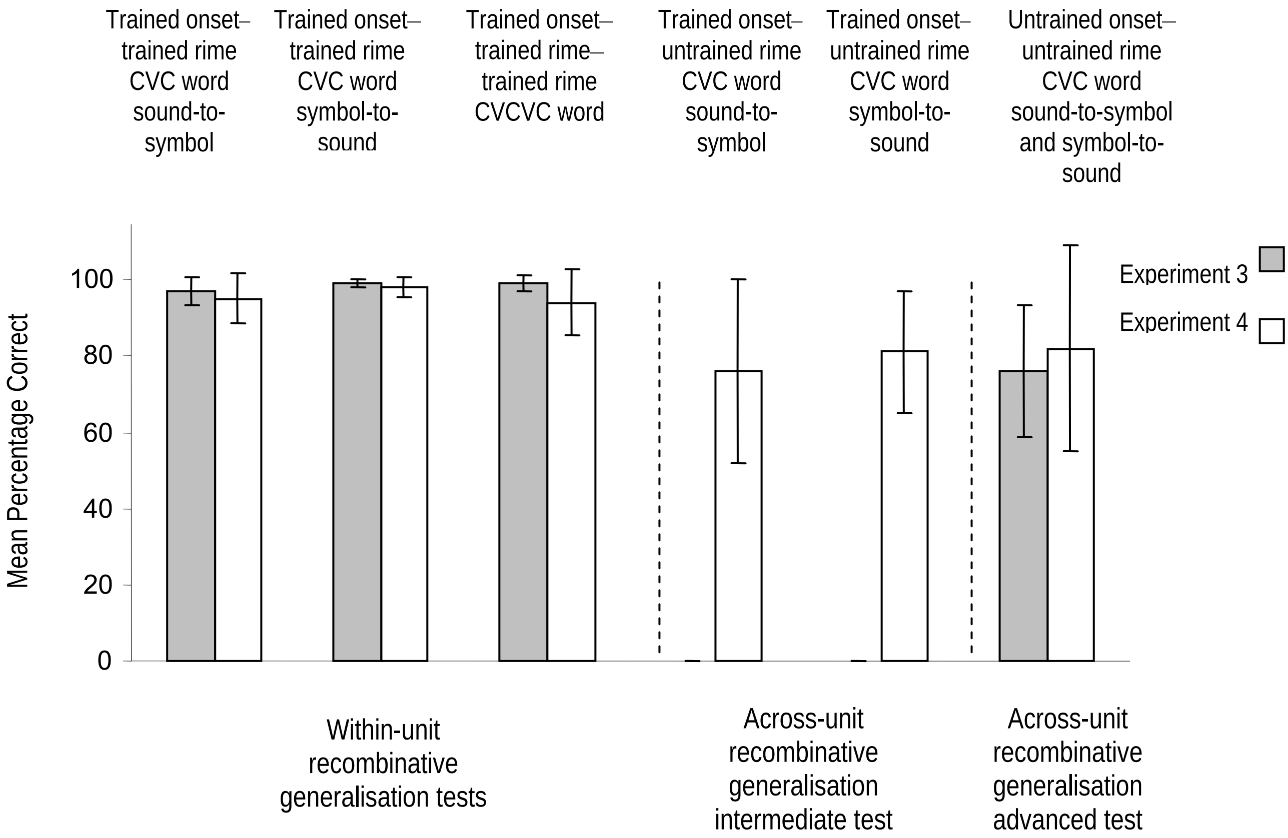


Figure 5.2 Mean percentage correct for the within-unit recombinative generalisation tests, the intermediate across-unit recombinative generalisation tests, and the advanced across-unit recombinative generalisation test. The grey bars show mean percentage correct for Experiment 3 participants. The white bars indicate mean percentage correct for Experiment 4 participants who were the only participants to complete the intermediate across-unit tests. Error bars representing standard deviation are shown for each bar.

5.8 Discussion

After examining the across-unit recombinative generalisation performance of participants in Experiment 3, an additional 'intermediate' across-unit test was added to the MTS protocol with the aim of facilitating recognition of the recombined words composed from derived, untrained onset and rime units. Prior to attempting the more complex across-unit generalisation test with the untrained onset–untrained rime CVC words (completed by participants in Experiment 3), participants in Experiment 4 were exposed to partly derived, trained onset–untrained rime CVC words in the intermediate across-unit generalisation test.

The participants in Experiment 4 who completed the intermediate across-unit test showed a small increase in the percentage of untrained onset–untrained rime words accurately recognised (mean accuracy = 82%) compared to the participants in Experiment 3 (mean accuracy = 76%).

Based on these findings, the benefits of the intermediate test in enhancing across-unit recombinative generalisation are questionable as the difference between the average performance of participants who did and did not experience the additional testing procedures is negligible. In the absence of prior exposure to words that utilised explicitly trained onsets alongside new, untrained rimes, the participants in Experiment 3 were still capable of recognising a large proportion of the untrained onset–untrained rime CVC words.

Through their pre-experimental reading experiences, the adults in Experiments 3 and 4 would be accustomed to recognising and sounding out letters in various word positions. Perhaps this may have contributed to their performance in the advanced across-unit test and lessened the need for additional preparatory testing with simpler trained onset–untrained rime recombined words. Nevertheless, the participants in Experiment 4 did show an improvement in across-unit recombinative generalisation performance after completing the intermediate across-unit test, albeit a small improvement.

It may well be that such an intermediate across-unit test would be more beneficial if used with truly beginning readers of English who may not be proficient at ‘rearranging’ acquired letter–sound relations to decipher unfamiliar words, an activity that the literate adults participating in the current experiments are skilled at.

In the intermediate across-unit test, only the final consonant symbol or sound was manipulated to form words containing known onsets but new rimes. According to

McCandliss et al. (2003), altering one letter or sound within a previously acquired word might help to convey to beginning readers that letters and sounds can be rearranged within words. Thus, the intermediate across-unit test might be more advantageous for beginning readers in drawing their attention to the concept of exchanging letters and sounds across words. Reading interventions that have employed techniques encouraging children to focus on individual letters and letter positions within words (i.e., initial, medial, final letter positions) have been associated with gains in decoding ability, word naming, and recognition of unfamiliar words containing known letter–sound associations (see Christensen and Bowey, 2005).

To summarise, the results from Experiment 4 suggested that completion of the intermediate across-unit test for the adult participants at least, did not seem to make a substantial contribution to improving across-unit recombinative generalisation performance. Critically though, the data from Experiments 3 and 4, did indicate that the MTS protocol appeared to be effective in fostering across-unit recombinative generalisation. According to Noell, Connell, and Duhon (2006), "in order for students to become literate they must exhibit response and stimulus generalisations that far exceed the originally taught relationships" (p. 122). Participants in these two studies could recognise words composed from derived, untrained units and seemed capable of extending and generalising their knowledge of the taught sound–symbol relations to identify words created from rearrangements of these sound–symbol patterns. These are encouraging findings that highlight the potential usefulness of the MTS protocol as a tool to promote generative word recognition (i.e., facilitating the identification of unfamiliar words).

The four experiments conducted so far have tested recognition of words arranged in CVC structures. Beginning readers typically progress from reading CVC words to reading words in various consonant and vowel formations. In the next experiment, the effectiveness of the protocol in facilitating across-unit recombinative generalisation will be further examined in regards to the reading of consonant blend words.

Chapter Six

Experiment 5: Testing Recognition of Consonant Blend Words

6.1 Introduction

In the previous experiments, although the length of test words and type of recombinative generalisation investigated have varied (e.g., monosyllable versus polysyllable recombined words, within-unit versus across-unit generalisation), the recombined words presented have consistently adhered to consonant–vowel formations. Single consonants have been employed as the initial sound in all test words given the prevalence of CVC word combinations typically presented to beginning readers (see Snow, Scarborough, & Burns, 1999).

However, learning to read requires that beginning readers encounter an assortment of words in various consonant–vowel structures. Guidelines for the English Primary School Curriculum (1999) published by the Department of Education and Science state that classroom instruction should be tailored to enable children to “learn to connect the beginnings of words and syllables with their rhyming parts as an auditory and visual exercise” (p. 25) and lists examples of words that should be introduced during this process including onset and rime words and words containing single consonants (e.g., c-at), consonant blends or clusters (e.g.. pl-an), and digraphs (e.g., ch-at).

The adult data collated so far have shown completion of the protocol to aid recognition of single consonant onset–rime words, constructed from taught or derived onsets and rimes. To be optimally effective, the MTS protocol should not be restricted to facilitating recognition of single consonant words (e.g. CVC and CVCVC words) but ideally should also facilitate recognition of words in various consonant–vowel formations, for instance, consonant blend words.

Words containing consonant blends have been referred to as phonologically complex words (Fletcher-Flinn, Shankweiler, & Frost, 2004). Research has indicated that such phonologically complex words may pose a particular challenge for children learning to read, with high error rates observed in the naming of consonant blend words (e.g., Brand, Giroux, Dujalon, & Rey, 2007; Bruck & Treiman, 1990; Fletcher-Flinn et al., 2004).

If the MTS protocol was found to increase recognition of the type of words introduced to children throughout early reading instruction, particularly a sub-class of words known to be problematic for developing readers, this would further strengthen the applied relevance and potential utility of the protocol as an aid to word recognition for children learning to read.

Experiment 5 was undertaken to examine if the protocol could facilitate recognition of recombined consonant blend CCVC words. Consonant blends were selected as a reasonable progression from the single consonant recombined words that participants were initially tested with. Presenting participants with consonant blend words again tested if the participants could generalise their knowledge of sound–symbol correspondences acquired from the initial training stages to identify words containing novel consonant blends derived from the sound–symbol script. If participants were unable to recognise the consonant blend recombined words, direct training with the consonant blend sound–symbol pairs may be necessary to produce accurate recognition of novel words containing such consonant blends.

6.2 Method

6.2.1 Participants

A convenience sample of five men and five women recruited from a university student population participated. Participants spoke English as their first language and reported no literacy difficulties nor any sight or auditory impairments. The median age of the participants was 21 years (range, 18 to 24 years).

6.2.2 Stimuli

The four onset and four rime sound–symbol pairs trained in Experiment 3 were utilised in the current experiment (please see section 5.2.2). One requirement in the construction of the consonant blend CCVC recombined words was that all of the consonant blends needed to be fully pronounceable. Thus, not all of the initial consonants trained as onsets (e.g. /t/, /s/, /g/, /y/) or the final consonants procured from the rimes (e.g. /f/, /k/, /l/, /m/) could be combined together to form the untrained consonant blends. After trialling possible consonant blend combinations, three pronounceable consonant blends emerged from the permutations, ‘sl’, ‘fl’, and ‘st’. These three consonant blends were joined to –VC rimes that were mostly derived (untrained) rimes formed from combinations of the eight letters found in the explicitly trained rimes (/a/, /e/, /o/, /i/, /f/, /k/, /l/, /m/), thereby resulting in pronounceable CCVC words such as /slig/ and /floy/. Three of the explicitly trained rimes (/af/, /ek/, /im/) were also used to form five of the CCVC recombined words (/stim/, /slaf/, /stek/, /staf/, /slek/), to forge a link to the previous training. Examples of the CCVC test words may be viewed in Table 6.1.

Table 6.1 Examples of the recombined consonant blend CCVC words presented in Experiment 5.

Training		*CVC Word Recombinative Generalisation test*			*CCVC Recombinative Generalisation Test*
Trained onset (C) symbol–sound relations	Trained rime (–VC) symbol–sound relations	Recombined trained onset–trained rime CVC words	Untrained consonant blends (CC)	Untrained rime (–VC) examples	Recombined consonant blend CCVC words
~ - /t/	□ » - /af/	□ » - /taf/ ~	₪ □ - /fl/	♋ ⊠ - /ig/	♋ ⊠ - /flig/ ₪ □
* - /s/	⌖ ♉ - /ek/	⌖ ♉ - /sek/ *	~ * - /st/	⊙ » - /am/	⊙ » - /stam/ ~ *
♋ - /g/	₪ ♌ - /ol/	₪ ♌ - /gol/ ♋	₪ * - /sl/	⊙ ♉ - /em/	⊙ ♉ - /slem/ ₪ *
❖ - /y/	⊙ ⊠ - /im/	⊙ ⊠ - /yim/ ❖		❖ ♌ - /oy/	❖ ♌ - /floy/ ₪ □

Note. Symbol sequences were read from bottom-to-top.

6.2.3 Procedure

Training stages (onset sound-to-symbol conditional discrimination training, onset symbol-to-sound symmetry training, mixed onset test, rime sound-to-symbol conditional discrimination training etc.,) were identical to those employed in Experiment 3. Likewise, the first recombinative generalisation test (onset–rime CVC word sound-to-symbol test and onset–rime CVC word symbol-to-sound test) examining recognition of recombined onset–rime CVC words was as in Experiment 3 (please see section 5.2.3).

Table 6.2 outlines the stages undertaken in the current experiment.

Table 6.2 The MTS protocol completed in Experiment 5. Examples of stimuli presented in each stage are provided.

Training and Testing Stages	*Stimuli Examples*
Onset sound-to-symbol conditional discrimination training	/t/ - ~
Onset symbol-to-sound symmetry training	~ - /t/
Mixed onset sound-to-symbol and symbol-to-sound test	/t/ - ~ , ~ - /t/
Rime sound-to-symbol conditional discrimination training	/af/ - □ »
Rime symbol-to-sound symmetry training	□ - /af/ »
Mixed rime sound-to-symbol and symbol-to-sound test	/af/ - □ , □ - /af/ » »
Onset and rime sound-to-symbol revision training	/t/ - ~ , /af/ - □ »
Onset and rime symbol-to-sound revision training	~ - /t/ , □ - /af/ »
Trained onset–trained rime CVC word sound-to-symbol recombinative generalisation test	□ /taf/ - » ~
Trained onset–trained rime CVC word symbol-to-sound recombinative generalisation test	□ » - /taf/ ~
Consonant blend CCVC word sound-to-symbol and symbol-to-sound recombinative generalisation test	♋ ⊙ /flig/ - ⊠ , ♉ - /slem/ ₪ ₪ □ *

Following the onset–rime CVC word sound-to-symbol and symbol-to-sound test blocks, a new stage was added to the protocol as a final recombinative generalisation test to assess the participants' ability to identify recombined consonant blend CCVC words composed from untrained consonant blends and mainly untrained rimes. For the CCVC word recombinative generalisation test, participants completed one mixed block of 18 CCVC word sound-to-symbol test trials and 18 CCVC word symbol-to-sound test trials presented in a quasi random order. Recognition of 36 different CCVC words was tested. All CCVC words contained one of three consonant blend sounds (/sl/, /st/, /fl/). Table 6.3 provides an overview of the CCVC word set.

Table 6.3 CCVC words presented in the consonant blend word recombinative generalisation test.

Sound-to-symbol test trials		*Symbol-to-sound test trials*	
CCVC spoken word	Symbols	CCVC spoken word	Symbols
/fleg/	☐ ₪ ♉ ♋	/flam/	☐ ₪ » ⊙
/flem/	☐ ₪ ♉ ⊙	/flet/	☐ ₪ ♉ ~
/flim/	☐ ₪ ⊠ ⊙	/flig/	☐ ₪ ⊠ ♋
/flot/	☐ ₪ ♌ ~	/flok/	☐ ₪ ♌ ⌖
/floy/	☐ ₪ ♌ ❖	/flom/	☐ ₪ ♌ ⊙
/slat/	* ₪ » ~	/slaf/	* ₪ » ☐
/slef/	* ₪ ♉ ☐	/slek/	* ₪ ♉ ⌖
/sleg/	* ₪ ♉ ♋	/slet/	* ₪ ♉ ~
/slem/	* ₪ ♉ ⊙	/slig/	* ₪ ⊠ ♋
/slif/	* ₪ ⊠ ☐	/slof/	* ₪ ♌ ☐
/slok/	* ₪ ♌ ⌖	/slom/	* ₪ ♌ ⊙
/stak/	* ~ » ⌖	/staf/	* ~ » ☐
/stat/	* ~ » ~	/stam/	* ~ » ⊙
/stef/	* ~ ♉ ☐	/stek/	* ~ ♉ ⌖
/stim/	* ~ ⊠ ⊙	/stit/	* ~ ⊠ ~
/stok/	* ~ ♌ ⌖	/stof/	* ~ ♌ ☐
/stot/	* ~ ♌ ~	/stog/	* ~ ♌ ♋
/stoy/	* ~ ♌ ❖	/stom/	* ~ ♌ ⊙

Note. Symbols were presented and read from bottom-to-top.

6.3 Results

6.3.1 Training performance

All ten participants successfully passed the three training stages. Table 6.4 presents the number of training trials completed to reach criterion across the onset sound-to-symbol conditional discrimination training through to the onset and rime symbol-to-sound revision training.

For the onset sound-to-symbol training, participants completed between 46 to 94 training trials (mean = 56 trials) to achieve the accuracy criterion. The ten participants all passed the onset symbol-to-sound training within one block of training trials, with eight participants demonstrating 100% accuracy in matching the onset symbol–sound relations. Similarly, the criterion for the mixed onset test was met at the first attempt and, aside from one participant, the remaining participants accurately matched all of the onset sound–symbol pairs tested.

On average, the participants required 47 training trials to fulfil the rime sound-to-symbol criterion (range, 32 to 62). The rime symbol-to-sound training was passed by all participants within one block of training trials. Only one exposure to the mixed rime test was necessary for all participants to proceed to the revision training, with a little over half of the participants (6/10) showing 100% accuracy in recognising the rime sound–symbol pairs.

Retraining was not needed for any of the participants. Accuracy was high in the onset and rime sound-to-symbol and symbol-to-sound revision training trials. Both of these stages were passed within one block of trials.

Table 6.4 Number of trials completed to reach criterion in each of the training stages. Percentage correct shown in parentheses.

Participant	Onset sound-to-symbol training	Onset symbol-to-sound training	Onset mixed test correct/16	Rime sound-to-symbol training	Rime symbol-to-sound training	Rime mixed test correct/16	Onset and rime sound-to-symbol revision training	Onset and rime symbol-to-sound revision training
1	48 (60)	14 (100)	16 (100)	48 (65)	14 (100)	16 (100)	30 (100)	30 (100)
2	46 (79)	14 (100)	16 (100)	46 (71)	14 (100)	16 (100)	30 (100)	30 (100)
3	47 (67)	15 (94)	16 (100)	46 (73)	14 (100)	16 (100)	30 (100)	30 (100)
4	46 (69)	14 (100)	16 (100)	32 (75)	15 (94)	16 (100)	31 (97)	30 (100)
5	94 (58)	14 (100)	16 (100)	62 (59)	15 (94)	15 (94)	31 (97)	30 (100)
6	62 (64)	14 (100)	16 (100)	46 (75)	14 (100)	16 (100)	30 (100)	31 (97)
7	64 (63)	14 (100)	15 (94)	62 (63)	14 (100)	15 (94)	30 (100)	30 (100)
8	46 (67)	14 (100)	16 (100)	32 (72)	14 (100)	16 (100)	30 (100)	31 (97)
9	78 (56)	14 (100)	16 (100)	46 (69)	14 (100)	15 (94)	31 (97)	31 (97)
10	32 (69)	15 (94)	16 (100)	46 (63)	14 (100)	15 (94)	30 (100)	30 (100)

6.3.2 Recombinative generalisation tests

Table 6.5 shows the number of test trials correctly responded to by each participant when presented with the recombined onset–rime CVC words and recombined consonant blend CCVC words.

Table 6.5 Number of correct responses on the recombinative generalisation tests with onset–rime CVC words and consonant blend CCVC words. Percentage correct is shown in parentheses.

Participant	Onset–rime CVC word sound-to-symbol recombinative generalisation test correct/32	Onset–rime CVC word symbol-to-sound recombinative generalisation test correct/32	Consonant blend CCVC words sound-to-symbol and symbol-to-sound recombinative generalisation test correct/36
1	32 (100)	32 (100)	20 (56)
2	31 (97)	31 (97)	29 (81)
3	32 (100)	32 (100)	30 (83)
4	32 (100)	32 (100)	31 (86)
5	30 (94)	31 (97)	27 (75)
6	32 (100)	32 (100)	30 (83)
7	31 (97)	31 (97)	28 (78)
8	32 (100)	32 (100)	29 (81)
9	30 (94)	31 (97)	27 (75)
10	32 (100)	32 (100)	32 (89)

Participants correctly matched a high percentage of the onset–rime sounds to the corresponding symbols. Two participants showed 94% accuracy, two participants demonstrated 97% accuracy, and six participants correctly recognised the associated symbols for all of the onset–rime CVC spoken words tested. Slightly fewer errors occurred when matching the recombined onset–rime symbols to their associated sounds. Accuracy reached 97% for four participants, with six participants showing 100% accuracy. As shown in Figure 6.1, mean accuracy in identifying the onset–rime CVC words was 98% and 99%, in the sound-to-symbol and symbol-to-sound test trials respectively.

Recognition of 36 different consonant blend CCVC words was examined in the final recombinative generalisation test. The mean number of CCVC words correctly identified was 28, resulting in a mean accuracy of 78%. All participants recognised over half of the CCVC words presented. The smallest number of CCVC words recognised by one participant was 20 (56% accuracy). Two participants identified 27 words (75% accuracy) and one participant recognised 28 words (78% accuracy). Two participants showed 81% accuracy, two participants performed at 83% accuracy, and 86% accuracy was attained by one participant. The greatest number of CCVC words identified by one participant was 32 (89% accuracy).

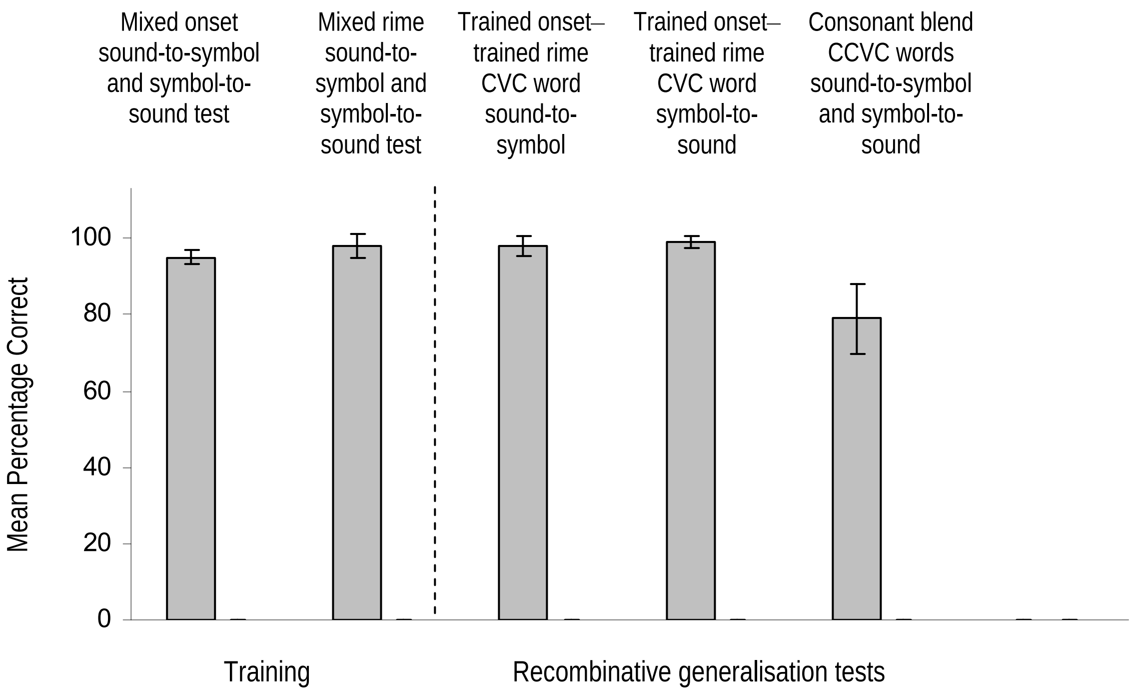


Figure 6.1 Mean percentage correct for the mixed onset and mixed rime sound-to-symbol and symbol-to-sound tests (presented as part of the training stages), onset–rime CVC word, and consonant blend CCVC word recombinative generalisation tests. Error lines representing standard deviation are shown for each bar.

6.4 Discussion

Following training of the onset and rime sound–symbol pairs, nearly all of the participants could recognise at least three quarters of the CCVC words presented that were primarily recombinations of untaught consonant blends and untrained rimes. In line with the data from Experiments 3 and 4, the current findings once more suggested that the adult participants were capable of recognising novel words that were recombinations of derived sub-lexical units, such as consonant blends and rimes, without the need for explicit training with these particular recombined units. Presumably given the participants' highly accurate performance in recognising recombined words that are created from directly taught onsets and rimes, additional training with the consonant blends and untrained rimes would enhance recognition accuracy. However, recognition of more complex derived words does seem possible without such training, thus indicating the potential of the protocol to facilitate productive learning.

Additionally, the findings from Experiment 5 suggested that the protocol is not limited to facilitating recognition of words constructed in single consonant–vowel formations (e.g., CVC and CVCVC words), but the training appeared to be relatively effective in preparing participants to recognise words containing consonant blends. If similar findings are evident from studies with beginning readers, this would certainly be advantageous, particularly in light of the difficulties that consonant blend words may present for children learning to read (e.g., Brand et al., 2007; Bruck & Treiman, 1990; Fletcher-Flinn et al., 2004).

One of the limitations of Experiment 5 was that testing concentrated exclusively on examining recognition of initial consonant blend words (e.g. CCVC words). Yet consonant blends may also occur in the end positions of words (e.g.

CVCC words). A more thorough examination of the protocol would have been to test recognition of both types of consonant blend words and to determine if the accuracy levels demonstrated in recognising the recombined CCVC words also extended to the recombined CVCC words.

During the previous experiments, the onset and rime training protocol has proved successful in promoting within- and across-unit recombinative generalisation and enabling recognition of CVC, CVCVC, and CCVC words. In the next experiment, modifications will be made to the size of unit employed to train the sound–symbol relations from which the recombined words are constructed to assess the impact of grain size (learning print–sound mappings at a small grain size e.g., phonemes, versus larger grain sizes, e.g., rimes and syllables) on recombinative generalisation performance.

Chapter Seven

Experiment 6: Exploring the Effects of Grain Size on Recombinative Generalisation

7.1 Introduction

For the majority of the experiments previously reported, an invented script modelled on an alphabetic type script (e.g., a one-to-one mapping between symbols and sounds) has been used. In order to recognise words formed in the novel script, it was necessary for the adults to learn how the printed symbols translated to the different consonant and vowel sounds. It is this knowledge of how symbols (i.e. letters) relate to sounds that researchers have emphasised is vital to reading development (e.g., Hulme, Snowling, Caravolas, & Carroll, 2005; Rayner et al., 2002; Share, 1995; Share & Stanovich, 1995). To learn these sound–symbol correspondences, onset and rime units have been employed throughout the training stages in the previous studies. The results obtained so far have indicated that following training of the onset and rime sound–symbol relations, the participants can accurately recognise recombined CVC, CCVC, or CVCVC words, thereby supporting the relative benefits of an onset and rime based MTS protocol in facilitating recombinative generalisation.

Onsets and rimes were selected as the explicitly trained sub-word units given the important status attached to these particular units when learning to read in English (see Goswami & Bryant, 1990; Treiman et al., 1995). From a developmental perspective too, it may be suggested that it was reasonable to commence training with the larger sized onset and rime units, as awareness of such phonological units has been suggested to follow a ‘large-to-small’ trajectory (see Anthony et al., 2003; Ziegler & Goswami, 2005, but see Duncan et al., 1997; Hulme, 2002). Children yet to commence reading are believed to initially demonstrate greater sensitivity to larger sized units such as whole words and syllables, followed by an awareness of onsets and rimes, before they progress to an awareness of the smallest available units, namely, phonemes.

Despite being typified as an alphabetic script, English is a complex script for beginning readers to master due to the many 'irregularities' that exist between its printed and spoken codes (Levy & Lysynchuk, 1997). In English, the same printed letter can represent multiple sounds. For example, think of the homographs 'row', 'tear', 'wind', and 'wound'. There are two possible pronunciations for each of these printed words. Likewise, an identical phoneme may be represented by various printed letters. This is most evident in homophones such as 'right', 'rite', and 'write', 'sail' and 'sale'. Notice that each pair of words is pronounced identically, despite utilising different printed letters. Thus, there is not a fixed, consistent, one-to-one correspondence between individual phonemes and graphemes in English, and herein lies the potential difficulty for beginning readers.

English is highly inconsistent at the level of the phoneme. For example, it is known that beginning readers of English often find vowel sounds more difficult to isolate and process due mainly to the variations in how vowels can be pronounced (Brown & Besner, 1987; Carr & Pollatsek, 1985). Indeed, much of the irregularity in English can be traced to inconsistency in the pronunciation of vowels, with consonants being generally more reliable and consistent in their pronunciation (Kessler & Treiman, 2001). Not only are consonants more predictable in pronunciation than vowels, but according to the two-cycles theory (Berent & Perfetti, 1995), consonants and vowels are also processed independently in separate 'cycles' during word recognition. The two-cycles theory predicts that consonants are processed initially on a 'first cycle', followed by vowels on a 'second cycle'. In support of this position, when eye movements have been tracked during silent word reading tasks, some experiments have found that consonants rather than vowels make a larger contribution to early word recognition (e.g., Lee, Rayner, & Pollatsek, 2001; but see Ashby, Treiman, Kessler, & Rayner, 2006).

Despite the inconsistency for phonemes in English, there is greater predictability at the level of the rime (see Treiman et al., 1995). Taken in its entirety, the sequence of letters which form a rime are more likely to be pronounced identically across words containing that rime (however, with the 'irregularity' of English, there are exceptions). It is this 'rime consistency' that has prompted some researchers to assert that success in learning to read cannot solely be reliant on learning and applying phoneme-to-grapheme mappings. Rather, to be an effective reader, a combination of smaller phoneme–grapheme and larger rime unit mappings are required (see Goswami, 2002). Thus, what is essential for proficient reading is flexibility in the size of mappings that are learned and applied, acquisition of an assortment of phonological–orthographic mappings at various grain sizes (e.g., phonemes, onsets and rimes, syllables), perhaps being most beneficial to reading development (see Brown & Deavers, 1999; Goswami et al., 2003, Goswami & Ziegler, 2005).

There are a range of orthographic and phonological units available at which the associations between letters and sounds can be taught. In terms of the use of the MTS protocol, it remains somewhat unclear as to how the size of the unit adopted to train the symbol–sound relations may influence ability to recognise novel, recombined words.

Perhaps in reflection of the saliency of the rime unit in English, previous MTS studies investigating the emergence of recombinative generalisation have principally employed onset and rime training procedures (e.g., Keaveney, 2005; Mueller et al., 2000; Saunders et al., 2003). More recently, de Souza, de Rose, Faleiros, Bortoloti, Hanna, and McIlvane (2009) developed a syllable-based training protocol that featured MTS procedures in conjunction with exclusion techniques. The protocol was procured to promote word naming of recombined Portuguese words in children aged between eight to twelve years. For the new syllable-based procedure, refinements were made to a previous training protocol employed by de Rose et al. (1996) which entailed whole word training with printed and spoken words. de Souza et al. (2009) added explicit training with individual CV syllabic units (e.g., /bo/, /lo/, /va/, /ca/) to their revised protocol to supplement the whole word training component (e.g., /bolo/, /vaca/). Testing examined if the children could name novel words that were recombinations of the explicitly taught intrasyllabic units (e.g., /boca/, /cabo/).

de Souza et al. (2009) observed that as a group, the children could accurately read aloud an average of 80% of the recombined words. In contrast, when the syllabic training was omitted from the earlier procedures used by de Rose et al. (1996), the participating children named approximately 40% of the generalisation words. Furthermore, a quarter of the children in the de Rose et al. (1996) study failed to read aloud any of the recombined test words. The results, therefore, indicated clear benefits for the revised training procedures, and highlighted the advantages of the additional training with the syllabic units featured in the generalisation words.

However, it is important to bear in mind that many words in the Portuguese language are constructed from sequences of CV units. As such, there was a level of congruency between the training procedures employed (i.e., explicit training with such CV units) and the inherent syllabic characteristics of the target language. It remains to be seen if there would be any changes in recombinative generalisation performance had a different sized unit, such as phonemes or onsets and rimes, been enlisted during training. Variations to the size of training unit employed and the potential impact on the emergence of recombinative generalisation may be especially relevant to ‘deeper’ alphabetic scripts such as English. It has been suggested that when learning to read in English it is necessary to develop decoding strategies to tackle unfamiliar words that are flexible with regards to grain size, utilising both larger and smaller units (see Georgiou, Parrila, & Papadopoulos, 2008; Rayner et al., 2001; Ziegler & Goswami, 2005).

As far as is known, to date, no other MTS studies have compared the effects of varying the size of unit employed to train the necessary symbol–sound knowledge required to identify words constructed from rearrangements of these symbols and sounds. Is there a particular sized unit, (e.g., phoneme, onset and rime, or syllable), that appears to best facilitate recognition of recombined words? Or is the size of unit utilised to train letter–sound correspondences of little significance in regards to the promotion of recombinative generalisation? Certainly, with the aim of trying to develop an effective training procedure to aid novel word recognition, it is important to investigate the effects of modifications to the training unit.

From an applied perspective, reading instruction in English is frequently orientated towards small unit phonics type instruction (e.g., focusing on individual letters, teaching phoneme-to-grapheme correspondences). The guidelines for the English Primary School Curriculum (1999) compiled by the Department of Education and Science state that from the very earliest stages of reading instruction, opportunities should be provided to “learn to recognise and name the letters of the alphabet” and “develop an awareness of some letter–sound relationships” (p. 16). Thus, it is important to examine the impact on recombinative generalisation performance when phonemes, being one of the phonological units typically encountered when learning to read in English, are employed as the training unit within the MTS protocol.

To address these issues, Experiment 6 was undertaken in which the conditional discrimination training consisted of training with onsets and rimes, syllables, or phonemes. Subsequent testing examined recognition of recombined CVC and CVCVC words. The recombined test words were identical regardless of the size of training unit encountered. Recognition of the recombined words was compared across the three training conditions (onsets and rimes, phonemes, syllables) to determine if there was a particular sized unit associated with the greatest accuracy in recognising the recombined words.

7.2 Method

7.2.1 Participants

A convenience sample of forty-five literate adults (19 men and 26 women) recruited from a university undergraduate student population participated. All participants were aged between 18 years to 28 years (median age = 20 years). Participants spoke English as a first language and presented with no visual or auditory impairments.

7.2.2 Apparatus and Stimuli

All materials were identical to those employed in Experiment 1 (please see p. 34), including the to-be-trained sound–symbol pairs.

7.2.3 General Procedure

There were three training conditions: (i) training with onsets and rimes; (ii) training with phonemes; (iii) training with syllables (whole CVC words). Fifteen participants were randomly allocated to each training condition.

In the onset and rime training condition the participants learned to match four onset (e.g., /t/, /s/, /n/, /y/) and four –VC rime (e.g., /af/, /ek/, /ol/, /im/) sound–symbol pairs. For the phoneme training condition, participants were trained with the individual sounds associated with each symbol (e.g., /t/, /a/, /f/); with the vowel and consonant sounds combined to form each rime in the onset and rime condition (e.g., /af/) trained as unique, unrelated sounds in the phoneme condition (e.g., /a/, /f/). Whole CVC words (e.g., /taf/, /sek/) formed from joining the onsets and rimes were employed in the syllable training condition.

Participants completed a MTS protocol which was similar to that utilised in Experiment 1 apart from the removal of the non-combined onset–rime training. As discussed in Chapter 3, this was a component not instrumental to producing the recombinative generalisation effect, thereby justifying its omission from the procedure. The number of trials in each stage and criterion levels remained unchanged from Experiment 1. Irrespective of condition, all participants attempted the same CVC and CVCVC word recombinative generalisation tests as presented in Experiment 1. Table 7.1 provides a summary of the stages completed in each condition.

Although the onset and rime training was identical to the training in Experiment 1, there were some variations in the phoneme and syllable training conditions. Practice sessions were adapted to reflect the training requirements of each condition. For example, syllable trained participants listened to whole CVC words and viewed three symbol combinations. Particular emphasis was made by the experimenter that the syllable trained participants needed to look at all of the symbols from bottom-to-top throughout the task to encourage the participants to view all of the symbols. In contrast, onset and rime and phoneme trained participants learned to choose one symbol–one sound pairs as part of their practice session.

Table 7.1 Overview of the three training conditions for Experiment 6 with examples of stimuli presented in each condition.

Condition 1 *Onsets and Rimes*	*Condition 2* *Phonemes*	*Condition 3* *Syllables*
Onset sound-to-symbol training	Onset sound-to-symbol training	CVC word sound-to-symbol training
Example /t/ - ~	/t/ - ~	/taf/ - ~ » □
Onset symbol-to-sound training	Onset symbol-to-sound training	CVC word symbol-to-sound training
Example ~ - /t/	~ - /t/	~ » □ - /taf/
Onset sound-to-symbol and symbol-to-sound testing	Onset sound-to-symbol and symbol-to-sound testing	CVC word sound-to-symbol and symbol-to-sound testing
Example /t/ - ~ ; ~ - /t/	/t/ - ~ ; ~ - /t/	/taf/ - ~ » □ ; ~ » □ - /taf/
Rime sound-to-symbol training	Vowel sound-to-symbol training	CVC word sound-to-symbol training
Example /af/ - » □	/a/ - »	/sek/ - *♉⊞
Rime symbol-to-sound training	Vowel symbol-to-sound training	CVC word symbol-to-sound training
Example » □ - /af/	» - /a/	*♉⊞ - /sek/
Rime sound-to-symbol and symbol-to-sound testing	Vowel sound-to-symbol and symbol-to-sound testing	CVC word sound-to-symbol and symbol-to-sound testing
Example /af/ - » □ ; » □ - /af/	/a/ - » ; » - /a/	/sek/ - *♉⊞ ; *♉⊞ - /sek/
	Final consonant sound-to-symbol training	
	/f/ - □	
	Final consonant symbol-to-sound training	
	□ - /f/	
	Final consonant sound-to-symbol and symbol-to-sound testing	
	/f/ - □ ; □ - /f/	
Onset and rime sound-to-symbol training	Onset, vowel, final consonant sound-to-symbol training	All CVC words sound-to-symbol training
Example /t/ - ~ ; /af/ - » □	/t/ - ~ ; /a/ - » ; /f/ - □	/taf/ - ~ » □ ; /sek/ - *♉⊞
Onset and rime symbol-to-sound training	Onset, vowel, final consonant symbol-to-sound training	All CVC words symbol-to-sound training
Example ~ - /t/ ; » □ - /af/	~ - /t/ ; » - /a/ ; □ - /f/	~ » □ - /taf/ ; *♉⊞ - /sek/
RG test CVC sounds-to-symbols	RG test CVC sounds-to-symbols	RG test CVC sounds-to-symbols
Example /saf/ - * » □	/saf/ - * » □	/saf/ - * » □
RG test CVC symbols-to-sounds	RG test CVC symbols-to-sounds	RG test CVC symbols-to-sounds
Example * » □ - /saf/	* » □ - /saf/	* » □ - /saf/
RG test CVCVC sounds-to-symbols,symbols-to-sounds	RG test CVCVC sounds-to-symbols,symbols-to-sounds	RG test CVCVC sounds-to-symbols,symbols-to-sounds
Example /tafek/ - ~ » □♉⊞ *♉⊞» □ - /sekaf/	/tafek/ - ~ » □♉⊞ *♉⊞» □ - /sekaf/	/tafek/ - ~ » □♉⊞ *♉⊞» □ - /sekaf/

For the phoneme training condition, participants completed sound-to-symbol conditional discrimination training, symbol-to-sound symmetry training, and mixed test trials for four initial onset sound–symbol pairs (/t/, /s/, /n/, /y/); followed by four vowel sound–symbol pairs (/a/, /e/, /i/ /o/); and lastly, four final consonant sound–symbol pairs (/f/, /k/, /l/, /m/). Depending on the type of training trial (i.e., sound-to-symbol or symbol-to-sound), each of the four initial onsets, vowels, and final consonants appeared four times as the sample sound or symbol across each block of 16 training trials.

Once all 12 sound–symbol pairs had been trained across the three subsets (e.g., onsets, vowels, final consonants), the 12 sound–symbol pairs were all presented together in revision training blocks of 32 sound-to-symbol training trials and 32 symbol-to-sound training trials. Each individual sound–symbol pair was presented at least twice as the sample sound or symbol across a block of 32 training trials.

In the syllable training condition, participants again experienced the training sequence of sound-to-symbol conditional discrimination training, symbol-to-sound symmetry training, and mixed test trials, but were trained to match whole CVC spoken words to three symbol combinations. Four CVC words (/taf/, /sek/, /yim/, /nol/) each employing one of the four onsets (/t/, /s/, /y/, /n/) or four rimes (/af/, /ek/, /im/, /ol/) used in the onset and rime protocol were initially trained. Each of the four CVC spoken words or symbols was employed four times as the sample so that the amount of exposure would be consistent with the onset and rime and phoneme conditions. Once the mixed test for these four words had been completed, four different CVC words (/tek/, /saf/, /yol/, /nim/) were trained and tested. All eight CVC words were subsequently revised across revision training blocks of 32 sound-to-symbol and 32 symbol-to-sound training trials. Each CVC word occurred four times as the sample spoken word or symbols.

7.3 Results

7.3.1 Training performance

All onset and rime, phoneme, and syllable trained participants passed the training stages.

Tables 7.2, 7.3, and 7.4 show the number of training trials completed to reach the criterion for each training stage by each of the 15 participants in the onset and rime, phoneme, or syllable conditions respectively. As shown in the tables, there were variations in the amount of training required by participants in each of the three conditions. Although all of the onset and rime trained participants passed the mixed tests at the first attempt and did not need any further conditional discrimination or symmetry training, three of the phoneme trained participants (Participants 17, 18, and 27) and one of the syllable trained participants (Participant 37) did require additional retraining with earlier stages.

7.3.2 Recombinative generalisation tests

Table 7.5 shows the number of correct responses provided on the recombinative generalisation tests by participants from the onset and rime, phoneme, and syllable conditions.

Figure 7.1 shows the mean accuracy on the CVC word sound-to-symbol and symbol-to-sound tests, and the CVCVC mixed test, for participants from the three training conditions.

Table 7.2 Number of trials required to reach criterion across the training stages for the onset and rime trained participants. Percentage of correct responses is shown in parentheses.

Participant	Onset sound-to-symbol	Onset symbol-to-sound	Onset mixed test correct/16	Rime sound-to-symbol	Rime symbol-to-sound	Rime mixed test correct/16	Onset and rime sound-to-symbol revision	Onset and rime symbol-to-sound revision
1	48 (67)	14 (100)	16 (100)	62 (72)	14 (100)	16 (100)	30 (100)	30 (100)
2	110 (47)	48 (81)	15 (94)	80 (61)	15 (94)	15 (94)	32 (94)	31 (97)
3	64 (73)	14 (100)	16 (100)	32 (72)	14 (100)	16 (100)	30 (100)	30 (100)
4	64 (58)	15 (94)	16 (100)	48 (73)	14 (100)	16 (100)	31 (97)	30 (100)
5	80 (54)	14 (100)	16 (100)	48 (65)	14 (100)	16 (100)	31 (97)	31 (97)
6	32 (69)	32 (78)	16 (100)	30 (81)	14 (100)	16 (100)	30 (100)	30 (100)
7	78 (74)	15 (94)	15 (94)	64 (61)	15 (94)	15 (94)	30 (100)	31 (97)
8	62 (73)	14 (100)	16 (100)	46 (75)	14 (100)	16 (100)	30 (100)	30 (100)
9	46 (71)	14 (100)	16 (100)	48 (79)	14 (100)	16 (100)	31 (97)	30 (100)
10	48 (54)	14 (100)	16 (100)	32 (72)	14 (100)	16 (100)	30 (100)	30 (100)
11	48 (73)	15 (94)	15 (94)	48 (65)	15 (94)	16 (100)	31 (97)	30 (100)
12	96 (60)	46 (83)	15 (94)	64 (69)	30 (91)	16 (100)	31 (97)	32 (94)
13	64 (67)	14 (100)	15 (94)	32 (84)	14 (100)	16 (100)	30 (100)	30 (100)
14	46 (72)	14 (100)	16 (100)	32 (78)	15 (94)	16 (100)	31 (97)	30 (100)
15	94 (58)	15 (94)	16 (100)	48 (71)	14 (100)	15 (94)	32 (94)	31 (97)

Table 7.3 Number of trials required to reach criterion across the training stages for the phoneme trained participants. Percentage of correct responses is shown in parentheses.

Participant	Onset sound-to-symbol	Onset symbol-to-sound	Onset mixed test correct/16	Vowel sound-to-symbol	Vowel symbol-to-sound	Vowel mixed test correct/16	Final consonant sound-to-symbol	Final consonant symbol-to-sound	Final consonant mixed test correct/16	Onset, vowel, and final consonant sound-to-symbol revision	Onset, vowel, and final consonant symbol-to-sound revision
16	16 (94)	14 (100)	15 (94)	32 (84)	30 (84)	16 (100)	32 (81)	14 (100)	16 (100)	30 (100)	30 (100)
17	80 (48), 14 (100)	32 (66), 32 (84)	14 (88), 15 (94)	48 (75)	14 (100)	16 (100)	80 (68)	15 (94)	16 (100)	30 (100)	30 (100)
18	112 (55), 14 (100), 14 (100)	32 (78), 32 (91), 14 (100)	14 (88), 14 (88), 16 (100)	80 (51), 16 (94)	62 (70), 14 (100)	13 (81), 16 (100)	64 (61)	15 (94)	15 (94)	64 (92)	32 (94)
19	48 (66)	14 (100)	15 (94)	32 (84)	14 (100)	16 (100)	30 (88)	14 (100)	16 (100)	30 (100)	30 (100)
20	64 (69)	14 (100)	16 (100)	48 (71)	15 (94)	16 (100)	46 (65)	14 (100)	16 (100)	30 (100)	30 (100)
21	78 (58)	15 (94)	15 (94)	32 (78)	14 (100)	15 (94)	48 (75)	15 (94)	16 (100)	31 (97)	30 (100)
22	46 (73)	14 (100)	16 (100)	16 (88)	32 (72)	15 (94)	32 (75)	14 (100)	15 (94)	30 (100)	30 (100)
23	96 (54)	16 (88)	16 (100)	62 (64)	14 (100)	16 (100)	32 (88)	15 (94)	16 (100)	64 (97)	30 (100)
24	48 (81)	14 (100)	16 (100)	30 (81)	14 (100)	16 (100)	16 (87)	15 (94)	15 (94)	32 (94)	30 (100)
25	80 (63)	15 (94)	16 (100)	64 (61)	15 (94)	16 (100)	46 (79)	14 (100)	16 (100)	30 (100)	30 (100)
26	78 (56)	14 (100)	16 (100)	46 (75)	14 (100)	16 (100)	32 (75)	14 (100)	16 (100)	30 (100)	31 (97)
27	112 (51), 30 (88)	48 (75), 14 (100)	14 (88), 16 (100)	80 (59)	32 (81)	15 (94)	48 (65)	15 (94)	16 (100)	62 (92)	30 (100)
28	64 (58)	14 (100)	15 (94)	80 (54)	15 (94)	16 (100)	48 (65)	14 (100)	16 (100)	31 (97)	30 (100)
29	46 (71)	14 (100)	16 (100)	32 (88)	14 (100)	16 (100)	30 (84)	14 (100)	16 (100)	30 (100)	30 (100)
30	62 (64)	15 (94)	16 (100)	30 (78)	14 (100)	16 (100)	64 (66)	14 (100)	16 (100)	31 (97)	31 (97)

Table 7.4 Number of trials required to reach criterion across the training stages for the syllable trained participants. Percentage of correct responses is shown in parentheses.

Participant	CVC words sound-to-symbol	CVC words symbol-to-sound	CVC words mixed test correct/16	CVC words sound-to-symbol	CVC words symbol-to-sound	CVC words mixed test correct/16	All CVC words sound-to-symbol revision	All CVC words symbol-to-sound revision
31	126 (48)	14 (100)	16 (100)	32 (81)	14 (100)	15 (94)	31 (97)	30 (100)
32	62 (53)	15 (94)	16 (100)	48 (79)	15 (94)	15 (94)	64 (92)	30 (100)
33	46 (73)	15 (94)	16 (100)	14 (100)	14 (100)	15 (94)	31 (97)	31 (97)
34	78 (54)	14 (100)	16 (100)	32 (66)	14 (100)	15 (94)	31 (97)	30 (100)
35	94 (51)	32 (84)	16 (100)	48 (67)	14 (100)	15 (94)	160 (72)	31 (97)
36	80 (64)	15 (94)	15 (94)	30 (84)	14 (100)	16 (100)	30 (100)	30 (100)
37	96 (61), 16 (94)	32 (88), 14 (100)	13 (81), 16 (100)	64 (59)	15 (94)	15 (94)	64 (89)	31 (97)
38	48 (69)	14 (100)	15 (94)	32 (69)	14 (100)	16 (100)	31 (97)	31 (97)
39	78 (50)	15 (94)	16 (100)	48 (73)	14 (100)	16 (100)	30 (100)	30 (100)
40	32 (69)	30 (91)	16 (100)	32 (75)	14 (100)	16 (100)	31 (97)	31 (97)
41	64 (66)	14 (100)	16 (100)	30 (78)	15 (94)	16 (100)	31 (97)	31 (97)
42	46 (75)	14 (100)	15 (94)	62 (80)	14 (100)	16 (100)	31 (97)	31 (97)
43	80 (66)	15 (94)	16 (100)	32 (66)	14 (100)	16 (100)	30 (100)	30 (100)
44	112 (50)	48 (81)	15 (94)	80 (55)	32 (88)	15 (94)	64 (91)	32 (94)
45	48 (69)	14 (100)	16 (100)	32 (88)	14 (100)	16 (100)	30 (100)	30 (100)

Table 7.5 Number of correct responses on the recombinative generalisation tests for the onset and rime, phoneme, and syllable trained participants. Percentage of correct responses is shown in parentheses.

	Onset and Rime Trained Participants			*Phoneme Trained Participants*			*Syllable Trained Participants*		
Participant	Onset–rime CVC word sound-to-symbol test correct / 32	Onset–rime CVC word symbol-to-sound test correct / 32	Onset–rime–rime CVCVC word sound-to-symbol and symbol-to-sound test correct / 32	Onset–rime CVC word sound-to-symbol test correct / 32	Onset–rime CVC word symbol-to-sound test correct / 32	Onset–rime–rime CVCVC word sound-to-symbol and symbol-to-sound test correct / 32	Onset–rime CVC word sound-to-symbol test correct / 32	Onset–rime CVC word symbol-to-sound test correct / 32	Onset–rime–rime CVCVC word sound-to-symbol and symbol-to-sound test correct / 32
1	31 (97)	31 (97)	31 (97)	30 (94)	32 (100)	31 (97)	16 (50)	20 (63)	7 (22)
2	29 (91)	30 (94)	28 (88)	30 (94)	30 (94)	30 (94)	13 (41)	11 (34)	31 (97)
3	32 (100)	32 (100)	32 (100)	18 (56)	28 (88)	26 (81)	32 (100)	31 (97)	31 (97)
4	31 (97)	32 (100)	31 (97)	32 (100)	32 (100)	32 (100)	14 (44)	21 (66)	29 (91)
5	31 (97)	31 (97)	31 (97)	31 (97)	32 (100)	31 (97)	13 (41)	14 (44)	27 (84)
6	32 (100)	32 (100)	31 (97)	30 (94)	31 (97)	31 (97)	26 (81)	29 (91)	31 (97)
7	32 (100)	32 (100)	32 (100)	32 (100)	32 (100)	32 (100)	19 (59)	22 (69)	29 (91)
8	31 (97)	31 (97)	31 (97)	31 (97)	32 (100)	31 (97)	30 (94)	30 (94)	31 (97)
9	30 (94)	31 (97)	31 (97)	31 (97)	31 (97)	30 (94)	17 (53)	21 (66)	26 (81)
10	32 (100)	31 (97)	31 (97)	30 (94)	30 (94)	30 (94)	16 (50)	25 (78)	28 (88)
11	32 (100)	32 (100)	32 (100)	30 (94)	31 (97)	31 (97)	24 (75)	21 (66)	25 (78)
12	31 (97)	31 (97)	30 (94)	26 (81)	29 (91)	27 (84)	13 (41)	17 (53)	19 (59)
13	31 (97)	30 (94)	31 (97)	31 (97)	31 (97)	32 (100)	26 (81)	28 (88)	31 (97)
14	32 (100)	32 (100)	32 (100)	30 (94)	30 (94)	29 (91)	19 (59)	24 (75)	29 (91)
15	31 (97)	31 (97)	30 (94)	31 (97)	30 (94)	30 (94)	30 (94)	31 (97)	29 (91)

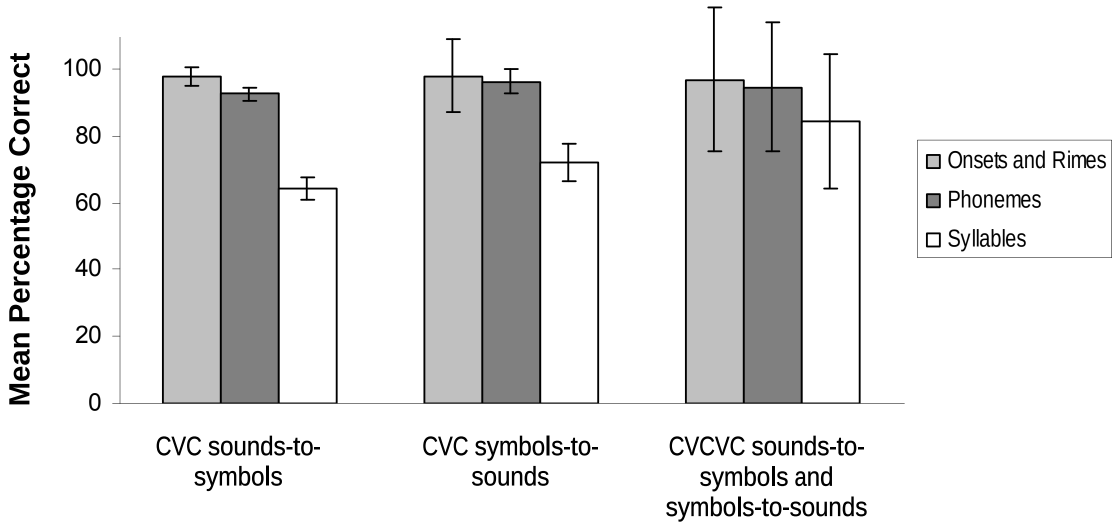


Figure 7.1 Mean percentage correct on the CVC word sound-to-symbol, CVC word symbol-to-sound, and CVCVC mixed sound-to-symbol and symbol-to-sound recombinative generalisation tests, for onset and rime, phoneme, and syllable trained participants. Error bars representing the standard deviation are shown.

7.3.2.1 Recombined CVC word sound-to-symbol test

Participants who completed onset and rime training were the most accurate in matching the correct symbols to the given sample CVC spoken words with a mean accuracy of 98% (range, 91% to 100%). The phoneme trained participants demonstrated a mean accuracy of 92% (range, 56% to 100%). Mean accuracy for the syllable participants was 64% (range, 41% to 100%).

A one-way between groups ANOVA was undertaken to explore the effect of unit size (onsets and rimes, phonemes, syllables) on accuracy in matching recombined CVC sounds-to-symbols. There was a significant effect for unit size on recognition performance, $F(2, 42) = 25.03$, $p < .001$. Post hoc comparisons using the Tukey test indicated that the onset and rime participants performed similarly to the phoneme participants ($p = .57$), and both onset and rime and phoneme participants performed significantly better than the syllable trained participants ($p < .001$).

7.3.2.2 Recombined CVC word symbol-to-sound test

A similar trend was evident in the CVC word symbol-to-sound test with little difference in recombinative generalisation performance between the onset and rime and phoneme trained participants. Participants from the onset and rime condition averaged 98% accuracy (range, 94% to 100%), while phoneme participants showed an average of 96% accuracy (range, 88% to 100%). The syllable trained participants generally performed better in selecting the correct CVC spoken words, compared to their performance in the CVC word sound-to-symbol test. Mean accuracy for the syllable participants was 72% (range, 34% to 97%).

Again, there was a statistically significant effect for unit size on CVC word symbol-to-sound recognition accuracy, $F(2, 42) = 6.10$, $p < .01$. Tukey post hoc comparisons revealed no significant difference in the performance of onset and rime participants compared to phoneme participants ($p = .93$). The syllable participants responded correctly to significantly fewer CVC symbol-to-sound test trials than the onset and rime participants ($p < .007$) and the phoneme participants ($p < .019$).

7.3.2.3 Recombined CVCVC word sound-to-symbol, symbol-to-sound mixed test

There was less variation in the performance of participants across the three conditions for the final generalisation test. The greatest number of CVCVC words identified was by the onset and rime participants (mean accuracy = 97%; range, 88% to 100%). Phoneme trained participants were also highly accurate in identifying the CVCVC words (mean accuracy = 95%; range, 81% to 100%). Mean accuracy in identifying the CVCVC words was 84% for the syllable participants (range, 22% to 97%). Although two participants from this condition recorded quite low accuracy percentages of 22% and 59%, nine of the syllable participants demonstrated above 90% accuracy.

For this final test, unit size did have a significant effect on the percentage of correct responses observed across the three training conditions, $F(2, 42) = 4.72$, $p = .014$. Post hoc analyses using Tukey showed that the onset and rime participants performed with greater accuracy than the syllable participants in recognising the CVCVC words ($p < .017$). Although the test revealed that the difference between the performance of the phoneme participants and the syllable participants was not statistically significant, this comparison was approaching statistical significance ($p = .059$). There was no significant difference in the performance of onset and rime participants compared to phoneme participants, with phoneme participants registering similar accuracy percentages to the onset and rime participants ($p = .858$).

7.4 Discussion

Across the three recombinative generalisation tests (recombined CVC sounds-to-symbols, CVC symbols-to-sounds, and CVCVC sound–symbol relations) there was little difference in overall accuracy in matching the recombined sounds and symbols shown by participants who completed onset and rime training compared to phoneme training. The majority of onset and rime and phoneme trained participants were highly successful in correctly recognising the recombined CVC and CVCVC words. These findings suggest that MTS training with onsets and rimes or phonemes is associated with successful recombinative generalisation in the current protocol. This finding is in accordance with recent reading literature which has progressed from contending whether onsets and rimes *or* phonemes are the optimal unit to employ for beginning readers, and has instead, concentrated more on the contribution that onsets and rimes *and* phonemes may make to reading development (see Goswami. 2002).

The current findings indicated a very different result for the syllable trained participants. Following training with whole CVC words, the syllable trained participants were the least accurate at recognising the recombined CVC and CVCVC words. As a group, their performance was noticeably poorer than that observed for the onset and rime and phoneme participants.

Indeed, despite receiving explicit training with eight of the CVC words, the error rate in matching the recombined CVC sounds and symbols was very high for the syllable participants. Even though upon commencing the CVC tests the syllable participants would already be proficient in matching half of the CVC words (due to the previous training to criterion), aside from three participants, the participants were largely highly inaccurate in responding to the eight novel recombined CVC words. These results suggest that, in the current experiment, the syllable training, incorporating the largest sized units, did not appear to be particularly conducive to the recognition of the CVC words. These findings concur with data obtained from children learning to read in English, showing that children who are taught to read using *only* whole word recognition techniques are often unable to read unfamiliar words that they have not been taught. In contrast, children who have received phonics based instruction emphasising grapheme–phoneme mappings are more proficient at decoding unfamiliar words (e.g., Bhattacharya & Ehri, 2004; Ehri, Nunes, Stahl, & Willows, 2001; Seymour & Elder, 1986).

Furthermore, to a certain extent, these findings are in line with the early data obtained by de Rose et al. (1996) who reported 40% naming accuracy for novel generalisation words following whole word CVCV training. In a subsequent study by de Souza et al. (2009), it was the training with individual CV syllabic units supplementing the whole word CVCV training that was associated with larger increases in naming accuracy for the generalisation words. It may also be worthwhile to recall that in the Mueller et al. (2000) investigation, the CVC word training alone did not result in improvements in novel word naming for two of the participants. Additional stimulus equivalence procedures were required before gains in naming ability were observed for these two participants.

The aforementioned studies all used MTS procedures. However, there is also evidence to suggest that training with smaller sub-word units can benefit word recognition and naming using other methodologies.

In a recent study by Ecalle, Magnan, and Calmus (2009), a computer program was designed for French speaking children. As part of the training, half of the children heard a whole polysyllabic French word (e.g., /retrouver/) and had to click on the corresponding printed word from a choice of three words. The remaining children heard the whole word (e.g., /retrouver/) followed by an individual syllable contained within the whole word (e.g., /ver/). These children needed to indicate if the syllable occurred at the start, middle, or end of the word. Although the researchers did not examine word recognition and naming of untrained, generalisation words, they did report significant advantages in word naming, recognition, and spelling of the trained words for the children taught using the smaller syllabic sub-word units. It may be suggested that these results, as with the MTS findings, point to the benefits of explicit training with the constituent smaller units from which words are composed when the aim is to promote recognition of words composed from alphabetic type scripts.

Why in the current experiment was the syllable MTS training not as effective as the onset and rime or phoneme MTS training in promoting recombinative generalisation? Arguably, the syllable training may not have established sufficient knowledge about the correspondences between the individual symbols and sounds from which the recombined CVC items were constructed. Foy and Mann (2006) stipulated that to read any script proficiently, the mappings between letters (symbols) and their associated sounds must be discovered. It is this symbol–sound knowledge that enables recognition of unfamiliar words (see also Dodd and Carr, 2003). Several computational models of reading (e.g. Plaut et al., 1996; Seidenberg & McClleland, 1989) have also emphasised that successful generalisation to novel unfamiliar items may be easier when the small grain correspondences between graphemes (symbols) and phonemes are taught. In Experiment 6, training with the onsets and rimes and phonemes (which were smaller sized units than the CVC syllables), arguably would have better equipped the participants with a more thorough knowledge of the specific symbol–sound relations. This may have enabled them to tackle the novel test words formed from rearrangements of these sounds and symbols more successfully.

When considering performance on all three recombinative generalisation tests, the onset and rime and phoneme participants performed with high accuracy when presented with the CVC or CVCVC words. However, the syllable participants performed best when tested with the more complicated CVCVC words, and fared less well when faced with the less challenging CVC words. As a point of interest, anecdotally, at the end of their participation, many of the syllable participants reported to the experimenter that they had actually found the final CVCVC test 'easier' than the CVC tests.

How can the superior CVCVC performance of the syllable participants be explained? These participants would have been familiar with the three symbol formations of the recombined CVC test words from their previous training, whereas the five symbol sequences and longer pronounced CVCVC spoken words would have been entirely new to the participants. Bearing this in mind, the current findings are interesting.

One possibility is to consider the role of context. It is known that beginning readers of English often find vowel sounds more difficult to isolate and process than consonants (Brown & Besner, 1987; Carr & Pollatsek, 1985). Additionally, there is some evidence to suggest that it is the consonants within words, rather than the vowels, that make a larger contribution to early word recognition (e.g., Berent & Perfetti, 1995; Lee, Rayner, & Pollatsek, 2001; but see Ashby, Treiman, Kessler, & Rayner, 2006).

When presented with the whole CVC words in the current experiment, possibly it may have been harder for the syllable participants to discriminate between the four vowel sounds. Instead, when learning how the CVC spoken words related to the three symbol sequences, the participants may have focused on the more distinctive first and last consonant sounds and associated symbols. Consequentially, this may have detracted their attention away from learning the vowel sound–symbol relations. For these participants then, the CVC word generalisation tests are potentially more difficult to respond to correctly than the CVCVC word generalisation tests. With a greater number of consonant symbols appearing when the longer CVCVC words are presented, the 'consonantal context' is richer. Hence, there is a greater chance of responding correctly compared to when there are fewer (consonant) symbols available. Less consonantal information is provided in the CVC word test trials, making the task seemingly more difficult.

Word length advantages have been demonstrated for actual consonantal scripts, such as Hebrew. Hebrew is a distinctive writing system as the printed letters primarily represent consonants, while the vowels are mostly omitted from text (see Frost, 2005, for details on the structure of Hebrew). There is some evidence from word recognition studies with Hebrew readers (e.g., Schiff, 2003), that longer words (e.g., five-letter words) are identified more accurately than shorter words (e.g., four-letter words). The additional information provided by the supplementary letter arguably places the reader in a better position to more accurately predict the identity of the word.

The data from Experiment 6 suggested that MTS training with onsets and rimes or phonemes is more effective than training with CVC syllables when the aim is to promote recognition of untrained recombined CVC and CVCVC words. Although the syllable training with whole CVC words did not appear to facilitate recognition of recombined CVC words, it is possible that such syllable training may be more suited to enabling successful recognition of a different type of word, for instance, irregular words, which do not conform to expected letter–sound correspondences. In Experiment 7, recognition of regular and irregular words following training at different grain sizes was investigated.

Chapter Eight

Experiment 7: The Print–Sound Consistency Problem

8.1 Introduction

Varying the size of the linguistic unit used to train the sound–symbol relations in Experiment 6 did appear to influence how accurately the participants could recognise the recombined words. Adults who participated in the onset and rime or phoneme training correctly identified a larger number of the recombined words than the syllable participants. Hence, the data were suggestive of a possible advantage for MTS training procedures utilising smaller sized units (such as phonemes, onsets and rimes), as opposed to larger units (such as syllables), when the aim is to promote recognition of novel CVC and CVCVC words.

In Experiment 6, the invented script from which the test words were constructed resembled an alphabetic type script. Although the defining characteristic of an alphabetic script is that printed letters (graphemes) map onto specific sounds (phonemes), the nature of these mappings can be far from straightforward.

As first described in Chapter 1, there are some alphabetic scripts, examples of which include Italian, Greek, and Finnish, in which a particular printed letter is associated almost unfailingly with only one pronunciation, and likewise, that pronounced sound is nearly always represented by the same printed letter. Collectively, such alphabetic scripts in which there are constant one letter–one sound relations are referred to as 'shallow' orthographies (see Katz & Frost, 1992).

Given that in Experiment 6, each abstract symbol was associated with only one particular sound, the invented script employed may be described as a shallow alphabetic type script.

Throughout these experiments, the MTS protocol has been modified and tested with a view to employing similar procedures with a small group of children with LD who have been experiencing problems in learning to read in English. However, English is not categorised as a shallow alphabetic script. Rather it is grouped amongst the second type of alphabetic script to which we now turn.

There are other alphabetic scripts which are characterised by a lack of consistency in their letter–sound relations. Such inconsistent scripts are referred to as 'opaque' or 'deep' alphabetic scripts due to the complexity of the associations between its letters and sounds. English is a prime example of such an inconsistent script (please see p. 112 for further details).

Research has shown that reading development is influenced by the type of orthography that a child learns to read (see Seymour, Aro, & Erskine, 2003; Ziegler & Goswami, 2005). Bearing in mind the inconsistency of letter–sound mappings in English, learning to read in English has often been described as an extraordinarily challenging task (Borgwaldt, Hellwig, & de Groot, 2005; Share, 2008). As mentioned in Chapter 1, beginning readers of English must cope with regular *and* irregular words.

Broadly speaking, words can be differentiated in terms of regularity (i.e., can a word be pronounced by reference to expected letter–sound patterns?) However, some researchers (e.g., Glushko, 1979; Jared & Seidenberg, 1990) suggested that this distinction (regular versus irregular words) was in itself not sufficient when classifying words. It was proposed that, rather than focusing exclusively on the regularity of a word, it was also necessary to reflect on the 'consistency' of a word.

Terms such as 'regular' and 'consistent' are often used alongside each other in the word recognition literature. These terms, however, are quite different (see Plaut et al., 1996; Yap & Balota, 2009, for further explanation). As previously alluded to, regularity is commonly used when describing if a word can be correctly pronounced through application of letter–sound correspondences. Consistency refers to whether words that are constructed from similar letter stings are pronounced in the same way (i.e., if similarly spelled words are *consistently* pronounced in a similar way).

Measures of consistency tend to be calculated through inspection of the rime unit, which is the initial vowel and remaining consonants (see Treiman et al., 1995), with words that contain the same rime compared. Together these rime sharing words may be referred to as a 'neighbourhood' (see Jared, McRae, & Seidenberg, 1990; Treiman, Goswami, & Bruck, 1990).

A word may be described as 'consistent' if its pronunciation is identical to that of other words which also contain the same printed rime sequence (i.e., neighbours). An example of a consistent word is 'gate'. All rime sharing words within the neighbourhood for the word 'gate' are all pronounced identically (e.g., 'date', 'hate', 'late', 'mate'). The pronunciation of the rime 'ate' does not deviate across neighbours.

Alternatively, the word 'pint' is an example of an inconsistent word. The pronunciation of the rime 'int', as found in the word 'pint', differs from how the rime is pronounced in other rime sharing neighbours (e.g., 'hint', 'mint', 'tint', 'print'). Jared, McRae, and Seidenberg (1990) further suggested that rime neighbourhoods could be subdivided into 'friends' and 'enemies' (see also Treiman et al., 1995). Neighbours that share an identical rime pronunciation are deemed to be 'friends' (e.g., 'hint', 'mint', 'tint', and 'print'). Neighbours that require an alternative pronunciation for the same string of letters are considered to be 'enemies' (e.g., 'pint').

According to dual-route theories of reading in cognitive psychology (e.g., Coltheart et al., 1993, 2001) it is assumed that two pathways are required for proficient word recognition. The indirect nonlexical route which relies on the application of grapheme-to-phoneme mappings to identify words can only be used to recognise regular words. Irregular words that violate letter–sound correspondences cannot be accurately read aloud through this pathway. Instead, it is the direct, lexical route that caters for irregular words through use of orthographic and phonological lexicons containing information on whole words, letter sequences, and associated pronunciations. Given the greater efficiency of the direct pathway, familiar regular words will also be read aloud via the direct pathway. Novel regular words (or nonwords) that are not represented in the lexicon are presumed to be processed through the indirect route.

Proficient reading in English therefore requires identification of regular and irregular words, consistent and inconsistent words. Being able to recognise irregular words and inconsistent words is perhaps especially important given that a large proportion of irregular words are high frequency words that tend to be encountered early on in reading development (e.g., words such as ‘what’, ‘have’, ‘was’, ‘said’, and ‘the’).

The final adult experiment in this research was designed to investigate if the MTS protocol could be suitably employed to facilitate recognition of words that do and do not conform to typical sound–symbol correspondences.

8.2 Outline of Experiment 7

By definition, as an irregular word is composed from atypical letter–sound correspondences, if an attempt were made to ‘sound out’ each letter based on its expected pronunciation, this would likely result in an incorrect (regularised) pronunciation for the irregular word. Generally, beginning readers learn to read aloud irregular words through whole word instructional approaches (e.g., Nielsen & Bourassa, 2008; Snow & Juel, 2005). The focus is on recognising the word as a whole or 'by sight', rather than relying on common letter–sound mappings to sound out (i.e., decode) individual letters.

In Experiment 6, all of the CVC and CVCVC words presented can be described as regular, consistent words. The symbols found in the recombined words were pronounced in line with the previously learned associated consonant or vowel sounds. Additionally, the –VC rime pairs (e.g., 'af', 'ek', 'ol', 'im') were always pronounced in the same way across test words containing that particular rime.

Thus, the results from Experiment 6 are perhaps indicative that, in the context of the MTS protocol, the onset and rime and phoneme trained participants were more accurate than the syllable trained participants in recognising the regular, consistent words. It remains unclear however, as to how the different training conditions may influence recognition of irregular or inconsistent words. Possessing an established symbol–sound knowledge (as was suggested in Chapter 7 that the onset and rime and phoneme participants may have acquired from the training) may be of little use when faced with inconsistent words containing symbols that deviate from expected pronunciations. Arguably, if the syllable participants are taught to associate the whole word with its unique pronunciation, this might place them at an advantage for recognising such inconsistent words. These questions were investigated further in the final adult experiment.

In Experiment 7, the MTS protocol was modified to try and facilitate recognition of consistent and inconsistent words. For this experiment, consistent words were defined as words in which the rime unit (i.e., a sequence of symbols) was always pronounced in the same way across words containing that rime. Inconsistent words were words in which a rime unit was pronounced differently in certain words containing that rime. The inconsistent words were divided into ‘friends’ (i.e., words that share a common rime pronunciation) and ‘enemies’ (i.e., words in which the rime assumes a different pronunciation). Accuracy in recognising the consistent and inconsistent words was compared across three training conditions; training with onsets and rimes, phonemes, or syllables, to determine if there was an optimal training condition most associated with the efficient recognition of consistent and inconsistent words.

To try and facilitate word identification, the training was organised to reflect the frequency of rime pronunciations as occurred in the number of friend and enemy words for each rime (more details are provided in the Method). As far as is known, this was one of the first experiments to utilise a MTS protocol in an attempt to promote recognition of recombined consistent and inconsistent (friend and enemy) words.

8.3 Method

8.3.1 Participants

A convenience sample of 24 literate adults (14 males and 10 females) participated. They were recruited from an undergraduate student university population. Participants ranged in age from 18 years to 23 years (median = 19 years). Each participant had normal or corrected to normal vision and hearing.

8.3.2 Apparatus and Stimuli

Lists were compiled of existing consistent and inconsistent VCC, VVC, and VCV rimes within the English language. A consistent rime was defined as a rime that was always pronounced the same way across monosyllable words containing that rime. An inconsistent rime was defined as a rime that assumed a different pronunciation in certain monosyllable words in which that rime was featured. Five consistent and five inconsistent rimes that could potentially be formed into a wide range of nonwords were chosen from the lists. Rimes were selected to ensure that each of the five consistent and five inconsistent rimes began with one of the five different vowel sounds. The five consistent rimes were ‘ate’, ‘est’, ‘ilt’, ‘old’, and ‘uds’. The five inconsistent rimes were ‘ave’, ‘ead’, ‘int’, ‘ost’, and ‘ull’. Each spoken rime corresponded to three abstract symbols (each vowel and each consonant was represented by a unique symbol).

Five consonants (/s/, /y/, /k/, /n/, /v/) were selected as the five onsets that would be joined to the rimes to form the complete nonwords. Again, each onset was represented by one symbol. Note that for this experiment, a consonant operating as an onset could also form part of the rime unit; thus a symbol could appear twice in a nonword to represent a particular consonant sound.

The five onsets were joined to the five consistent and five inconsistent rimes to form the recombined consistent and inconsistent nonwords. Any combinations that resulted in actual words (e.g., /nest/, /sold/, /save/) were excluded. In total, 16 recombined consistent nonwords (e.g., /yuds/, /nold/, /vilt/) and 23 recombined inconsistent nonwords (e.g., /yint/, /vost/, /yave/) remained.

Table 8.1 shows the associated sounds and symbols for both the onsets and the consistent and inconsistent rimes. As in previous experiments, all symbols were presented and read from bottom-to-top.

Table 8.1 The five onset, five consistent rime, and five inconsistent rime sound–symbol relations. Examples of recombined onset–consistent rime nonwords and onset–inconsistent rime nonwords are also presented.

Training			*Testing*	
Onset sounds and symbols	Consistent rime sounds and symbols	Inconsistent rime sounds and symbols	Recombined onset–consistent rime nonwords	Recombined onset–inconsistent rime nonwords
/y/ - ❖	/ate/- □₪♉	/ave/ - □~♉	/yate/- ❖□₪♉	/yave/-❖□~♉
/s/ - ♓	/est/- ♉♓₪	/ead/ - ♉□♋	/sest/- ♓♉♓₪	/sead/-♓♉□♋
/v/ - ~	/ilt/ - ⊙>>₪	/int/ - ⊙✳₪	/vilt/- ~⊙>>₪	/kint/-⌖⊙✳₪
/n/ - ✳	/old/- ♌>>♋	/ost/ - ♌♓₪	/nold/-✳♌>>♋	/nost/-✳♌♓₪
/k/ - ⌖	/uds/- ▽♋♓	/ull/ - ▽>>>>	/kuds/- ⌖▽♋♓	/vull/- ~▽>>>>

Note. Symbols were presented and read from bottom-to-top.

In English, it is possible for inconsistent enemy words to have different rime pronunciations despite utilising the same printed rime (e.g., ‘cone’ versus ‘done’ versus ‘gone’). However for this experiment, for each inconsistent rime, there was only one other different rime pronunciation that was shared by all enemy nonwords for that inconsistent rime. Rime consistency percentages were computed for each of the inconsistent rimes to determine how many of the nonwords for each rime would function as friends and enemies.

The rime consistency percentages were calculated in line with a formula devised by Treiman et al. (1995). For each rime, lists of all monosyllable words containing that printed rime were obtained from the MRC Psycholinguistic database (Coltheart, 1981; Wilson, 1988). These monosyllable words were separated into two groups: (i) words in which the rime was pronounced identically (i.e., ‘friends’); (ii) words in which the same rime was pronounced differently (i.e., ‘enemies’).

To calculate the percentage consistency for each rime, the number of friends was divided by the combined total of friends and enemies. In addition to computing the rime consistencies, the mean written frequencies for friend and enemy monosyllable words were calculated for each rime using the Kucera-Francis written frequencies from the MRC Psycholinguistic database (Kucera & Francis, 1967). For the purposes of the current small scale experiment, the Kucera-Francis frequency norm was deemed appropriate for use as it is one of the most widely available, frequently employed word frequency counts used in studies of word processing and word recognition. The Kucera-Francis list also correlates well with other measures, particularly for high frequency words (see Balota, Pilotti & Cortese, 2001).

When the five onsets were joined to each inconsistent rime, there were at least four or five possible nonwords (excluding any actual words). Together, the rime consistencies and mean written frequencies were used to decide on the ratio of friends and enemies for each rime from a total of either four or five nonwords. Generally, higher rime consistency percentages resulted in more rime friends and fewer rime enemies. Once the ratio of friends to enemies had been established for each inconsistent rime, the required number of nonwords was selected to be the enemy nonwords for that rime. Rime consistencies, mean written frequencies, and the ratio of friends and enemies for each inconsistent rime may be viewed in Table 8.2.

Table 8.2 The five inconsistent rimes. For each rime, the computed rime consistency and mean written frequency for rime friends and enemies that were used to determine the number of friends and enemies for each rime are shown.

Inconsistent rime	*Rime consistency (monosyllable words)*	*Mean Kucera-Francis written frequency friend monosyllable words*	*Mean Kucera-Francis written frequency enemy monosyllable words*	*Total number of nonwords (excluding actual words)*	*Ratio of friends to enemies*
ave	61%	45.55	692.5	4	2:2
ead	42%	44.71	105.8	5	2:3
int	93%	31.26	13	5	4:1
ost	50%	136	186.86	5	3:2
ull	81%	9.83	98.33	4	3:1

Note. Certain enemy rime words have very high individual written frequencies (e.g., ‘have’ is included in the enemy word subset for the rime ‘ave’) which increased the mean written frequency.

The rime contained in the friend or enemy nonwords was pronounced in accordance with the rime pronunciation for actual (English language) friend or enemy words containing that printed rime. For example, the rime contained in the friend nonwords for the rime ‘int’, was articulated to match the pronunciation of ‘int’ as is heard in the actual rime friend words ‘hint’ and ‘tint’. Whereas the rime contained in the enemy nonword for the rime ‘int’ was voiced to match the pronunciation of ‘int’ as occurs in the actual enemy word for this rime, which is ‘pint’.

To distinguish the enemy pronunciations for each rime, reference was made to how actual words containing particular rimes were classified as friends or enemies in previous studies. For instance, Pexman, Trew, and Holyk (2005), listed ‘host’ and ‘bull’ as exemplars of the enemy words for the rimes ‘ost’ and ‘ull’ respectively (see also word lists used by Plaut et al., 1996). Thus, the pronunciation of the rime in these actual words was taken as the template for the pronunciation of the enemy nonwords for the rimes ‘ost’ and ‘ull’ in the current experiment. Table 8.3 shows the friend and enemy nonwords for each inconsistent rime accompanied by an actual word comparison as an indication of how the rime in each nonword was pronounced.

8.3.3 General Procedure

There were three training conditions: (i) training with onsets and rimes; (ii) training with phonemes; (iii) training with syllables (whole CVCC or CVVC nonwords). Eight participants took part in each training condition.

Table 8.3 Recombined inconsistent rime nonwords (friends and enemies).

Rimes	*Ratio of friends:enemies*	*Onsets* s	y	k	n	v
ave	2:2		yave (gave) ❖□~♉	kave (have) ⌖□~♉	nave[1] (gave) ∗□~♉	vave (have) ~□~♉
ead	2:3	sead (head) ♓♉□♋	yead (bead) ❖♉□♋	kead (bead) ⌖♉□♋	nead (head) ∗♉□♋	vead (head) ~♉□♋
int	4:1	sint (pint) ♓⊙∗₪	yint (hint) ❖⊙∗₪	kint (hint) ⌖⊙∗₪	nint (hint) ∗⊙∗₪	vint (hint) ~⊙∗₪
ost	3:2	sost (lost) ♓♌♓₪	yost (host) ❖♌♓₪	kost (host) ⌖♌♓₪	nost (lost) ∗♌♓₪	vost (lost) ~♌♓₪
ull	3:1	sull (gull) ♓▽>>>>	yull (bull) ❖▽>>>>	kull (gull) ⌖▽>>>>		vull (gull) ~▽>>>>

Note. The enemy nonwords for each rime are the highlighted nonwords in each row. Real word comparisons are included underneath the recombined nonwords to indicate how the rime found within each nonword was pronounced. Symbols were presented and read from bottom-to-top.

8.3.3.1 Pre-exposure task

One concern that arose during the preparation of the experiment was that some participants might experience difficulties completing the protocol. It was anticipated that some participants may have found the training and testing ambiguous given that the inconsistent rimes would be represented by the same sequence of symbols, but this identical string of symbols would have two different pronunciations. To try and alleviate confusion, a pre-exposure task was developed. This task was completed by all participants before the MTS training commenced.

The aim of the pre-exposure task was to try and increase awareness that the same sequence of symbols could have more than one pronunciation. Using the lists of consistent and inconsistent rimes in the English language, five consistent rimes (/act/,

[1] While 'nave' is a real word, it is of very low frequency. It does not appear in common frequency ratings, such as Thorndike and Lorge's (1942) corpus, the London-Lund Corpus of English Conversation by Brown (1984), or in the norms of Kucera and Francis (1967). It receives a (low) familiarity (FAM) rating of 203 in the MRC Psycholinguistic database values, which were derived by merging three sets of familiarity norms: Paivio (unpublished), Toglia and Battig (1978) and Gilhooly and Logie (1980). FAM values occur in the range 100 to 700 with the maximum entry of 657, a mean of 488, and a standard deviation of 99. Because of the constraints on nonword selection (e.g., pronounceable nonwords, shared onsets across nonwords etc.), this limited the possible nonwords for inclusion; therefore 'nave' was included as a stimulus.

/eld/, /ice/, /oat/, /usk/) and five inconsistent rimes (/and/, /eaf/, /ind/, /olf/, /ush/) not employed in the subsequent MTS training were chosen. Two nonwords were formed for each consistent or inconsistent rime by adding one of six onsets (/p/, /r/, /d/, /l/, /f/, /t/) to the rime. Each onset–rime nonword corresponded to a four symbol sequence. These symbols were different to those used in the MTS training.

The rime contained in the two nonwords for the consistent rimes was pronounced identically in each consistent rime nonword. For the two inconsistent rime nonwords, although the same sequence of symbols was used to represent the rime in each nonword, there were two different pronunciations for this rime. Examples of the consistent and inconsistent nonwords and rime pronunciations are shown in Table 8.4.

Rather than simply requiring the participants to listen to the nonwords and view the related symbol sequences, each nonword was associated with a picture of an object. Pictures were used to increase the meaningfulness of the task and to initiate a greater awareness in the participants that the same sequence of symbols could potentially have different pronunciations because the symbols (nonwords) were referring to different objects.

Table 8.4 Pre-exposure task consistent and inconsistent rime nonwords.

Consistent Rimes			*Inconsistent Rimes*		
Consistent nonword pair	Real word comparisons	Symbols	Inconsistent nonword pair	Real word comparisons	Symbols
bact	fact	♒ Φ ❐ ‽	pand	sand	⌘ Φ # §
lact	fact	± Φ ❐ ‽	rand	wand	¥ Φ # §
peld	held	⌘ ⁂ ± §	peaf	leaf	⌘ ⁂ Φ ☾
leld	held	± ⁂ ± §	beaf	deaf	♒ ⁂ Φ ☾
fice	mice	☾ Ж ❐ ⁂	tind	find	‽ Ж # §
tice	mice	‽ Ж ❐ ⁂	lind	wind	± Ж # §
loat	coat	± ◖ Φ ‽	dolf	golf	§ ◖ ± ☾
poat	coat	⌘ ◖ Φ ‽	lolf	wolf	± ◖ ± ☾
fusk	dusk	☾ ✚ ⭘ ◃	dush	rush	§ ✚ ⭘ ↑
pusk	dusk	⌘ ✚ ⭘ ◃	fush	bush	☾ ✚ ⭘ ↑

Note. Symbols were presented and read from bottom-to-top.

In total, participants completed 20 pre-exposure trials. The consistent and inconsistent nonword pairs were presented consecutively (i.e., ‘bact’ was followed by ‘lact’, ‘dolf’ was followed by ‘lolf’). However the five consistent and five inconsistent rime nonword pairs were presented in a quasi-random order (i.e., consistent pair trials could be alternated with inconsistent pair trials).

At the start of each trial, a nonword was played to the participant. After 2000 ms, a black and white picture appeared in the centre of the screen. Underneath the picture was a sequence of symbols that represented the spoken nonword. Participants were reminded by the experimenter in the initial instructions to look carefully at the symbols and to view the symbols from bottom-to-top. Once a participant had seen the symbols, he or she pressed the spacebar to continue with the next trial.

8.3.3.2 Training and testing matching-to-sample protocol

Across the three training conditions, the training and testing stages were (i) training for consistent rimes; (ii) testing for recombined onset–consistent rime nonwords; (iii) training for inconsistent rimes; (iv) testing for recombined onset–inconsistent rime nonwords (friends and enemies).

Participants completed sound-to-symbol and symbol-to-sound training and test trials which were identical in format to those utilised throughout the adult experiments previously reported. Likewise, the 90% accuracy criterion for passing a training or mixed test block was also observed. Practice trials were undertaken by all participants prior to the start of training.

Table 8.5 shows the training and test stages for participants in the three training conditions.

Table 8.5 Training and test stages completed in each of the three training conditions.

Condition 1 *Onsets and Rimes*	*Condition 2* *Phonemes*	*Condition 3* *Syllables*
Training for consistent rimes (/ate/, /est/, /ilt/, /old/, /uds/)		
Onset sound-to-symbol training	Initial consonant sound-to-symbol training	Whole word sound-to-symbol training
e.g., /s/ - ♓	e.g., /s/ - ♓	e.g., /sest/ - ♓♉♓₪
Onset symbol-to-sound training	Initial consonant symbol-to-sound training	Whole word symbol-to-sound training
e.g., ♓ - /s/	e.g., ♓ - /s/	e.g., ♓♉♓₪ - /sest/
Mixed onset testing	Mixed initial consonant testing	Mixed whole word testing
e.g., /s/ - ♓; ♓ - /s/	e.g., /s/ - ♓; ♓ - /s/	e.g., /sest/ - ♓♉♓₪; ♓♉♓₪ - /sest/
Rime sound-to-symbol training	Vowel sound-to-symbol training	
e.g., /ate/ - ☐₪♉	e.g., /a/ - ☐	
Rime symbol-to-sound training	Vowel symbol-to-sound training	
e.g., ☐₪♉- /ate/	e.g., ☐ - /a/	
Mixed rime testing	Mixed vowel testing	
e.g., /ate/ - ☐₪♉; ☐₪♉- /ate/	e.g., /a/ - ☐; ☐ - /a/	
	Final consonant sound-to-symbol, symbol-to-sound training, and mixed testing	
	e.g., (i) /t/ - ₪; (ii) ₪ - /t/; (iii) /t/ - ₪; ₪ - /t/	
Revision of onsets and rimes	Revision of initial consonants, vowels, final consonants	Revision of whole words
e.g., /s/ - ♓; /ate/ - ☐₪♉; ♓ - /s/; ☐₪♉- /ate/	e.g., /s/ - ♓; /a/ - ☐; /t/ - ₪ ♓ - /s/;☐ - /a/; ₪ - /t/	e.g., /sest/ - ♓♉♓₪; ♓♉♓₪ - /sest/
Spoken nonword-to-symbols, symbols-to-spoken nonword testing for 16 recombined onset–consistent rime nonwords		
e.g., /yest/ - ❖♉♓₪ ; ❖☐₪♉ - /yate/		
Training for inconsistent rimes (/ave/, /ead/, /int/, /ost/, /ull/)		
Rime symbols-to-sounds	Vowel symbol-to-sound	Whole word symbols-to-sounds
e.g., ☐~♉ - /ave/ [gave] ☐~♉ - /ave/ [have]	e.g., ☐ - /a/ [g*a*ve] ☐ - /a/ [h*a*ve]	e.g.,❖☐~♉- /yave/ [gave] ~☐~♉ - /vave/ [have]
Rime sounds-to-symbols	Vowel sound-to-symbol	Whole word sounds-to-symbols
e.g., /ave/ [gave] - ☐~♉ /ave/ [have] - ☐~♉	e.g., /a/ [g*a*ve] - ☐ /a/ [h*a*ve] - ☐	e.g.,/yave/ [gave] -❖☐~♉ /vave/ [have] - ~☐~♉
Symbols-to-spoken nonword, spoken nonword-to-symbols testing for 23 recombined onset–inconsistent rime nonwords (friends and enemies)		
e.g., ❖⊙∗₪ - /yint/ [hint]; /nost/ [lost] - ∗♌♓₪		

8.3.3.3 Training for consistent rimes

8.3.3.3.1 Onset and rime training condition

Training commenced with blocks of 20 onset sound-to-symbol trials, followed by blocks of 20 onset symbol-to-sound trials, and finally, one mixed test block of 10 onset sound-to-symbol and 10 onset symbol-to-sound trials. Five onset sound–symbol relations were taught (/s/-)(, /y/-❖, /k/-⌗, /n/-✳, /v/- ~). Each of the five onset sounds or symbols appeared four times as the sample in each block. The comparisons for each trial were comprised of the correct comparison sound or symbol and three incorrect comparisons selected from the remaining four sounds or symbols.

Next, the participants completed sound-to-symbol training, symbol-to-sound training and mixed testing for the five consistent rime sound–symbol relations (/ate/, /est/, /ilt/, /old/, /uds/). This training was identical to the onset training in terms of the number of trials etc.

Revision of the previously trained onset and consistent rime sound–symbol relations was then undertaken. Participants completed blocks containing 10 onset and rime sound-to-symbol training trials, followed by blocks of 10 onset and rime symbol-to-sound training trials.

8.3.3.3.2 Phoneme training condition

In this training condition, 13 individual sound–symbol relations were trained. Phoneme participants completed a sequence of sound-to-symbol training, symbol-to-sound training, and mixed testing for: (i) four onset sound–symbol relations (/s/, /y/, /k/, /n/); (ii) five vowel sound–symbol relations (/a/, /e/, /i/, /o/, /u/); (iii) four final consonant sound–symbol relations (/t/, /l/, /d/, /v/). Each initial consonant, vowel, or final consonant was presented four times as the sample within the training and mixed test blocks. Thus, participants completed blocks of 16 trials for the initial and final consonant training and blocks of 20 trials for the vowel training. Once the 13 individual sound–symbol relations had been acquired, revision blocks were attempted. Each individual sound–symbol relation was presented once as the sample in blocks of 13 sound-to-symbol training trials, followed by blocks of 13 symbol-to-sound training trials.

8.3.3.3.3 Syllable training condition

This condition entailed training with whole spoken nonwords and corresponding four symbol sequences (e.g., /yilt/ - ❖⦿>>₪). Five nonwords (/nate/, /sest/, /yilt/, /vold/, /kuds/), each utilising one of the five onsets and one of the five consistent rimes, were trained. To ensure that participants received the same amount of exposure to the sounds and symbols as the onset and rime and phoneme participants, each of the five spoken nonwords or four-symbol sequences was presented four times as the sample within the training blocks. Syllable participants completed blocks containing 20 sound-to-symbol training trials, 20 symbol-to-sound training trials, and 20 mixed test trials. Lastly, revision blocks of ten sound-to-symbol training trials, followed by ten symbol-to-sound training trials, were undertaken, with each of the five nonwords appearing twice as the sample.

8.3.3.4 Testing for recombined onset–consistent rime nonwords

Irrespective of training condition, all participants completed the same recombinative generalisation tests. This testing examined recognition of 16 nonwords that were formed by joining the five onsets and five consistent rimes (e.g., /yest/, /nold/). All participants completed one block of 16 spoken nonword-to-symbols test trials, followed by one block of 16 symbols-to-spoken nonword test trials.

Recognition of all 16 onset–consistent rime nonwords was assessed in each test block. As with the previous recombinative generalisation tests, particular care was taken in the construction of the comparison nonwords to ensure a sufficient overlap in terms of shared symbols or sounds between the correct comparison and the three incorrect comparisons.

8.3.3.5 Training for inconsistent rimes

The aim of this training was to provide the participants with exposure to the two different pronunciations for each of the five inconsistent rimes.

In the onset and rime training condition, participants were presented with the five inconsistent rimes (/ave/, /ead/, /int/, /ost/, /ull/) and training encapsulated the two different possible pronunciations for each rime.

As the inconsistency in a rime unit frequently arises due to variations in the pronunciation of the vowel contained within the rime (see Kessler & Treiman, 2001; Treiman et al., 1995; Vousden, 2008), the phoneme trained participants experienced training with the two different pronunciations for each of the five symbols associated with the five vowels (/a/, /e/, /i/, /o/, /u/).

Lastly, the syllable participants encountered training with all of the enemy nonwords for each inconsistent rime. In total, there were nine enemy nonwords that were trained (/kave/, /vave/, /sead/, /nead/, /vead/, /sint/, /kost/, /yost/, /yull/). These participants also received training with nine friend nonwords (/nave/, /yave/, /yead/, /kead/, /nint/, /vint/, /sost/, /vost/, /sull/) to ensure that the participants had sufficient exposure to all of the onset and rime sound–symbol relations. Thus, there remained five friend nonwords that were untrained (/yint/, /kint/, /nost/, /kull/, /vull/). These five nonwords were not used as comparisons during the training and were presented to the participants for the first time in the recombinative generalisation tests.

Participants in all three training conditions completed two blocks of symbol-to-sound training trials, followed by two blocks of sound-to-symbol training trials. It was essential that the symbol-to-sound training trials were presented first to enable the participants to actually hear the two different pronunciations for the sample symbol (phoneme trained) or symbols (onset and rime, and syllable trained) as the comparison sounds were played. If the sound-to-symbol training trials were presented first, choosing the correct symbol for the target sound may have been too easy for the participants, and they may not have realised that a symbol or symbol sequence could have more than one possible pronunciation.

There were 40 training trials in each block. Eight trials were assigned to each of the five inconsistent rimes. The eight trials were organised to reflect the ratio of friend nonwords to enemy nonwords for each rime. As an example, the rime /ave/ formed two friend nonwords (/nave/, /yave/) and two enemy nonwords (/kave/, /vave/). In four of the eight trials, the pronunciation of /ave/ or /a/, for the onset and rime or phoneme trained participants respectively, as found in the friend nonwords was trained. In the remaining four trials, the pronunciation of /ave/ or /a/, matched the pronunciation found in the enemy nonwords. The syllable participants completed two training trials for each of the friend nonwords (/nave/, /yave/) and each of the enemy nonwords (/kave/, /vave/).

Some slight alterations were made in the composition of the incorrect comparisons for this training stage. In the symbol-to-sound training, for the onset and rime and phoneme trained participants, the comparisons were comprised of the correct comparison sound (e.g., friend pronunciation for /ave/ or /a/ [as in gave]) and three incorrect comparison sounds (e.g., enemy pronunciation for /ave/ or /a/ [as in have], and a friend and enemy pair from one of the four remaining inconsistent rimes, such as, /ull/ or /u/ [as in gull] and /ull/ or /u/ [as in bull]).

For the syllable trained participants, the two possible pronunciations (friend and enemy) of each of the 18 explicitly trained nonwords needed to be included in the comparisons so that the participants could learn which pronunciation was correct for each nonword (i.e., is ‘yave’ pronounced to sound like /gave/ [friend] or /have/ [enemy])? Therefore, on each trial for the syllable trained participants, the correct comparison (e.g., /yave/ [as in gave]) was presented with the nonword containing the incorrectly pronounced rime (e.g., /yave/ [as in have]), and two nonwords that shared the same onset as the correct comparison but which each utilised a different rime pronunciation (e.g., /yull/ [as in bull] and /yull/ [as in gull]).

For the sound-to-symbol trials presented to the onset and rime and syllable participants, it was ensured that there was sufficient overlap between the symbols contained in the correct comparison and the incorrect comparisons. On the sound-to-symbol trials for the phoneme participants, the correct comparison was presented alongside three incorrect comparisons which were chosen from the four remaining vowel symbols.

Before the start of training, the experimenter reminded the participants to attend carefully to all of the symbols and sounds and encouraged them to try and persevere as best as possible with the task even though they might find it quite challenging at times.

The main source of difficulty arose because previously correct responses could be deemed as incorrect in subsequent trials. For example, a participant may have learned that the ‘friend’ pronunciation is correct for a three symbol rime. But when shown the same three symbol rime in a later trial that is actually a trial designed to train the alternative ‘enemy’ pronunciation for that three symbol rime, choosing the previously correct friend pronunciation for this trial would now be incorrect. It was important that learning the enemy rime pronunciations was not contextually controlled in some way, as although this would undoubtedly facilitate learning, no such cues exist in real life. For instance, it is only through practice, that beginning readers learn that ‘pint’ is pronounced one way, and ‘mint’ is pronounced another way. Thus, the participants were informed to expect a high number of incorrect responses in the inconsistent rime training, especially in the symbol-to-sound training.

8.3.3.6 Testing for recombined onset–inconsistent rime nonwords (friends and enemies)

In the final recombinative generalisation tests, recognition of each of the 23 possible nonwords (14 friends and 9 enemies) formed through combining the five onsets and five inconsistent rimes was examined. Nonwords categorised as friends shared the same rime symbol sequence and the same rime pronunciation. Nonwords that were enemies shared the same rime symbol sequence as the friend nonwords but a different rime pronunciation. Participants from all three training comparisons attempted the same two test blocks

First, the participants completed 23 symbols-to-spoken nonword test trials, during which, each of the four symbol sequences corresponding to the 23 spoken nonwords was presented once as the sample. Comparisons were constructed in line with the details outlined in the previous section for the comparisons presented to the syllable trained participants (e.g., two pairs of rime sharing nonwords each utilising one of the possible rime pronunciations, /yave/ [gave], /yave/ [have], /vave/ [gave], /vave/ [have]).

To conclude the experiment, the participants completed one block of 23 spoken nonword-to-symbols test trials. Each of the 23 nonwords was presented once as the sample spoken nonword.

8.4 Results

8.4.1 Consistent rimes

All onset and rime, phoneme, and syllable participants passed the consistent rime training stages. Tables 8.6, 8.7, and 8.8, show the number of training trials completed and percentage of correct responses for participants in each training condition. As can be seen from the tables, once participants had achieved the criterion for the initial sound-to-symbol training, they generally required only one block of symbol-to-sound training trials, before passing the mixed test for the previously trained sound–symbol relations at the first attempt.

Table 8.6 Number of trials completed to reach criterion across the consistent rime training for the onset and rime trained participants. Percentage correct in parentheses.

Participant	Onset sound-to-symbol training	Onset symbol-to-sound training	Mixed testing correct /20	Rime sound-to-symbol training	Rime symbol-to-sound training	Mixed testing correct /20	Onset and rime sound-to-symbol training	Onset and rime symbol-to-sound training
1	60 (72)	18 (100)	20 (100)	80 (69)	19 (95)	20 (100)	9 (100)	9 (100)
2	60 (78)	18 (100)	20 (100)	60 (70)	18 (100)	20 (100)	9 (100)	10 (90)
3	38 (83)	18 (100)	19 (95)	80 (78)	18 (100)	19 (95)	9 (100)	9 (100)
4	60 (57)	18 (100)	20 (100)	78 (76)	19 (95)	20 (100)	9 (100)	9 (100)
5	20 (90)	60 (70)	19 (95)	100 (63)	18 (100)	20 (100)	9 (100)	9 (100)
6	58 (68)	18 (100)	20 (100)	60 (63)	18 (100)	20 (100)	9 (100)	9 (100)
7	98 (53)	40 (93)	19 (95)	80 (55)	18 (100)	20 (100)	9 (100)	10 (90)
8	60 (83)	18 (100)	20 (100)	100 (52)	20 (90)	19 (95)	10 (90)	9 (100)

Table 8.7 Number of trials completed to criterion across the consistent rime training for the syllable trained participants. Percentage correct in parentheses.

Participant	Whole word sound-to-symbol training	Whole word symbol-to-sound training	Mixed testing correct/20	Whole word sound-to-symbol training	Whole word symbol-to-sound training
1	80 (69)	18 (100)	20 (100)	9 (100)	9 (100)
2	60 (77)	18 (100)	20 (100)	9 (100)	9 (100)
3	58 (68)	18 (100)	19 (95)	9 (100)	9 (100)
4	78 (60)	18 (100)	20 (100)	9 (100)	9 (100)
5	100 (56)	20 (90)	20 (100)	10 (90)	9 (100)
6	40 (80)	20 (90)	20 (100)	9 (100)	9 (100)
7	80 (54)	18 (100)	20 (100)	10 (90)	10 (90)
8	60 (70)	18 (100)	19 (95)	9 (100)	9 (100)

Table 8.8 Number of trials completed to reach criterion across the consistent rime training for the phoneme trained participants. Percentage correct in parentheses.

Participant	Initial consonant sound-to-symbol training	Initial consonant symbol-to-sound training	Mixed testing correct /16	Vowel sound-to-symbol training	Vowel symbol-to-sound training	Mixed testing correct /20	Final consonant sound-to-symbol training	Final consonant symbol-to-sound training	Mixed testing correct /16	Initial consonant, vowel, final consonant sound-to-symbol training	Initial consonant, vowel, final consonant symbol-to-sound training
1	62 (63)	14 (100)	16 (100)	40 (72)	18 (100)	19 (95)	48 (73)	15 (94)	15 (94)	12 (100)	12 (100)
2	64 (61)	14 (100)	16 (100)	58 (75)	18 (100)	20 (100)	62 (64)	14 (100)	16 (100)	12 (100)	13 (92)
3	64 (74)	14 (100)	15 (94)	60 (69)	18 (100)	20 (100)	32 (75)	15 (94)	16 (100)	13 (92)	12 (100)
4	48 (62)	16 (90)	15 (94)	40 (75)	38 (91)	19 (95)	64 (73)	14 (100)	16 (100)	13 (92)	13 (92)
5	46 (73)	14 (100)	16 (100)	78 (66)	20 (93)	20 (100)	46 (79)	14 (100)	15 (94)	26 (88)	12 (100)
6	80 (48)	14 (100)	16 (100)	60 (77)	18 (100)	20 (100)	78 (65)	14 (100)	16 (100)	12 (100)	12 (100)
7	64 (63)	14 (100)	16 (100)	100 (60)	18 (100)	20 (100)	48 (79)	15 (94)	16 (100)	12 (100)	12 (100)
8	32 (78)	16 (90)	15 (94)	58 (79)	20 (93)	19 (95)	30 (88)	15 (94)	16 (100)	13 (92)	12 (100)

For the recombinative generalisation tests for the consistent rimes, recognition of 16 different onset–consistent rime nonwords was examined. Table 8.9 shows the number of onset–consistent rime nonwords correctly identified by participants from the three training conditions.

Table 8.9 Number of recombined onset–consistent rime nonwords correctly identified by the onset and rime, phoneme, and syllable trained participants. Percentage correct shown in parentheses.

	Participant	Recombined onset–rime words (consistent rimes) spoken nonword-to-symbols test correct / 16	Recombined onset–rime words (consistent rimes) symbols-to-spoken nonword test correct / 16
Onsets and Rimes	1	16 (100)	16 (100)
	2	16 (100)	15 (94)
	3	16 (100)	16 (100)
	4	16 (100)	16 (100)
	5	13 (81)	14 (88)
	6	15 (94)	16 (100)
	7	15 (94)	15 (94)
	8	16 (100)	15 (94)
	Mean	15 (96)	15 (96)
Phonemes	1	15 (94)	16 (100)
	2	16 (100)	15 (94)
	3	16 (100)	16 (100)
	4	15 (94)	15 (94)
	5	15 (94)	12 (75)
	6	14 (88)	15 (94)
	7	16 (100)	16 (100)
	8	15 (94)	16 (100)
	Mean	15 (96)	15 (95)
Syllables	1	7 (44)	10 (63)
	2	11 (69)	13 (81)
	3	8 (50)	9 (56)
	4	12 (75)	11 (69)
	5	8 (50)	8 (50)
	6	9 (56)	11 (69)
	7	8 (50)	10 (63)
	8	7 (44)	10 (63)
	Mean	9 (55)	10 (64)

Overall, there was little difference in the performance of the onset and rime and phoneme participants on the spoken nonword-to-symbols and symbols-to-spoken nonword tests. Participants from both of these training groups correctly identified a larger number of the recombined onset–consistent rime nonwords compared to the syllable participants. The mean number of nonwords recognised by the onset and rime and phoneme participants was 15 nonwords in each test. Syllable participants recognised a mean of 9 nonwords in the spoken nonword-to-symbols test, and 10 nonwords in the symbols-to-spoken nonword test.

Figure 8.1 shows the mean percentage of onset–consistent rime nonwords correctly recognised by participants across the three training conditions.

On the spoken nonword-to-symbols test, onset and rime trained participants showed a mean accuracy of 96% (range, 81% to 100%). A high level of accuracy was also evident for the phoneme trained participants who demonstrated a mean accuracy of 96% (range, 88% to 100%). In contrast, the syllable trained participants were the least accurate in matching the 16 spoken nonwords to their corresponding symbols. Accuracy for the syllable trained participants ranged between 44% and 75%, with a mean accuracy of 55%.

A one-way between groups ANOVA was undertaken to explore the effect of unit size (onsets and rimes, phonemes, syllables) on accuracy in matching the recombined onset–consistent rime spoken nonwords-to-symbols. There was a significant effect for unit size on recognition performance, $F(2, 21) = 69.83$, $p < .001$. Post hoc comparisons using the Tukey test indicated that the onset and rime participants performed similarly to the phoneme participants ($p = .99$), and both onset and rime and phoneme participants were significantly more accurate in selecting the symbols corresponding to the onset–consistent rime spoken nonwords than the syllable trained participants ($p < .001$).

On the symbols-to-spoken nonword test, the mean accuracy was 96% for the onset and rime participants, and 95% for the phoneme participants (range, 88% to

100%, and 75% to 100%, respectively). Of the three training conditions, the syllable trained participants were the least accurate in choosing the correct spoken nonword to match the sample symbols. The mean accuracy for the syllable trained participants was 64% (range, 50% to 81%).

Again, there was a statistically significant effect for unit size on onset–consistent rime symbol-to-spoken nonword recognition accuracy, $F(2, 21) = 43.91$, $p < .001$. Tukey post hoc comparisons revealed no significant difference in the performance of onset and rime and phoneme participants ($p = .91$). The syllable trained participants were significantly less accurate in the symbol-to-spoken nonword test trials than the onset and rime participants ($p < .001$) and the phoneme participants ($p < .001$).

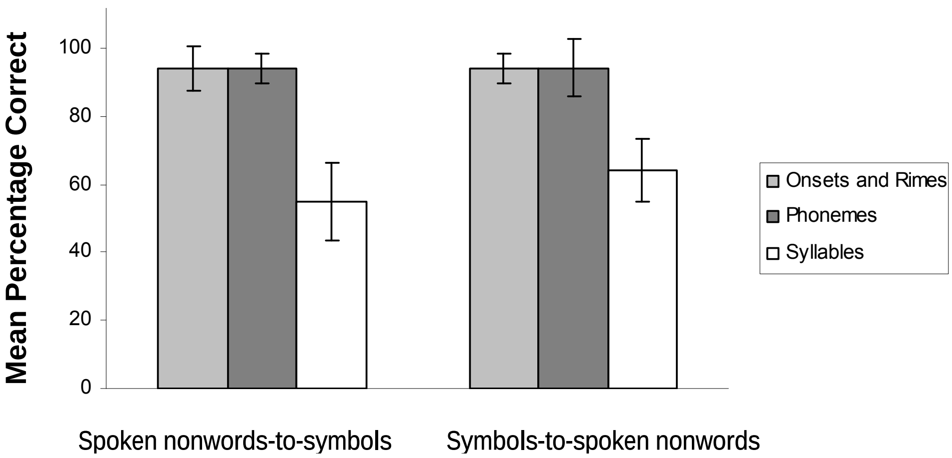


Figure 8.1 Mean percentage correct on the recombinative generalisation tests (matching spoken nonwords-to-symbols and symbols-to-spoken nonwords) for the recombined onset–consistent rime nonwords across the onset and rime, phoneme, and syllable training conditions. Error bars indicate standard deviation.

8.4.2 Inconsistent rimes

Table 8.10 shows the number of correct responses on the inconsistent rime training stages provided by each participant across the three training conditions. Participants completed two blocks of symbol-to-sound training trials, followed by two blocks of sound-to-symbol training trials, utilising onsets and rimes, phonemes, or syllables to train the sound–symbol relations.

Table 8.10 Number of correct responses on each of the two symbol-to-sound and two sound-to-symbol training blocks for the inconsistent rimes completed by the onset and rime, phoneme, and syllable participants. Percentage correct in parentheses.

	Onsets and Rimes		Phonemes		Syllables	
Participant	Rime symbol-to-sound training correct / 40	Rime sound-to-symbol training correct / 40	Vowel symbol-to-sound training correct / 40	Vowel sound-to-symbol training correct / 40	Whole word symbol-to-sound training correct / 40	Whole word sound-to-symbol training correct / 40
1	22 (55), 25 (63)	40 (100), 40 (100)	16 (40), 19 (48)	39 (98), 39 (98)	19 (48), 28 (70)	34 (85), 38 (95)
2	17 (43), 18 (45)	38 (95), 39 (98)	21 (53), 22 (55)	37 (93), 39 (98)	16 (40), 20 (50)	33 (83), 38 (95)
3	20 (50), 22 (55)	38 (95), 40 (100)	19 (48), 19 (48)	38 (95), 38 (95)	19 (48), 29 (73)	34 (85), 39 (98)
4	13 (33), 11 (28)	36 (90), 37 (93)	21 (53), 20 (50)	40 (100), 40 (100)	25 (63), 31 (78)	35 (88), 39 (98)
5	19 (48), 23 (58)	38 (95), 38 (95)	20 (50), 23 (58)	38 (95), 39 (98)	20 (50), 34 (85)	39 (98), 40 (100)
6	17 (43), 15 (38)	39 (98), 40 (100)	14 (35), 15 (38)	33 (83), 36 (90)	18 (45), 30 (75)	38 (95), 40 (100)
7	21 (53), 22 (55)	40 (100), 40 (100)	19 (48), 15 (38)	38 (95), 38 (95)	27 (68), 29 (73)	39 (98), 37 (93)
8	10 (25), 11 (28)	39 (98), 40 (100)	18 (45), 15 (38)	37 (93), 40 (100)	24 (60), 29 (73)	35 (88), 38 (95)

All participants responded correctly to a higher number of trials in the sound-to-symbol training than in the symbol-to-sound training. Onset and rime, phoneme, and syllable participants demonstrated at least 93%, 83%, and 83% accuracy respectively, in the sound-to-symbol training, with accuracy remaining similarly high in both blocks of sound-to-symbol training trials.

Notably, on the symbol-to-sound training, the syllable trained participants showed the greatest gains in accuracy when comparing performance on the first and second training blocks. On the first symbol-to-sound block, the mean accuracy was 53% for the syllable trained participants. This increased to 72% on the second symbol-to-sound block. For the onset and rime participants, the mean accuracy for the first and second symbol-to-sound blocks was 44% and 46% respectively. There was no difference in the mean accuracy for the phoneme trained participants which persisted at 47% for both symbol-to-sound training blocks.

Recognition of 23 recombined onset–inconsistent rime nonwords (14 friends and 9 enemies) was tested in the final recombinative generalisation tests. Table 8.11 shows the number of onset–inconsistent rime nonwords correctly identified by each participant across the three training conditions. Figure 8.2 shows the mean accuracy on the symbols-to-spoken nonword and spoken nonword-to-symbols generalisation tests for all participants.

Table 8.11 Number of recombined onset–inconsistent rime nonwords (friends and enemies) correctly recognised by onset and rime, phoneme, and syllable trained participants. Percentage correct in parentheses.

		Recombinative generalisation test onset–rime nonwords symbols-to-spoken nonwords			Recombinative generalisation test onset–rime nonwords spoken nonwords-to-symbols		
		Friends correct / 14	Enemies correct / 9	Total correct/ 23	Friends correct / 14	Enemies correct / 9	Total correct / 23
	Participant						
Onsets and Rimes	1	5 (36)	2 (22)	7 (30)	12 (86)	8 (89)	20 (87)
	2	3 (21)	2 (22)	5 (22)	14 (100)	9 (100)	23 (100)
	3	6 (43)	3 (33)	9 (39)	12 (86)	9 (100)	21 (91)
	4	5 (36)	2 (22)	7 (30)	13 (93)	7 (78)	20 (87)
	5	4 (29)	1 (11)	5 (22)	11 (79)	7 (78)	18 (78)
	6	4 (29)	2 (22)	6 (26)	14 (100)	9 (100)	23 (100)
	7	5 (36)	3 (33)	8 (35)	13 (93)	9 (100)	22 (96)
	8	3 (21)	3 (33)	6 (26)	14 (100)	8 (89)	22 (96)
	Mean	4 (31)	2 (25)	7 (29)	13 (92)	8 (92)	21 (92)
Phonemes	1	3 (21)	1 (11)	4 (17)	10 (71)	8 (89)	18 (78)
	2	3 (21)	3 (33)	6 (26)	11 (79)	7 (78)	18 (78)
	3	2 (14)	2 (22)	4 (17)	14 (100)	8 (89)	22 (96)
	4	4 (29)	3 (33)	7 (30)	13 (93)	8 (89)	21 (91)
	5	5 (36)	2 (22)	7 (30)	13 (93)	7 (78)	20 (87)
	6	4 (29)	2 (22)	6 (26)	13 (93)	8 (89)	21 (91)
	7	5 (36)	1 (11)	6 (26)	14 (100)	9 (100)	23 (100)
	8	4 (29)	1 (11)	5 (22)	12 (86)	7 (78)	19 (83)
	Mean	4 (27)	2 (21)	6 (24)	13 (89)	8 (86)	20 (88)
Syllables	1	7 (50)	7 (78)	14 (61)	7 (50)	8 (89)	15 (65)
	2	8 (57)	7 (78)	15 (65)	8 (57)	8 (89)	16 (70)
	3	5 (36)	6 (67)	11 (48)	7 (50)	8 (89)	15 (65)
	4	7 (50)	7 (78)	14 (61)	10 (71)	9 (100)	19 (83)
	5	5 (36)	4 (44)	9 (39)	6 (43)	6 (67)	12 (52)
	6	9 (64)	8 (89)	17 (74)	9 (64)	9 (100)	18 (78)
	7	7 (50)	6 (67)	13 (57)	6 (43)	7 (78)	13 (57)
	8	5 (36)	6 (67)	11 (48)	6 (43)	6 (67)	12 (52)
	Mean	7 (47)	6 (71)	13 (57)	7 (57)	8 (85)	15 (65)

8.4.2.1 Symbols-to-spoken nonword test (friends and enemies)

On the first symbols-to-spoken nonword test, the syllable participants were the most accurate in selecting the correct spoken word to match a given sequence of symbols. For the friend nonwords, the mean accuracy was 31% (range, 21% to 43%), 27% (range, 14% to 36%), and 47% (range, 36% to 64%), for the onset and rime, phoneme, and syllable trained participants respectively. For this first test, unit size did have a significant effect on the percentage of correct responses observed across the three training conditions, $F(2, 21) = 12.05$, $p < .001$. Post hoc comparisons using Tukey showed that the syllable trained participants performed with greater accuracy in recognising the correct friend spoken nonword to match a given symbol sequence than both the onset and rime participants ($p < .004$) and the phoneme participants ($p < .001$).

There was also a significant difference in accuracy in recognising the enemy nonwords on the symbol-to-spoken nonword test for participants from the three training conditions, $F(2, 21) = 39.48$, $p < .001$. Mean accuracy for the enemy nonwords was 25% (range, 11% to 33%), 21% (range, 11% to 33%), and 71% (range, 44% to 89%), for the onset and rime, phoneme, and syllable participants respectively. The syllable participants showed higher accuracy than both the onset and rime ($p < .001$) and phoneme ($p < .001$) trained participants when matching the enemy nonwords. Recall that the syllable trained participants received exposure to, and training with, the enemy nonwords in their entirety (i.e., how the enemy nonwords were pronounced). Conversely, the onset and rime and phoneme trained participants were exposed to the alternative 'friend' and 'enemy' pronunciations in isolation as occurred at the level of the rime (onset and rime trained) or vowel (phoneme trained), but could only guess when the friend or enemy pronunciation was appropriate for use when presented with a symbol sequence sample. Indeed, post hoc comparisons using Tukey revealed that the onset and rime and phoneme participants performed with similar accuracy when selecting the enemy spoken nonwords ($p = .50$). Through their whole word exposure, the training trials were designed to show the syllable trained participants when the enemy pronunciation was required and appropriate (i.e., in what symbol context is the enemy pronunciation needed). Given the superior performance of the syllable participants, the findings suggest that the whole word training was the most effective in facilitating enemy spoken nonword recognition.

8.4.2.2 Spoken nonwords-to-symbols test (friends and enemies)

The second generalisation test required the participants to choose the correct sequence of symbols corresponding to a sample spoken onset–inconsistent rime nonword. Accuracy was much higher for the onset and rime and phoneme trained participants on this test compared to their performance in the previous test.

Of the three training groups, the onset and rime participants were the most accurate in recognising the friend and enemy nonwords. These participants demonstrated a mean accuracy of 92% for both the friend and enemy nonwords (friend range, 79% to 100%; enemy range, 78% to 100%). The phoneme trained participants also showed high accuracy, achieving a mean accuracy of 89% (range, 71% to 100%) and 86% (range, 78% to 100%) for the friend and enemy nonwords respectively. Although the syllable trained participants correctly identified a smaller number of the friend nonwords than participants from the onset and rime and phoneme training groups, (mean accuracy = 57%; range, 43% to 71%), they did show high accuracy in matching the enemy nonwords. Enemy nonword recognition was superior to friend nonword recognition for the syllable trained participants, with mean accuracy reaching 85% (range, 67% to 100%).

There was a statistically significant effect for unit size on spoken nonword-to-symbol matching accuracy for the friend nonwords only, $F(2, 21) = 42.24$, $p < .001$. Although Tukey post hoc analyses indicated that there was no difference in the recognition performance of onset and rime participants compared to phoneme participants ($p = .84$), both the onset and rime and phoneme participants performed significantly better than the syllable participants ($p < .001$) in recognising the symbols for the friend spoken nonwords.

The effect of unit size on spoken nonword-to-symbol matching accuracy for the enemy nonwords did not reach statistical significance, $F(2, 21) = .97$, $p = .39$, with participants from the three training conditions demonstrating similar accuracy in identifying the symbol sequences to match a given spoken enemy nonword sample. Syllable trained participants received explicit training with all nine enemy nonwords but only nine of the fourteen friend nonwords that were presented in the test trials. This is one possible reason as to why enemy nonword recognition was better than friend nonword recognition for these participants.

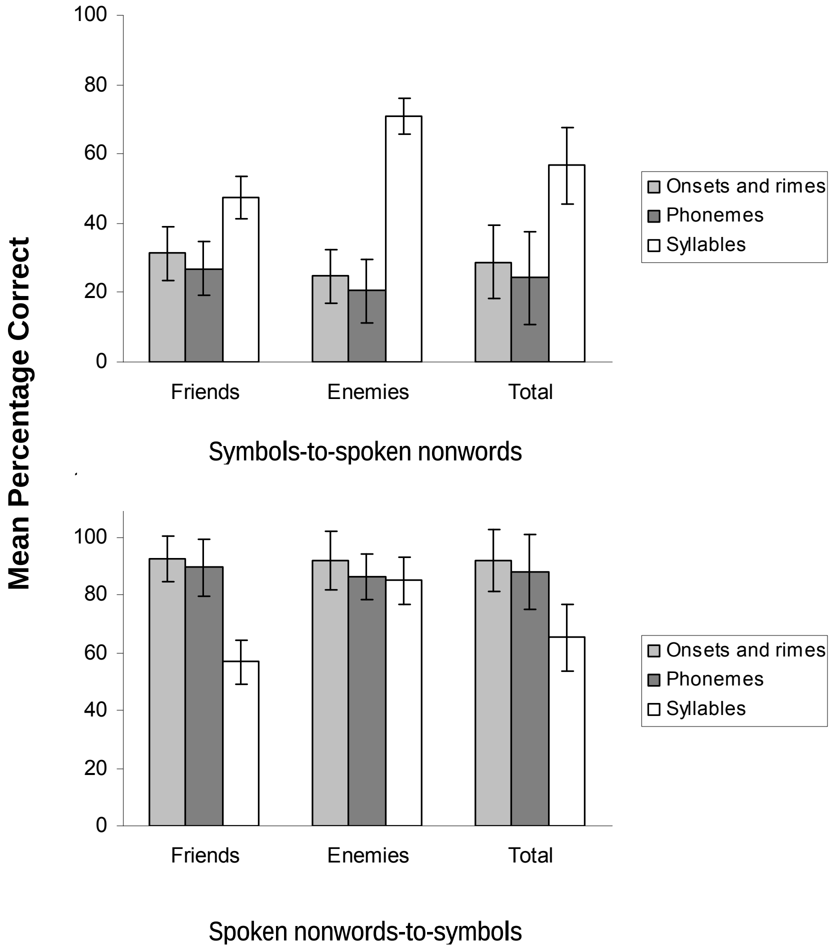


Figure 8.2 Mean percentage correct on the recombinative generalisation tests (symbols-to-spoken nonwords and spoken nonwords-to-symbols) for the recombined onset–inconsistent rime friend and enemy nonwords across the onset and rime, phoneme, and syllable training conditions. Standard deviation lines are shown for each bar.

8.5 Discussion

For this final adult experiment, modifications were made not only to the type of training completed by participants, but also to the consistency of the symbol–sound relations from which the recombined test words were formed. There was a particular interest in exploring how accurately participants could recognise recombined nonwords constructed from consistent rimes and inconsistent rimes following training with onsets and rimes, phonemes, or syllables. Although the findings obtained are preliminary, they do seem to suggest that there are advantages and disadvantages for the different MTS training procedures in terms of facilitating recognition of words containing consistent or inconsistent rimes.

Firstly, the onset and rime and phoneme trained participants appeared to have an advantage over the syllable trained participants when presented with the recombined consistent rime nonwords. While the syllable trained participants, on average, correctly recognised just over half of the consistent rime nonwords tested, the onset and rime and phoneme trained participants accurately identified nearly all of the consistent rime nonwords.

Recombined words that adhered to the sound–symbol mappings posed little difficulties for the onset and rime and phoneme participants. However, a very different finding emerged when the participants were presented with the recombined words constructed from the inconsistent rimes. For the symbols-to-spoken nonword test, it was the syllable trained participants who showed an advantage in recognising the correct spoken nonword to match a sample symbol sequence. This advantage was most apparent for the enemy nonwords, with the syllable trained participants correctly identifying considerably more of the enemy nonwords than the onset and rime or phoneme trained participants. The syllable trained participants also correctly recognised a greater number of the friend nonwords in the symbols-to-spoken nonword test, although the difference in performance between participants from the three training conditions in identifying the friend nonwords was much smaller.

Interestingly, this advantage for the syllable trained participants did not extend to the spoken nonword-to-symbols test. Overall, the onset and rime participants were the most accurate in recognising the friend and enemy nonwords in this second test. The onset and rime and phoneme participants demonstrated higher accuracy than the syllable participants in recognising the friend nonwords. However, the syllable trained participants demonstrated a high level of accuracy which was comparable to the phoneme trained participants in matching the enemy nonwords.

These findings suggest that the syllable training in which all enemy nonwords and a subset of friend nonwords were explicitly trained as whole words was beneficial, especially in facilitating recognition of the enemy nonwords. Although the onset and rime and phoneme participants completed training in which the two different possible rime or vowel (as found within the rime) pronunciations were presented, these participants were largely inaccurate in matching the enemy nonwords.

The syllable participants received direct instruction in how the enemy nonwords, in their entirety, were pronounced. Such explicit instruction in how whole words are pronounced has been suggested to be effective in promoting the recognition of irregular words. According to Rayner et al. (2001), with continual practice and exposure to words, beginning readers develop an awareness of how context can affect the pronunciation of both individual letters (i.e., phonemes) and larger units (i.e., rimes) found within words (see also Nielsen & Bourassa, 2008).

It may be suggested that the whole word training completed by the syllable participants may possibly have triggered some awareness in the participants of how context, in terms of an initial symbol or consonant sound, could affect the pronunciation of the remaining three symbol sequence (the rime) contained within that word. Thus, perhaps through their explicit whole word training, the syllable trained participants may have begun to learn that a rime symbol sequence is pronounced one way in a certain context (e.g., when the rime symbols are preceded by a particular symbol), and another way in a different context (e.g., when the same rime symbols are preceded by a different symbol this changes the pronunciation). As an example, the syllable participants may have learned in training that the rime /int/ is pronounced one way when combined with /s/ (/sint/ as in /pint/), and another way when joined with /y/ (/yint/ as in /hint/).

The onset and rime and phoneme participants did not have such a context-based knowledge established in their training, which instead focused on the vowel mappings and rime mappings in isolation. Although the training may have increased awareness that the pronunciation of a symbol or symbols was variable, these participants did not know when the variation in pronunciation occurred (i.e., in what context). This may have impeded enemy nonword recognition, at least in the symbols-to-spoken nonword test. A number of studies (e.g., Craig, Kim, Rhyner & Chirillo, 1993; Nittrouer & Boothroyd, 1990; Roe et al., 2000) have stressed the importance of context for beginning readers who are trying to decipher the pronunciation of a word.

Yet the onset and rime and phoneme participants demonstrated high accuracy in matching the enemy and friend nonwords presented during the spoken nonword-to-symbols test. It may be suggested that this test was simpler than the symbols-to-spoken nonword test. Participants did not have to choose between the enemy and friend rime pronunciation which increased the difficulty of the first test for those participants who did not know in which context the friend or enemy rime pronunciation was applicable.

Based on the supposition that the onset and rime and phoneme trained participants may have acquired a greater knowledge of the sound–symbol relations (as was discussed in Chapter 7), they may have relied upon their sound–symbol knowledge more when responding in the spoken nonword-to-symbols test. If they could see the symbols matching three of the sounds contained within the spoken nonword sample and could also deduce the correct vowel sound and corresponding symbol, they might have been able to pinpoint the correct comparison symbols for the spoken nonword, whether friend or enemy.

Noticeably, the syllable trained participants were not as accurate as the onset and rime and phoneme participants in recognising the friend nonwords in this second test. During the syllable training for the inconsistent rimes, the participants were exposed to all of the enemy nonwords, but only a proportion of the friend nonwords. Without explicit training with all of the friend nonwords, and perhaps with less knowledge of the individual sound–symbol discriminations, this may have reduced the syllable participants' ability to recognise all of the friend nonwords.

To summarise, the current findings suggest that each training approach, taken individually, appears to be insufficient for the recognition of both consistent and inconsistent (friend and enemy) words. While the onset and rime and phoneme training facilitates recognition of consistent words and inconsistent friend words, such training was not conducive to facilitating enemy word recognition. On the other hand, the syllable training with whole words was associated with more accurate enemy word recognition. Thus, when exception words were incorporated into the protocol, a whole word method seemed to be the most effective, at least for this size of vocabulary. However, the major disadvantage for the syllable training was that the participants were not as accurate in recognising the consistent nonwords.

These findings concur with data (e.g., Frith, Wimmer, & Landerl, 1998; Goswami et al., 1998; Seymour et al., 2003) showing that beginning readers of English (an inconsistent script) are less likely to sound-out unfamiliar words and are extremely poor at decoding nonwords compared to beginning readers of more consistent scripts such as Finnish, German or Spanish. The superior decoding performance of children learning to read more consistent scripts is thought to be directly linked to the unambiguous and highly predictable individual letter–sound relations within their language, a predictability that is largely absent from English when considering its individual letter–sound correspondences (see Caravolas, 2005).

What is perhaps needed is an amalgamation of the two training approaches. If we subscribe to the dominant dual-route view (e.g., Coltheart et al., 2001) that there are two pathways needed for proficient recognition of regular and irregular words, it is reasonable then, that any form of reading instruction should aim to tap into, make use of, and ideally develop both of these processes.

One option might be a MTS protocol that combines elements of the onset and rime training with the syllable whole word training component to promote consistent and inconsistent word identification. Integrating the two approaches together would ideally benefit the participants by establishing a more developed sound–symbol knowledge, which is essential to decode novel consistent words. It might also enable the participants to cope with inconsistent words that cannot be read through the application of sound–symbol mappings, by providing direct instruction in how such words are pronounced, and introducing the context in which the pronunciation for a rime can change.

The results from the current experiment also coincide with the findings from studies with beginning readers of English highlighting the detrimental effects to word recognition when only one form of reading instruction, decoding (i.e., applying letter–sound rules) or sight word reading (i.e., teaching whole words) is emphasised (see Seymour & Duncan, 2001). Seymour and Elder (1986) compared the reading skills of children who were taught using a whole word instructional approach, or who received a combination of sight word reading and decoding instruction. Only the children who experienced the mixed instruction incorporating both processes (i.e., reading by sight and reading by decoding) were capable of naming some novel words, and were observed to engage in both decoding and sight word reading practices. Conversely, children from the whole word training group made few attempts to read unfamiliar words, and were restricted in their ability to only read words that they had been explicitly taught (see also Bhattacharya & Ehri, 2004; Ehri et al., 2001).

Taken together, the overarching finding from previous studies and the current experiment, points to the importance of learning letter–sound relations to enable decoding of novel regular words, and learning to read some words (such as irregular or 'enemy' words) through whole word approaches. Although different training approaches were compared, the preliminary data is in accordance with the view expressed by Ziegler and Goswami (2005) in the psycholinguistic grain size theory that what is essential when learning to read inconsistent orthographies (such as English) is flexibility in the size of orthographic–phonological mappings that are acquired and applied. MTS training in isolation with either small grain sizes (e.g., phonemes, onsets and rimes) or larger grain sizes (syllables) did not seem to be sufficient to enable participants to tackle all possible words formed from the invented inconsistent script. Through the research with the children with LD, described in the remaining chapters, it was possible to develop such a MTS training procedure using a combination of small units (e.g., phoneme–grapheme relations) and large units (e.g., rimes, syllables, and whole words), and to explore the effectiveness of this 'flexible' training protocol for the children learning to read an inconsistent script such as English.

Furthermore, throughout the completion of the current experiment, it was observed that many of the participants from all training conditions did find the inconsistent rime training and testing challenging. Possibly, this may have been due to the quite abstract nature of the training and testing. It may be helpful to incorporate a stimulus equivalence type component into the protocol whereby participants would learn to relate spoken words and printed words with pictures of what the words are referring to. Such a stimulus equivalence component might help participants to learn and retain the different pronunciations of words containing the same printed rime when each word can be related to a unique picture. As part of the research conducted with the children with LD, such a MTS protocol including onset and rime, syllable and stimulus equivalence training components was developed. It is to this second part of the thesis to which we now turn.

Chapter Nine

Experiment 8A: Using the Matching-to-Sample Protocol with Children with Learning Difficulties

9.1 Introduction

Up to this point, the experiments reported have been conducted with adult participants. After modifications were made to the MTS procedures, it was necessary to test the suitability of these revisions, and the studies with the adults enabled this. Once established that the amended protocol was effective in promoting recombinative generalisation and facilitating recognition of novel recombined words, the next step was to extend the use of the protocol. Arguably this research was instructive in providing a glimpse into the different ways in which the protocol could potentially be used to support recognition of the types of words that beginning readers of English may be likely to encounter during reading instruction (e.g., consonant blend words, consistent words, exception words). The results from these experiments were not only informative, but they were encouraging. For example, participants could recognise untrained words formed from new onsets and rimes, they could identify consonant blend words. But the participants in question who demonstrated these performances were adults; adults who had already mastered the skill of reading in English. Although an invented alphabetic type script was employed that was modelled on English, there is no escaping the fact that because the adults were already able to read, this may have influenced, even improved, their performance on the recombinative generalisation tests. Through their reading experiences, the adults were all capable of forming relations between arbitrary symbols (letters) and sounds. A child who has not yet learned how to read may not be proficient in this relational process. As it stands, it could be that the protocol was effective in the previously reported experiments in facilitating recombinative generalisation skills with the adults because they had already acquired the relational process. It is too much of an extrapolation to assume that the protocol would be effective with children learning to read. What was needed then to rectify this problem was to see if the MTS procedures could be of any benefit to children who cannot read.

For the purpose of the current thesis, rather than investigating the use of the procedures with typically developing children, the focus was on whether the procedures could be used as a remedial aid to support the oral reading skills of a small group of children with learning difficulties (LD). Primarily, this was due to my own classroom experiences working with children at a school for children with mild learning disabilities, and my interest in exploring ways to facilitate learning for children from this population. While some of the children attending this particular school can read, other children have extremely minimal reading skills. To try and help these children experiencing problems in learning to read, it was felt that some of the children might benefit from taking part in the training procedures. Thus, in part, the aim of the current thesis was to see if the MTS protocol could be used as a remedial tool to help aid and hopefully improve the printed word recognition and word naming skills of a specific group of children with LD.

With appropriate instruction, practice and support, many children do learn to read in English. It is a skill that can be difficult for typically developing children to acquire, but for children with LD, learning to read can be an extremely difficult and challenging task (see Conners, 2003; Swanson & Hoskyn, 1998). Furthermore, research has highlighted that children with LD are more at risk of not acquiring basic reading skills compared to typically developing children (Cawley & Parmar, 1995).

Given the somewhat worrying nature of these findings, it might be expected that research investigating ways to facilitate reading skills in children with LD would be plentiful. Unfortunately, the great strides that have been made in terms of what is known about reading development and effective reading instruction for typically developing children have not been followed by similar advances in research geared towards helping children with LD learn to read (Saunders, 2007). The shortage of research exploring instructional practices to promote reading skills in children with LD was another reason why, the focus of this thesis was on using the protocol with children with LD, and not, at least for the current body of research, typically developing children.

It is widely recognised that children with LD constitute a heterogeneous group of learners, with varying cognitive abilities, strengths and weaknesses (see Bergeron & Floyd, 2006). What seems to be effective for one child will not necessarily be as effective for another child. Bearing all this in mind, it becomes increasingly important to try and develop procedures for children with LD that can be used to help support their reading skills, ideally procedures that can be tailored to meet individual needs and capabilities (see Verhoeven & Vermeer, 2006).

Several behavioural studies have pointed to the advantages of using MTS procedures specifically with children with LD (e.g., Connell & Witt, 2004; Lane & Critchfield, 1998), although there is little published data on the use of such methods to promote word attack skills, such as recombinative generalisation, in children from this population. This is surprising, especially as past research has indicated that children with LD find it particularly difficult to learn and utilise letter–sound mappings to read aloud unfamiliar words (e.g., Cawley & Parmar, 1995; Conners et al., 2006; Lovett, Laceranza, Borden, Frijers, Steinbach, & DePalma, 2000). Through the current research with the children with LD, it was possible to test the effectiveness of one particular MTS protocol as used in an actual applied classroom setting.

9.2 Learning to read in children with learning difficulties

Traditionally, sight word reading practices have been used to teach children with LD to read (e.g., Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Browder & Xin, 1998; Farrell & Elkins, 1995). Children are explicitly taught to recognise whole individual printed words, generally high frequency words (e.g., ‘and’, ‘the’, ‘she’) and words that are functionally important within the child’s environment (e.g., signs, objects). Undoubtedly, there are advantages to this approach. Children can quickly accumulate an ever-increasing repertoire of words that can be easily recognised. Moreover, research has shown that children with LD can benefit from sight word instruction (e.g., Browder et al., 2006; Hodapp & Fidler, 1999). Yet the main drawback of this approach is that children are taught to focus exclusively on whole words to the detriment of learning about the relations between letters and sounds. Consequentially, while recognition of words that have been deliberately taught is good, recognition of novel words that have not been taught is often very poor (e.g., Barudin & Hourcade, 1990). When sight-word instruction alone is practised, there is not the foundation of letter–sound knowledge in place required for decoding, that enables children to tackle unfamiliar words, which in itself, can be detrimental to reading development (Share, 1995; Snow, Burns, & Griffin, 1998; Stanovich, 2000).

As an alternative to sight word reading instruction, phonics-based strategies that focus on enhancing awareness of individual letter–sound relations have been employed. Somewhat mixed results have been reported when phonics orientated interventions have been used with children with LD. Practices that have included intensive instruction in sounding out words, blending sounds, and learning grapheme–phoneme correspondences have been associated with increases in word naming for both trained and untrained words (e.g., Calhoon, 2001; Conners et al., 2006; Hendrick, Katims, & Carr, 1999; Hoogeveen, Smeets, & Lancioni, 1989; Singh & Singh, 1988) On the other hand, however, Al Otaiba and Fuchs (2003) suggested that perhaps as many as 50% of children with LD may gain little from taking part in phonics-based instruction alone. Again, what is apparent from these studies is that, in terms of reading instruction for children with LD, there is no one universal approach that is suitable for all children with LD. Research incorporating various techniques and strategies is needed as it is through such exploration that effective practices can be uncovered.

To summarise, the aim of the current body of research was to see if the MTS protocol could be used as a remedial tool to support the oral reading skills of a small group of children with LD. A case study approach was adopted to focus on each child's individual progress.

Lastly, it is important to highlight that real words were used throughout the tasks with the children, as opposed to the nonwords employed with the adult participants. From an applied perspective, actual words were selected given that the children could potentially encounter these words in the future, and any gains in their ability to recognise and read aloud even a small number of actual words would be helpful for these children. Furthermore, from an ethical perspective, for these children who were already struggling to read actual English words, it was felt that using nonwords could be a potential source of confusion for the children.

When planning the research tasks, time was spent examining the types of reading materials that the children currently use in their classes (e.g., books found within the reading schemes followed, word lists used etc.,). As far as possible, the training and test words used in these studies were printed words that the children were unlikely to have received explicit reading instruction in their classrooms regarding how to read aloud (although they may have heard the words spoken before, but rarely directly related to the equivalent printed word). As described in the forthcoming chapters, baseline word recognition and naming measures were used to establish how many, if any, of the words the children were able to identify prior to the start of the training. This was balanced against a need to include some words that would be valuable for the children to be able to read aloud and recognise in terms of likelihood of future use.

Specific details will be provided on the selection of the words utilised with the children in the following sections, as relevant to each particular task.

9.3 Introducing the participating children

Seven children (four boys and three girls) attending a school for children with mild learning disabilities participated in this research. At the start of research, the children were aged between nine years and one month and thirteen years and four months. Two of the participants (Participants 4 and 6) have Down syndrome.

All seven children were previously assessed by educational or clinical psychologists. All of the children completed the Wechsler Intelligence Scales for Children (WISC IV), and were found to be functioning within the range associated with mild learning disabilities in terms of their full scale I.Q. (i.e., I.Q. between 50 and 70). Many of the children were reported to have difficulties with working memory, processing speed, verbal comprehension and vocabulary retention.

Specific measures of reading were also acquired through administration of the Wechsler Individual Achievement Test (WIAT-II) and the Phonological Assessment Battery (PhAB), (Fredrickson, Frith, & Reason, 1997). On the word reading measure of the WIAT-II, all of the children produced scores classified as “extremely low”. Likewise, on the pseudoword decoding measure, the children’s scores fell within the “extremely low” range. When using the PhAB to assess phonological awareness, many of the children were described as having underlying difficulties in attending to the sounds in words. Furthermore, some of the children were noted to have fluency difficulties relating to impairments in accessing and retrieving words from memory using typical letter–sound correspondences and phonological codes.

9.3.1 Ethical considerations

Ethical approval for the research with the children was granted from the University Ethics Committee. Prior to commencing the research, written consent was obtained from the principal and Governing Board of the school. After detailing the aims of the research, the principal provided a list of seven children experiencing difficulties in learning to read. Letters and consent forms explaining the nature of the research were distributed to the parents of the identified children (please see Appendix 2, p. 342). All of the parents provided written permission for their child to take part in the research. Parental permission was also sought and obtained for access to psychological assessments conducted with the children. When recording the responses of the children on the data collection sheets, each child was referred to by number, and never by name. The data sheets were securely stored within folders at all times.

For all tasks, the children were individually assessed by the researcher at a table set up in a quiet corner of a classroom. So as not to disturb the classroom routine of the participating children (or the other children present in the classroom), the children attempted the research tasks at times deemed suitable by their teachers. For example, when a child had yet to commence or had finished completing another activity.

From working with the children on multiple previous occasions, all of the children were already highly familiar with the researcher before the research began. A number of the tasks were constructed for use with the children, with reference to the types of classroom tasks that the children were familiar with (e.g., word matching tasks, use of whiteboards) and the interests of the children, which were observed from time spent with the children prior to the start of the research. The aim was to make the tasks as enjoyable and fun as possible for the children.

If during the sessions, a child displayed any signs of tiredness or lack of motivation, the researcher would tell the child that the task was nearly finished and would end the session as quickly as possible. Likewise, if a child was experiencing difficulties with a task, participation ended and the child was invited to complete an activity that he or she found enjoyable, such as playing a card game or using the computer. After discussion with class teachers, it was agreed that at the end of each task, regardless of performance, children were given a ‘reward’, such as a sticker or a sweet, which are both reward systems used in the participating school.

9.4 Baseline entry reading skills

Prior to commencing the recombinative generalisation training with the children, it was essential to obtain a baseline measure of the entry reading skills of each child to refer to alongside the psychological assessment measures.

There are many core skills identified as important contributors to reading development. Among the most widely acknowledged are phonological awareness, letter–sound knowledge, letter–name knowledge, and print exposure (e.g., de Jong, 2007; Foy & Mann, 2006; Hulme et al., 2005). For the baseline assessment, some of the most widely recognised component skills for reading were measured.

One of the factors influencing the selection of the baseline tasks was that the tasks needed to be suitable for use with children with LD. Hence, it was vital to ensure that the children could understand the task requirements, acquire and process the necessary information, and be able to signal or generate a response as an indication of their knowledge. The cognitive requirements of the tasks could not be too demanding. If a task was too cognitively complex, especially in terms of memory demands, the complexity of the task could conceal the appearance of the very skills that the task was designed to measure. Steps were taken to ensure that the tasks did not overburden cognitive resources and were sensitive enough to detect the required skill.

In particular, children with LD may experience deficits in auditory working memory (see van der Molen et al., 2007), and may be at a disadvantage when faced with tasks relying strongly on this memory system (see Alloway et al., 2005; Pickering & Gathercole, 2004). To reduce the load on verbal working memory, the tasks were designed and modified to incorporate visual stimuli such as pictures which could function as prompts of the given verbal material.

Sustaining attention may also prove challenging for some children with LD (e.g., Richards, Samuels, Turnure, & Ysseldyke, 1990; Sterr, 2004). Thus the tasks were designed to be as engaging and interesting as possible for the children through adopting ‘game-like’ procedures and requiring the children to make active responses (e.g., selecting stimuli, providing written responses if suitable) as well as verbal responses. Furthermore, the tasks were to be employed with a heterogeneous group of children who differed in terms of their learning difficulties, developmental ages, and chronological ages. Taking these factors into consideration, a number of the tasks were constructed as a series of levels, ranging from foundation levels designed to detect the emergence of skills to more advanced levels designed to measure the proficiency of a particular skill. All of the children could attempt the task initially, and the level of complexity that the task scaled to would be determined by the child.

The baseline tasks were piloted with five children with mild LD (two boys, three girls) whose ages were matched as closely as possible to the ages of the seven children participating in the research. These five children also attended the school at which the seven children taking part in the research were enrolled. These five children did not undertake any of the recombinative generalisation training. Piloting took place across April and June 2007. Following initial instruction and completion of the practice trials for each task, all five pilot children were able to attempt the set tasks. Across the tasks, no obvious difficulties were observed in the children's ability to understand the task requirements or respond to the trials. Thus, no changes were made to the format of any of the tasks.

9.5 Procedure for the baseline tasks

In total, 14 baseline tasks were employed to measure entry reading skills. A number of the tasks were adapted from assessments utilised in previous studies with children who are typically developing or were modified from tasks designed for use with children with Down syndrome. In all of the baseline tasks, real words were used. Sometimes, it was necessary to include both printed and spoken words within the tasks that the children may not have normally encountered in their classroom instruction.

The children completed the baseline assessments from September 2007 to April 2008. Sessions were completed where possible in the mornings. Session times were flexible; typically the length of time of the sessions ranged from 10 minutes to 30 minutes, depending on the participating child, motivation levels, the type of task being undertaken, classroom routines and commitments. Normally, one session was devoted to one task to avoid carryover effects.

With the exception of the phonological awareness tasks, the order of presentation of the remaining baseline tasks was randomised for each child. For the phonological awareness tasks, the children completed three preliminary item familiarity tasks over the course of two weeks. The order in which these three item familiarity tasks were undertaken by the children was counterbalanced. Subsequently the remaining five phonological awareness tasks were completed as soon as possible and the order of presentation of these tasks was individually randomised to ensure that the children completed the tasks in a different order. However for all of the baseline tasks, the order in which trials were presented within a task was identical for all of the children.

The set procedures for each task were adhered to as much as possible, however there was a certain degree of variation within the tasks in terms of examples and verbal assistance provided, which was determined by the strengths and needs of each individual child. Each task began with a practice session in which the researcher explained and visually enacted the task for the child. Following this demonstration, the child completed some practice trials with help and instruction from the researcher as was required.

Verbal feedback and encouragement was provided for the practice trials, and motivating comments (e.g., "well done") to help the child remain on task were used during test trials. In cases when a child sought confirmation for their response, the researcher repeated the instruction. All responses were recorded on specially prepared data sheets. If any cues or prompts were given to help a child complete a task, these additional comments were logged on the record sheet.

9.6 Outline of the baseline reading skills tasks

9.6.1 Letter–sound knowledge

Three tasks were employed to examine letter–sound knowledge for the 26 letters of the English alphabet: (i) recognition; (ii) production; (iii) writing. There was an interval of approximately one week between the completion of each task.

For the recognition task, knowledge of the corresponding sounds for all 26 lowercase and uppercase letters was examined. Trials were presented on a computer. For each trial, four printed letters (the target and three distractors) in lowercase or uppercase appeared across the screen in a horizontal line. Next, the target sound was articulated by the researcher, "can you point to the letter for /b/?", and the participant pointed to the letter on the computer screen to signal their response. If the participant did not respond or seemed puzzled, a further instruction was provided that included an example of a word familiar to the child that contained the target sound (e.g., "can you point to the letter for /b/, /b/ for /ball/).

The position of the target letter was counterbalanced across trials to ensure that the target letter could be found equally in each of the four letter locations. To try and ensure a more stringent recognition test, where possible, the distractors contained similar graphic features to the target letter (e.g., straight vertical or horizontal line, round curve, or tail). For example, when the target sound was /b/, the four printed letters of ‘d’ ‘b’ ‘p’ and ‘q’ were shown.

Half of the children commenced testing with the lowercase letters followed by the uppercase letters, while the other half of the children started with the uppercase letters followed by the lowercase letters.

For the production task, one of the 26 lowercase or 26 uppercase letters was shown on screen and the children were invited to say the sound of the given letter (e.g. “what sound does this letter make?”). All responses were transcribed by the researcher. If a child was unable to provide the sound, the researcher provided the sound for the child and the next trial commenced.

For the writing task, the children were provided with a small whiteboard on which they wrote down the letter corresponding to the target sound voiced by the researcher. Knowledge of all 26 letter sounds was examined. Either lowercase or uppercase letters were acceptable as written responses (the majority of children tended to write in lowercase letters).

9.6.2 Letter–name knowledge

The tasks used to assess letter–name knowledge were identical to the recognition, production and writing tasks used to measure letter–sound knowledge.

9.6.3 Reading of high frequency words

Children were presented with 64 high frequency words and were asked to read aloud each individual word as it appeared on the computer screen. In the school attended by the children participating in this research, the Dolch word lists (Dolch, 1941) and the Schonell Graded Word Reading Test (Schonell & Goodacre, 1971) are used to assess reading skills. For the current task, list words were selected from the high frequency words included in the National Literacy Strategy Framework, first published in 1998, which is a literacy programme implemented in primary schools in the United Kingdom. The high frequency words are classified by class level (e.g., Junior Infants, Senior Infants) and are denoted as words that children should be able to read easily for each particular class group.

The 64 high frequency words employed in the baseline task were derived from the words that children should be familiar with from the ages of four to seven years. Typical examples include words such as ‘and’, ‘they’, ‘said’ and ‘house’. Words were arranged on the lists to ensure that the children attempted the lower class level words before the higher class level words.

At present there is no equivalent version implemented in Irish primary schools. The English Curriculum Guidelines for Irish primary schools published by the Department of Education and Science (1999) state that children should be enabled to “build up a sight vocabulary of common words from personal experience, from experience of environmental print, and from books read” (p. 18). However, no lists of set words that should be taught are included.

9.6.4 Print exposure task

For this task, the children had to identify printed words that were exemplars of a specific category. Four categories or word sets were employed: (i) days of the week; (ii) colours; (iii) weather; (iv) animals.

As shown in Table 9.1, each word set was comprised of target exemplar words and distractor words. For each target word, there were three distractor words that were visually similar to the target words in terms of shared letters and number of letters.

For each word set, up to twenty printed words were arranged in a random order on the table in front of the child. After informing the participant as to the type and number of words that he or she would be looking for (e.g., five animals), a child was invited to find the printed words for that category. Depending on individual abilities, the number of printed words presented for each set could be reduced. For example, some of the children experienced a two or three word choice task choosing between the target printed word and one or two distractors for each target, rather than viewing all set words concurrently. The order in which the four word sets were presented was randomised for each child.

Table 9.1 Print exposure task stimuli.

Word Set Category	*Target Words*	*Distractors*
Colours	Red	Rid, Rod, Read
	Blue	Blur, Blot, Bled
	Green	Greek, Grain, Gleam
Weather	Sun	Sum, San, Set
	Rain	Raid, Rang, Rank
	Hot	Hat, Hop, Hid
	Cold	Cola, Colt, Coat
Animals	Cat	Cut, Cap, Can
	Dog	Dug, Dot, Dig
	Bird	Bide, Biro, Bike
	Hen	Hem, Her, Him
	Elephant	Eldest, Elegant, Elevator
Days of the week	Monday	Midway, Modify, Monkey
	Tuesday	Tumbly, Tutorly, Today
	Wednesday	Weekday, Waylay, Weeding
	Thursday	Thurify, Thirdly, Thundery
	Friday	Forsay, Flyway, Friary

9.6.5 Spelling of regular and irregular words

This task was included to explore the children's knowledge of typical letter–sound relations activated when spelling regular words, and their knowledge of irregular letter patterns where there is disparity between the letters used to represent sounds. It was partly modelled on a task utilised by Funnell (1996). The regular and irregular words consisted of ten concrete regular words (e.g., plum), ten concrete irregular words (e.g., crow), ten abstract regular words (e.g., it) and ten abstract irregular words (e.g., of).

For each set (concrete or abstract), the regular and irregular words were matched as far as possible on word length and CVC structure. Printed word frequencies were obtained from the Children's Printed Word Database (Masterson, Stuart, Dixon, & Lovejoy, 2003) for all task words. Regular concrete words (mean word frequency = 107.25, S.D. = 60.21) were of a similar printed word frequency to the irregular concrete words (mean word frequency = 114.70, S.D. = 118.85); $t(16) = -.161$, $p = .874$. Similarly, there was no difference in the printed word frequencies of the regular abstract words (mean = 2268.20, S.D. = 3673.58) and the irregular abstract words (mean = 3677.00, S.D. = 4500.03); $t(18) = -.767$, $p = .453$. The 40 words employed in this task can be viewed in Table 9.2.

Many of the abstract words were selected from the Dolch word lists (Dolch, 1941). Regular and irregular words were also derived from tasks used by Funnell (1996) and Masterson, Laxon, and Stuart (1992). Trials increased in complexity so that the children began spelling shorter words and progressed to attempting to spell longer words containing more syllables. Once the 40 words had been arranged in terms of advancing complexity, it was ensured that there was a sufficient mix of word types for the order in which the trials would be presented.

Table 9.2 Regular and irregular word spelling task stimuli.

Regular abstract words	*Irregular abstract words*	*Regular concrete words*	*Irregular concrete words*
at (vc)	as (vc)	jam (cvc)	cow (cvc)
it (vc)	of (vc)	zoo (cvv)	pie (cvv)
fun (cvc)	for (cvc)	rat (cvc)	foot (cvvc)
well (cvcc)	want (cvcc)	mud (cvc)	doll (cvcc)
lad (cvc)	was (cvc)	plum (ccvc)	crow (ccvc)
best (cvcc)	many (cvcc)	frog (ccvc)	knot (ccvc)
just (cvcc)	work (cvcc)	sock (cvcc)	pint (cvcc)
stop (ccvc)	know (ccvc)	stem (ccvc)	ghost (ccvcc)
seven (cvcvc)	begin (cvcvc)	napkin (cvccvc)	dance (cvccv)
drink (ccvcc)	brown (ccvcc)	mitten (cvccvc)	watch (cvccc)

For each trial, a strip of card divided up into six boxes was used. Letters were spread out on the table in front of the child. The five vowels (a, e, i, o, u) were always present in the letter array, alongside a mixture of necessary (target) and unnecessary (distractor) consonants. Care was taken to ensure that consonants that would seem to be correctly included within a word were amongst the letters. This was particularly important for the irregular word trials. As the number of letters in a word increased so did the number of potential letters. A letter could be placed in each of the boxes. Any boxes that would not be required were concealed to help to indicate to each child the number of letters that would need to be selected for the word.

Practice trials incorporating the child's name and four other highly familiar words ('my', 'so', 'and', 'look') were used to introduce the procedure. For each trial, the researcher spoke aloud with emphasis, the target word (e.g., "the word I would like you to spell is *jam*"), followed by a short sentence in which the word could be appropriately used (e.g., "I like to eat bread and *jam*") and ending with a final instruction "can you spell the word *jam*?" The sentence was provided in order to set the context for the target word.

9.6.6 Phonological/ orthographic neighbours word identification task

For each word, there are other words that sound similar, be it through the removal or addition of other letters. Any words that differ from a target word through the addition, subtraction or changing of a single phoneme can be combined to form a 'phonological neighbourhood' (see Luce & Pisoni, 1998). As an example, consider the word 'pray'. By adding, deleting and altering one phoneme from the word 'pray', the words '**s**pray', 'ray', and 'play' can be derived. These 'sound related' words may be referred to as 'phonological neighbours' for the word 'pray'. Similarly, there are words that appear visually similar in printed form to a target word without necessarily sharing phonological properties, and thus, might be described as 'orthographic neighbours' (see Sears, Campbell, & Lupker, 2006). For example, for the target word 'sand', possible orthographic neighbours include the words 'send', 'said', and 'sang'.

The current task was included to explore how the children's word recognition skills were influenced by phonological or orthographic similarity.

Each child was presented with a printed sheet featuring six practice trials (three orthographic and three phonological trials) followed by sixteen test trials. The first practice trial always consisted of the child's name with an alteration to one of the letters (e.g., Tom/ Tam). Next, each child completed eight orthographic and eight phonological test trials. Trials were arranged in increasing complexity with regard to the number of orthographic or phonological neighbours (i.e., distractors) presented. Early test trials consisted of one distractor plus the target word, with the latter test trials incorporating three distractors plus the target word. The order of trials was arranged to ensure a suitable spread of each trial type. Target words were chosen from words that the children would be highly likely to hear on a regular basis within their home and school environments (e.g., door, food, house). Some of the children were able to read some of the words (e.g., mum), however these known words were included alongside unfamiliar words (e.g., gate) to see if the children could disregard the competing distractors that appeared similar to the known word to correctly identify the target word.

The target and distractor words varied in length from three letters to six letters. All of the target words had printed word frequencies per million between 81 and 3100 (M = 953.38, S.D. = 669.65) as listed on the Children's Printed Word Database (Masterson et al., 2003). Target words utilised in the phonological trials were of a similar printed word frequency to those employed in the orthographic trials (phonological target word frequency, M = 822.36, S.D. = 410.24; orthographic target word frequency, M = 1097.50, S.D. = 874.90; $t(19) = -.937$, $p = .360$).

In each trial, the target word and distractor words were printed in a row across the sheet and the children circled with a pencil the word that matched the target word articulated by the researcher. The researcher instructed the children as follows "can you draw a circle around the word *door*?" A short sentence was also given to establish the context of the word, often incorporating the child's name (e.g., Tom close the *door*), followed by a reiteration of the target word (e.g., "*door*").

Predominantly actual words were used as distractors, although in the phonological type trials, it was sometimes necessary to include a nonword that did sound similar to the target word (e.g., house - hause). To create the phonological and orthographic distractors in the early test trials containing one or two distractors, one letter was added to, removed from, or changed from the target word, ensuring as far as possible that auditory or visual similarity between the target word and distractors was sustained. For the latter trials containing three distractors, as far as possible, it was ensured that one distractor had a different initial phoneme or middle letter to the target, one distractor had either a phoneme or letter added to, or subtracted from the target, and one distractor had a different end phoneme or letter to the target. (For example, pig – fig, ping, pick [phonological], and door – dour, donor, doom [orthographic]). A list of the practice and test trials and associated distractors may be viewed in Table 9.3.

Table 9.3 Stimuli for the phonological and orthographic neighbours word identification task.

Target word	*Trial type (phonological neighbours or orthographic neighbours)*	*Number of distractors*	*Distractors*
"Child's name"	Orthographic	1	
Fox	Phonological	1	Pox
Duck	Orthographic	1	Dock
Gate	Phonological	2	Mate, Gate
Pig	Phonological	2	Ping, Pick
Star	Orthographic	2	Scar, Start
Egg	Orthographic	1	Ebb
School	Orthographic	1	Scoot
Bear	Phonological	2	Pear, Beer
House	Orthographic	2	Hose, Hause
Car	Phonological	2	Kar, Core
Sea	Phonological	2	Tea, Sigh
Cat	Phonological	3	Kat, Chat, Cap
Boy	Orthographic	3	Bay, Bouy, Boa
Mouse	Phonological	3	Muse, Maze, Rouse
Dog	Orthographic	3	Dug, Doug, Dot
Man	Phonological	3	Nan, Main, Mine
Tree	Orthographic	3	True, Tre, Twee
Food	Phonological	3	Mood, Feared, Feed
Bed	Phonological	3	Bud, Bead, Bee
Mum	Orthographic	3	Mom, Mump, Mud
Door	Orthographic	3	Dour, Donor, Doom

Note. Practice trials are highlighted in grey.

9.6.7 Test of the Reception of Grammar

To assess the children's understanding of grammatical constructs, the Test of the Reception of Grammar – Version 2 (TROG-2) (Bishop, 2003), was administered. During the TROG-2, a child listens to a verbal statement (e.g., "the pencil is on the book") and points to one of four pictures that accurately depicts the spoken statement.

The TROG-2 is comprised of a series of blocks, with each block assessing a different grammatical element (e.g., negatives, pronoun binding). A child continues to attempt the trial blocks until five consecutive blocks have not been passed. After administering this test to each child, a standard score, percentile score, and age equivalent score were obtained for all of the children.

9.6.8 Working memory task

To obtain an approximate indication of the children's auditory short term memory, the children completed a short span based colour building task based on a colour memory test for children with Down syndrome developed by Laws (2002). Using four colours of multilink blocks (red, green, blue, white), the children listened to a string of colours spoken by the researcher and selected the corresponding coloured blocks in the correct order. Starting with a baseline colour string of two colours, the length of the colour string increased to a maximum length of eight colours. Trials were arranged by increasing string length, and the children needed to respond correctly to all of the trials for a specific string length before proceeding to the next string length.

9.6.9 Phonological awareness

Phonological awareness was assessed using five tasks (rime oddity, phoneme blending, alliteration, phoneme isolation, and rhyme awareness). The rime oddity, phoneme blending, phoneme isolation, and alliteration tasks were modelled on tasks devised by Kennedy and Flynn (2003) and Fletcher and Buckley (2002). The rhyme awareness task was developed for use in this research. Details of each task are provided in the following sections.

In total, 201 words were employed across the five phonological awareness tasks. All of the words could be represented pictorially and consisted primarily of distinct, concrete nouns. To reduce memory load, the majority of words did not exceed four letters in length. However word length exceptions were made for highly familiar words, for example, words such as ‘snake’ and ‘spider’.

Prior to attempting the five tasks, a two week period was designated for the children to complete three item familiarity tasks for the 201 words (word–picture identification task, word recognition task, word reading aloud task). The order in which these tasks were presented varied across the children. Once the item familiarity tasks had been undertaken, the phonological awareness tasks were administered. Again, the sequence in which the children completed the tasks differed for each child.

9.6.9.1 Rime oddity

Prior to the start of this task, the researcher briefly introduced the concept of ‘rhyming words’ to the children by providing some verbal examples of rhyming words and emphasising that all of these words ‘rhyme’ or ‘sound the same’.

Three pictures were presented in each trial: the target word; rhyming comparison word; and non rhyming comparison word. Once the researcher had named all three pictures, the child pointed to the comparison that rhymed with the target picture.

To increase the difficulty of the task, modifications were made to the non-rhyming comparison. The non rhyming comparison varied to yield four trials types as follows: the non rhyming comparison shared (i) the same initial phoneme as the target word (e.g., *k*ing, ring, *k*ite); (ii) the same medial phoneme as the target word (e.g., p*e*g, egg, n*e*t); (iii) the same final phoneme as the target word (e.g., boo*k*, hook, duc*k*); (iv) a semantic link to the target word (e.g., car, star, bike).

A minimum of six training trials with corrective feedback were completed. At least four correct responses were required in the training session to proceed to the testing trials. Twelve test trials without feedback were attempted; with three test trials allocated to each trial type (e.g., non rhyming comparison sharing initial, medial, final phoneme or semantic link). Table 9.4 lists the words presented in the practice trials and test trials.

Table 9.4 Rime oddity task stimuli.

Training Trials	*Testing Trials*			
	Initial	Medial	Final	Semantic
house	king	peg	bee	plate
mouse snake	ring kite	egg net	tree eye	skate cup
clock	thumb	bin	hen	rain
sock jug	drum three	pin lid	pen bun	train hat
frog	spoon	red	book	car
dog bell	moon spider	bed web	hook duck	star bike
wig				
pig tree				
bat				
cat bag				
nail				
tail boat				

Note. Rhyming comparison words are underlined in each trial.

9.6.9.2 Phoneme isolation

During this task the children listened to a spoken word articulated by the researcher and viewed the corresponding picture to this word. The aim of the task was for the children to identify and say aloud the initial phoneme in the presented word.

Six training trials and 14 testing trials were undertaken. The words employed in these trials may be viewed in Table 9.5. Familiar words were selected for use in the training trials to facilitate successful responding. Slightly more unfamiliar words were presented in the test trials to ensure that the children were focusing on the sounds of the words to voice the initial phonemes, rather than using the spelling of the words to derive the initial phonemes. Words started with a variety of phonemes so that awareness of a range of sounds was examined. In the training trials only, as the target word was spoken, the word was also simultaneously 'spelled out' using printed letters underneath the corresponding picture as an additional cue for the children that they were trying to identify the first sound in each word.

Table 9.5 Phoneme isolation task stimuli.

Practice trials	*Test trials*	
Dog	Brick	Girl
Cake	Crab	Witch
Pig	Face	Trunk
Ring	Lamp	Pip
Apple	Sled	Hive
Snake	Nose	Rake
	Jelly	Drum

9.6.9.3 Phoneme blending

In this task, each of the phonemes contained within a target word was articulated separately in sequence (e.g., /b/, /a/, /g/). The aim was for the child to select the picture comparison that correctly matched the spoken target word (e.g., 'bag' or 'bat'). To avoid overtaxing the phonological memory capacities of the children, none of the words exceeded four phonemes in length.

Table 9.6 shows the practice and test trial stimuli. Eight practice trials with feedback (four practice trials with one picture comparison, four practice trials with two picture comparisons) were completed. Next, participants attempted five test trials in which the comparisons shared the same initial phoneme (e.g., '*h*en', '*h*at'), five test trials in which the comparisons shared the same initial and medial phonemes (e.g., '*ba*g', '*ba*t'), and five test trials in which the comparisons only differed by the addition of one extra phoneme (e.g., 'net', 'nest').

Table 9.6 Phoneme blending task stimuli.

Practice Trials		*Test Trials*		
One comparison	Two comparisons	Initial phoneme	Initial and medial phoneme	Additional phoneme
/c/ /a/ /n/	/m/ /a/ /p/	/p/ /o/ /t/	/b/ /a/ /g/	/b/ /a/ /r/
can	map – mug	pot – pin	bag – bat	bar – bark
/p/ /e/ /t/	/l/ /e/ /g/	/h/ /e/ /n/	/w/ /e/ /b/	/n/ /e/ /t/
pet	leg – lion	hen – hat	web – well	net – nest
/s/ /u/ /n/	/d/ /e/ /s/ /k/	/r/ /u/ /g/	/b/ /u/ /s/	/f/ /a/ /n/
sun	desk – doll	rug – red	bus – bug	fan – flan
/t/ /a/ /p/	/v/ /e/ /s/ /t/	/f/ /o/ /x/	/d/ /o/ /t/	/t/ /i/ /n/
tap	vest – van	fox – frog	dot – dog	tin – twin
		/m/ /o/ /p/	/c/ /a/ /r/	/b/ /e/ /a/ /d/
		mop – man	car – cat	bead – bread

9.6.9.4 Alliteration task

Before the children attempted this task, the researcher reinforced the idea of words starting with the same sound by providing examples of words that shared the same first sound and emphasising this similarity.

For the task itself, on each trial, the children were presented with two comparison pictures that were labelled by the researcher (e.g., “lamb”, “frog”). A third target picture (positioned above the two comparison pictures) was then introduced and named by the researcher (e.g., “lamp”). The children were required to select the comparison picture that started with the same sound as the target picture (e.g., “can you pick up the picture that starts with the same sound as lamp”).

Six practice trials with feedback and 27 test trials without feedback were completed. Task items may be viewed in Table 9.7. Task words were chosen to test awareness of a range of initial sounds.

To increase task stringency, three different trial types were employed in the test trials in which variations were made to the comparison that did not share the same initial sound as the target (e.g., the non matching comparison). The trial types were as follows: (i) the non matching comparison shared an end match sound with the target (e.g., ‘zi*p*’, ‘zebra’, ‘cli*p*’); (ii) the non matching comparison shared a semantic link with the target (e.g., ‘*jug*’, ‘jumper’, ‘*cup*’); (iii) the non matching comparison did not share any initial, medial or final phonemes with the target, but was simply a general distractor (e.g. ‘*bug*’, ‘bus’, ‘*coat*’).

Table 9.7 Words presented in the alliteration task. The correct comparison is underlined for each trial.

Practice Trials	*Test Trials*		
	End sound match	Semantic link	General distractor
map	horse	coat	well
mat cup	house mouse	comb glove	web ring
bird	desk	leaf	bug
bike nest	deer mask	leg flower	bus coat
lamp	orange	pig	fox
lamb frog	octopus badge	pin cow	fork dog
green	zip	ant	yo-yo
grass train	zebra clip	axe butterfly	yogurt kite
money	bath	queen	hat
monkey flower	ball teeth	quilt crown	hand jar
whale	ear	vest	kite
wand table	egg car	van shirt	king bell
	tent	jug	sock
	teeth boat	jumper cup	sun knife
	line	nest	cap
	lion bone	net bird	cat ball
	rope	spoon	lid
	road pipe	spade fork	lips fox

9.6.9.5 Rhyme awareness task

The objective of this task was for the children to identify as many rhyming words as possible when presented with an initial target base rhyme. Each participant was presented with cards containing one to four pictures. The pictures functioned as the target base rhymes. Children selected the comparison pictures that rhymed with the base rhyme, and placed these pictures on top of that particular base rhyme. This task was designed to increase gradually in complexity in terms of the number of rhyming comparison pictures presented to be matched with the base rhymes. Initial cards featured base rhymes with one rhyming comparison. Depending on individual performance, the number of rhyming comparisons available to match a base rhyme was increased sequentially to two, three, four and five rhyming comparisons.

Non rhyming distractor pictures were presented alongside the rhyming comparisons for each card. Approximately eight to ten distractors were employed; the number of distractors utilised depended on the number of base rhymes and rhyming comparisons allocated to a particular card. Distractors were randomly selected from a set of cards depicting pictures that did not feature as base rhymes or rhyming comparisons for this task.

For each base rhyme, however, there were always three predetermined distractors included to more thoroughly test if the children were aware of 'rhyme', which would be demonstrated if they could choose the rhyming comparisons. These three distractors were as follows: (i) one distractor shared the same initial phoneme as a base rhyme (e.g., *h*ouse-*h*and); (ii) one distractor was semantically associated to the base rhyme (e.g., house-castle); (iii) one distractor was 'globally similar' to the base rhyme, (i.e., globally similar words appear as if they should rhyme when comparing the words as 'wholes' against each other, but the words actually do not rhyme, for example, house-horse).

The base rhymes, rhyming comparisons, and three fixed distractors for each base rhyme may be viewed in Table 9.8.

Table 9.8 Rhyme awareness task stimuli.

		Practice			
Base rhyme	Number of rhyming comparisons	Targets	Distractors Initial phoneme	Semantic	Global similarity
bag	one	flag	bell	box	bat
pot	one	knot	pin	cup	pet
flower	two	shower tower	fish	tree	floor
sock	two	lock clock	spoon	glove	soap
		Testing			
Base rhyme	Number of rhyming comparisons	Targets	Distractors Initial phoneme	Semantic	Global similarity
house	one	mouse	hand	castle	horse
fox	one	box	frog	dog	fog
shell	one	bell	snake	stone	small
bath	one	path	bone	soap	bat
van	one	can	vase	bike	vet
train	one	rain	tree	boat	tray
book	one	hook	ball	pen	boot
moon	one	spoon	mouse	star	man
nose	one	rose	nest	eye	note
sun	two	bun one	stone	moon	sand
cake	two	lake snake	cat	jelly	cave
bone	two	stone phone	bath	dog	bin
egg	two	peg leg	ear	hen	eye
hen	two	pen ten	hat	duck	hand
king	two	ring string	key	crown	kite
whale	two	snail tail	witch	sea	wall
dog	two	log frog	doll	cat	dot
coat	three	boat goat throat	comb	glove	cat
car	three	star jar guitar	cake	bike	cat
jug	three	mug plug bug	jelly	bowl	jar
bed	four	bread head shed red	ball	chair	bear
shoe	four	glue blue two queue	sock	boot	shop
bee	five	knee sea three tree pea	bath	flower	bell

9.7 Results from the baseline reading skills assessment tasks

Table 9.9 shows the scores obtained by each of the participants for the baseline assessment tasks and Table 9.10 presents the scores for the phonological awareness tasks.

Table 9.9 Baseline assessment performance (April 2008) on the reading skills tasks for each of the seven children. Percentage correct is shown in parentheses where appropriate.

Participant	1	2	3	4	5	6	7
Age	10 years 2 months	9 years 1 month	9 years 11 months	9 years 8 months	13 years 3 months	13 years 4 months	9 years 2 months
Sex	Male	Male	Female	Male	Male	Female	Female
Learning Disability (LD)	Mild LD	Mild LD	Mild LD	Mild LD, Down syndrome	Mild LD	Mild LD, Down syndrome	Mild LD
Letter-sound							
Recognition							
Lowercase	5 (19)	6 (23)	3 (12)	1 (4)	1 (4)	3 (12)	1 (4)
Uppercase	5 (19)	5 (19)	3 (12)	1 (4)	1 (4)	2 (8)	1 (4)
Production							
Lowercase	4 (15)	3 (12)	2 (8)	0 (0)	1 (4)	2 (8)	1 (4)
Uppercase	4 (15)	3 (12)	2 (8)	0 (0)	1 (4)	2 (8)	1 (4)
Writing	7 (27)	4 (15)	2 (8)	0 (0)	0 (0)	3 (12)	1 (4)
Letter-name							
Recognition							
Lowercase	22 (85)	24 (92)	24 (92)	23 (88)	19 (73)	25 (96)	20 (77)
Uppercase	25 (96)	26 (100)	26 (100)	19 (73)	18 (69)	24 92)	19 (73)
Production							
Lowercase	24 (92)	26 (100)	25 (96)	24 (92)	17 (65)	24 (92)	18 (69)
Uppercase	26 (100)	26 (100)	23 (88)	21 (81)	17 (65)	23 (88)	18 (69)
Writing	21 (81)	26 (100)	24 (92)	20 (77)	18 (69)	20 (77)	19 (73)
High frequency correct/ 64	14 (22)	17 (27)	8 (13)	2 (3)	3 (4)	5 (8)	3 (4)
Print exposure correct/ 17	13 (76)	11 (65)	8 (47)	4 (24)	4 (24)	5 (29)	5 (29)
Regular/ irregular spelling correct/ 40	3 (8)	10 (25)	3 (8)	0 (0)	0 (0)	0 (0)	0 (0)
Phonological/ orthographic neighbours correct/ 16	12 (75)	10 (63)	13 (81)	2 (13)	4 (25)	7 (44)	2 (13)
TROG standard score	88	55	78	55	55	55	55
Working memory span /8	5	5	4	3	3	4	3

Table 9.10 Baseline performance (April 2008) on the phonological awareness tasks for each of the seven children. Percentage correct is shown in parentheses.

Participant	1	2	3	4	5	6	7
Age	10 years 2 months	9 years 1 month	9 years 11 months	9 years 8 months	13 years 3 months	13 years 4 months	9 years 2 months
Sex	Male	Male	Female	Male	Male	Female	Female
Learning Disability (LD)	Mild LD	Mild LD	Mild LD	Mild LD, Down syndrome	Mild LD	Mild LD, Down syndrome	Mild LD
Rime Oddity correct / 12	8 (67)	8 (67)	6 (50)	4 (33)	5 (42)	6 (50)	3 (25)
Phoneme Isolation correct / 12	8 (67)	9 (75)	6 (50)	3 (25)	4 (33)	5 (42)	3 (25)
Phoneme Blending correct / 15	11 (73)	9 (60)	7 (47)	5 (33)	5 (33)	6 (40)	4 (27)
Alliteration correct / 27	24 (89)	25 (93)	22 (81)	8 (30)	11 (41)	16 (59)	6 (22)
Rhyme Awareness correct/ 23	19 (83)	18 (78)	14 (61)	10 (43)	12 (52)	13 (57)	7 (30)

9.7.1 Summary of outcomes

As shown in Tables 9.9 and 9.10, performance on the baseline reading skills tasks varied considerably for the seven participating children. Indeed, the only task on which the children performed similarly was the letter–name knowledge measure, with all seven children demonstrating good awareness of the corresponding letter names for printed letters. Most of the children had very little knowledge of the letter–sound relations, aside from Participants 1 and 2 who recognised a small number of letter–sound relations. Overall, Participants 1, 2, and 3 tended to produce higher scores on the reading skills tasks compared to the other four participants. For example, these three children named a small proportion of the high frequency words, identified a greater number of printed words, and responded to more trials correctly on the phonological awareness tasks. In contrast, Participants 4, 5, and 7, appeared to have less developed reading skills and less developed phonological awareness skills. These three children named almost none of the high frequency words, and tended not to score as highly across the reading skills measures as the remaining four participants.

Chapter Ten

Experiment 8B: Promoting Word Naming and Recognition Skills in Children with Learning Difficulties: The Role of Grain Size

10.1 Introduction

Once the baseline measures of each child's entry reading skills had been obtained, the next phase of the research was undertaken to examine if the MTS protocol could actually be used in a classroom setting as an aid to teaching recombinative generalisation skills and helping to improve the children's word naming and recognition accuracy. This preliminary research was important in highlighting any modifications that needed to be made to the procedures to bolster the effectiveness of the training in line with the learning requirements of each child.

Ambiguity surrounds how the size of the orthographic unit employed to teach print–sound mappings to children with LD may affect word reading skills. While the prominent role of larger onset and rime units for typically developing readers of English is well established (see Ziegler & Goswami, 2005), there is comparatively less data available to determine whether this also holds true for children with LD. Generally, interventions for typically developing children and children with reading disabilities without any learning disabilities incorporating onset and rime training have proved successful (e.g., Greaney & Tunmer, 1996; Greaney, Tunmer, & Chapman, 1997; Hines, 2009; Levy & Lysynchuk, 1997; Savage, Carless, & Stuart, 2003). In the main, both onset and rime and phoneme–grapheme training procedures have been associated with greater gains in reading compared to whole word training approaches for typically developing children (Christenson & Bowey, 2005; Walton & Walton, 2002).

Potentially though, children with LD may learn in a qualitatively different way than typically developing children (see Lemons & Fuchs, 2010), and practices that focus on promoting onset and rime awareness may not be the most effective approach to adopt. To date, studies with children with LD utilising onset and rime based instruction have proved inconclusive. Joseph and McCachran (2003) employed a word-sort phonics technique with eight children with mild mental retardation. The children were taught to categorise CVC words that shared similar rime spelling patterns and were encouraged to read aloud the rime sharing words (i.e., to read by analogy). When comparing pre-and post-training performance, Joseph and McCachran (2003) found little increase in word naming accuracy for untrained words, even though the words overlapped in terms of shared rimes with the words trained in the word-sort task.

In contrast, Cupples and Iacono (2002) evaluated the efficacy of whole word instruction versus a word analysis type instruction for children with Down syndrome. As part of the word analysis instruction, the children learned to blend onsets and rimes to form words. For the whole word teaching, the children matched spoken words and printed words. Only children who had completed the onset–rime based training demonstrated improvements in naming taught and untrained words (see also O'Shaughnessy & Swanson, 2000).

Without letting the children train with different units (e.g., onsets and rimes, phonemes, and syllables), it is virtually impossible to know what sized unit each child will respond best to. It may be that, while one child can quickly and easily learn about individual letter–sound relations, and can use this knowledge to recognise recombined words, another child might benefit more from syllable or onset and rime training. Furthermore, as detailed in Chapter 7, the key finding to emerge from Experiment 6 was that both onset and rime and phoneme trained participants correctly identified a significantly greater number of novel recombined CVC words than the syllable trained participants, and that there was little difference in the novel word recognition accuracy shown by onset and rime and phoneme participants. In the case of the adult participants, MTS training at smaller grain sizes (e.g., phonemes, onsets and rimes) rather than at a larger grain size (e.g., syllables) appeared to best facilitate novel word recognition. Yet it remained unclear as to whether there was a similar advantage for MTS training with onsets and rimes and phonemes over syllables for the seven children with LD taking part in this research. Thus, a further aim was to determine for each individual child, if there was a particular sized training unit that best facilitated the naming and recognition of novel recombined CVC words. By comparing word naming and recognition performance following training with onsets and rimes, phonemes, and syllables, it was possible to uncover if there was an optimal training unit for each child.

10.2 Method

There were three training conditions and the seven children all completed MTS training with: (i) onsets and rimes; (ii) phonemes; (iii) syllables.

10.2.1 Stimuli

For the onset and rime, phoneme, and syllable training, 13 different recombined CVC words were presented in each condition. The letter–sound relations taught for each training unit and the accompanying recombined CVC test words may be viewed in Table 10.1.

There were five different –VC rimes constructed for each training unit that utilised each of the five vowels (/a/, /e/, /i/, /o/, /u/). Initial consonant letters were joined to these rimes to form the 13 recombined CVC words. As actual CVC words were employed, there were some constraints on the initial letters employed and thus, there was some overlap in the initial letters that featured in the recombined words across the training conditions. For example, the letter ‘h’ was evident as a first letter for words in all three training conditions. However, where possible, different initial letters were used to try and decrease the amount of retraining and re-exposure that would occur when a child attempted subsequent training with a different sized unit.

There were no constraints on the selection of CVC words; the words simply needed to be direct recombinations of the taught units (whether onsets and rimes, phonemes, or syllables). As far as possible, care was taken to ensure that for each training condition, the 13 recombined test CVC words contained an assortment of highly familiar words grouped with less familiar words. There was no difference in familiarity ratings between the recombined words employed in the onset and rime training (M = 541, S.D. = 58.21), phoneme training (M = 506, S.D. = 74.71), and syllable training (M = 534.67, S.D. = 49.31), $F(2, 20) = .649$, $p = .533$. Additionally, the printed word frequencies of the recombined words utilised across the training conditions were similar, $F(2, 29) = .418$, $p = .662$.

Thirty CVC control words were also selected (as shown in Table 10.1). These words contained similar initial consonant letters to the recombined CVC test words, but featured entirely new rimes. There was some overlap in the control words in terms of shared rimes to resemble the recombinative aspects and overlapping of words present in the recombinative generalisation tests.

Table 10.1 The training units and recombined CVC test words presented in the onset and rime, phoneme, and syllable training conditions.

		Onsets and Rimes		
Trained Onsets	Trained Rimes		Recombined CVC test words	
t	ap		bap	bid
m	en		lap	hid
h	id		map	lid
b	oy		tap	boy
l	us		hen	toy
			men	bus
			ten	
		Phonemes		
Trained Phonemes	Trained Phonemes	Trained Phonemes	Recombined CVC test words	
r	a	b	hag	hop
h	e	d	mag	mop
w	i	g	rag	top
t	o	p	tag	mud
m	u	s	wag	rud
			web	tud
			his	
		Syllables		
Trained Syllables			Recombined CVC test words	
lad			had	lit
peg			*lad*	pit
hit			sad	sit
fox			leg	*fox*
sum			*peg*	hum
			fit	*sum*
			hit	
		Control CVC words		
mac	low	rob	fog	
mat	ton	rot	fun	
mug	tow	wax	fig	
ham	tub	won	set	
has	buy	wed	sob	
how	bay	pat	son	
let	bar	pan		
law	ram	pal		

10.2.2 Procedure

The study was comprised of three phases: (i) baseline assessments; (ii) MTS training and recombinative generalisation testing; (iii) follow up post-tests.

Trials were presented on a computer located in a quiet area of the classroom. The researcher controlled the presentation of trials, articulated the required letter sounds and words, and provided corrective feedback where appropriate. Practice trials utilising five different individual letter–sound relations were completed by all children in each training condition to ensure familiarity with the procedures.

10.2.3 Training trials

Two types of MTS training trials were used, letter-to-sound matching trials, and sound-to-letter matching trials.

For the letter-to-sound trials, a lowercase black letter (or letters) appeared in the centre of the screen. The sample letter remained on the screen throughout the trial. Between two to five different coloured stars could appear around the sample. As the researcher vocalised each comparison letter sound, she pointed to the star associated with that sound. For the initial trials, two sounds (the correct comparison plus one incorrect comparison) and corresponding stars were displayed to encourage the acquisition of the letter–sound relations. Depending on each child’s performance, the number of comparison sounds was gradually increased across trials if appropriate, and could be decreased again if the child was finding the task too challenging. To signal their response, the participant pointed to the coloured star (i.e., “position” of the sound) that matched the letter shown in the centre of the screen. A white intertrial screen appeared before commencing with the next trial. Both the colour and location of the correct comparison sound altered across the trials to try and prevent any response patterns.

For the sound-to-letter trials, a white screen featuring a coloured star was shown. As part of the practice trials, the children learned to touch the coloured star when they were ready to listen to the sound. After touching the star, the researcher pronounced the sample sound. Up to five black letters (or words) appeared on screen, one in the top centre and the remaining four slightly lower in each of the four corners of the screen. Again, the number of comparisons presented on screen was determined by the child's performance. The sample sound was repeated every two seconds until the participant pointed to one of the letters. This was followed by the appearance of the white intertrial screen.

Feedback was presented for the training trials only. At the start of each block of training trials the researcher placed a line of coloured blocks on the table in front of the participant and explained that the participant needed to build a chain to match that particular length. The length of the chain corresponded to the number of correct trials required to pass each stage. Each time a correct response occurred, the researcher said "very good that's right", and gave the participant a coloured block. Once each block of training trials had been completed, the child compared the length of their constructed chain to the target chain. If the criterion was met, the participant was given a small card emblazoned with a star, and these cards were exchanged for two sweets at the end of the session (providing single sweets is one of the forms of incentive and reward used at the participating school and thus was deemed appropriate to use in these studies).

For the incorrect trials the researcher said "let's try again" and the coloured block representative of a correct response was not presented.

10.2.4 Test trials

Test trials consisted of word recognition MTS test trials and word naming test trials using untrained, recombined words. The word recognition MTS test trials followed the same format as the sound-to-letter training trials, except that the correct comparison word was shown alongside three to four incorrect comparison words, and feedback was omitted.

For the word naming test trials, one printed word appeared in the centre of the screen for the participant to read aloud. All participants attempted the word naming trials followed by the word recognition test trials. In certain cases where a child was experiencing difficulties in naming the words, printed-word-to-spoken-word test trials were employed, which were identical to the letter-to-sound MTS training trials apart from the elimination of feedback for the test trials.

Phase 1: Baseline assessments

Prior to training, baseline recognition and word naming measures of the test and control words were obtained. For the word recognition task, the children pointed to the printed word that matched a sample spoken word. In each trial, three incorrect comparison words and the correct comparison word were shown. In the word naming task, individual printed words appeared on the screen for the children to read aloud. All of the children completed the reading aloud naming task first, and following a one day interval, attempted the recognition task.

Phase 2: MTS training and testing

Following completion of the baseline measures, and after a one week interval period, training and follow-up testing took place over a four month period. Two children completed the three training conditions in the same order (e.g., syllables, onsets and rimes, phonemes) and the remaining five children each completed the three conditions in a different order to ensure that all possible training combinations were undertaken.

For each training condition, training and the initial post-training testing took place on the same day. No time constraints were fixed on the length of the sessions, and the duration of training and testing varied for each participant, particularly as some participants required more training compared to others. Sometimes it was necessary to have a short break between training and testing. For each training unit, this was the only training with feedback that the children completed. There was no further training in the intervening times between the follow up post-tests. Table 10.2 shows the stages completed by participants in each of the three training conditions

Table 10.2 Overview of stages completed in each training condition.

Onsets and Rimes	*Phonemes*	*Syllables*
Onset sound-to-letter training	Onset sound-to-letter training	CVC spoken-word-to-printed-word training
/t/ - ‘t’, /m/ - ‘m’	/w/ - ‘w’, /h/ - ‘h’	/lad/ - ‘lad’, /hit/ - ‘hit’
Onset letter-to-sound training	Onset letter-to-sound training	CVC printed-word-to-spoken-word training
‘t’ - /t/, ‘m’ - /m/	‘w’ - /w/, ‘h’ - /h/	‘lad’ - /lad/, ‘hit’ - /hit/
Mixed onset test	Mixed onset test	Mixed CVC word test
/t/ - ‘t’, ‘t’ - /t/	/w/ - ‘w’, ‘w’ - /w/	/lad/ - ‘lad’, ‘lad’ - /lad/
Rime sound-to-letter training	Vowel sound-to-letter training	
/ap/ - ‘ap’, /en/ - ‘en’	/a/ - ‘a’, /o/ - ‘o’	
Rime letter-to-sound training	Vowel letter-to-sound training	
‘ap’ - /ap/, ‘en’ - /en/	‘a’ - /a/, ‘o’ - /o/	
Mixed rime test	Mixed vowel test	
/ap/ - ‘ap’, ‘ap’ - /ap/	/a/ - ‘a’, ‘a’ - /a/	
	Final consonant sound-to-letter training	
	/s/ - ‘s’, /p/ - ‘p’	
	Final consonant letter-to-sound training	
	‘s’ - /s/, ‘p’ - /p/	
	Mixed final consonant test	
	/s/ - ‘s’, ‘s’ - /s/	
Onset and rime sound-to-letter training	Onset, vowel, final consonant sound-to-letter training	CVC spoken-word-to-printed word training
/t/ - ‘t’, /ap/ - ‘ap’	/h/ - ‘h’, /a/ - ‘a’, /s/ - ‘s’	/lad/ - ‘lad’, /hit/ - ‘hit’
Onset and rime letter-to-sound training	Onset, vowel, final consonant letter-to-sound training	CVC printed-word-to-spoken-word training
‘t’ - /t/, ‘ap’ - /ap/	‘h’ - /h/, ‘a’ - /a/, ‘s’ - /s/	‘lad’ - /lad/, ‘hit’ - /hit
Recombined onset–rime word naming test	Recombined onset–vowel–final consonant word naming test	Recombined CVC word naming test
‘tap’, ‘map’	‘hop’, ‘his’	‘had’, ‘lit’
Recombined onset–rime CVC spoken-word-to-printed-word recognition test	Recombined onset–vowel–final consonant CVC spoken-word-to-printed-word recognition test	Recombined CVC spoken-word-to-printed-word recognition test
/tap/ - ‘tap’, /ten/ - ‘ten’	/hop/ - ‘hop’, /web/ - ‘web’	/had/ - ‘had’, /sad/ - ‘sad’

Training conditions

Onset and rime training

During onset sound-to-letter conditional discrimination training, participants were trained to match five onset sounds (/t/, /b/, /l/, /h/, /m/) to their respective printed letters. Each onset sound was presented five times as the sample within one block of 25 sound-to-letter trials. Up to four incorrect comparison letters (plus the correct comparison) could be presented. Depending on each child's attention and motivation, the 25-trial block could be divided into smaller blocks of five trials with short intervals between each block. Criterion to proceed to the next stage was set at 90% accuracy from one block of 25 trials.

During onset letter-to-sound symmetry training, 25 training trials were presented in a quasi-random order in each block. Training continued until accuracy reached 90% within one block of trials. Mixed onset test trials presented 10 onset sound-to-letter and 10 onset letter-to-sound test trials. Only one block was attempted, and if a participant did not fulfil the criterion of 18/20 correct responses, retraining commenced with the onset sound-to-letter training trials. Otherwise, a participant proceeded to the rime training stages.

Rime sound-to-letter conditional discrimination training, rime letter-to-sound symmetry training, and mixed rime test trials, were identical to their respective onset training or test trials, except that five rime sound–letter relations (/ap/, /en/, /id/, /oy/, /us/) were trained.

In the onset and rime sound-to-letter training, the five onset and five rime sound-to-letter relations were revised in blocks of 30 training trials (15 onset and 15 rime sound-to-letter trials). To pass this training, 27/30 correct responses from one block were required. Participants attempted a maximum of four blocks before returning to the onset sound-to-letter training if the criterion had not been achieved. The onset and rime letter-to-sound training was identical to the onset and rime sound-to-letter training, except that letter-to-sound training trials were employed.

Recombinative generalisation tests

Onset–rime CVC word naming test

The first recombinative generalisation test was a word naming test that examined if the children could read aloud 13 CVC words that were direct recombinations of the previously trained onsets and rimes (e.g., /tap/, /toy/). Each CVC printed word appeared twice on the computer screen in an order randomly determined prior to testing.

If a participant experienced difficulties in naming the recombined CVC words, a printed-word-to-spoken-word matching recognition test was employed as an additional measure. In such cases, the participant completed a block of 26 printed-word-to-spoken-word MTS test trials, the 13 onset–rime CVC words each appeared twice as the sample printed word and the participant was required to select the correct corresponding spoken word from a choice of five comparisons. The incorrect spoken word comparisons were words that overlapped with the correct comparison and remaining comparisons in terms of shared onsets or rimes. Further details on the construction of the incorrect comparisons are provided in the following section.

Onset–rime CVC spoken-word-to-printed-word recognition test

Participants attempted a single block of 26 spoken-word-to-printed-word test trials, with the 13 recombined onset–rime CVC words each featuring two times as the sample spoken word. After hearing the spoken word sample (e.g., /hid/), the correct comparison printed word and four incorrect comparisons were displayed on screen.

Care was taken in the construction of the incorrect comparisons to ensure that the children could not select the correct comparison solely on the basis of an onset or rime. Therefore, one comparison shared the same onset as the sample but a different rime (e.g., /hen/). A second comparison shared the same rime as the sample but a different onset (e.g., /bid/), while a third comparison was formed from the onset and rime from the second and first incorrect comparisons respectively (e.g., /ben/). The final comparison shared the same onset and final consonant as the sample but a different vowel (e.g., /hed/).

Phoneme training

In this training condition, participants completed sound-to-letter training and letter-to-sound training for each of the individual letter–phoneme relations utilised in the 13 recombined CVC words presented in this condition. The number of training trials, criteria, and test stages were exactly the same as those described in the onset and rime training, except for the stimuli trained and the recombined CVC words tested.

Participants underwent sound-to-letter conditional discrimination training, letter-to-sound symmetry training, and mixed testing for: (i) five onset letter–sound relations (/r/, /h/, /w/, /m/, /t/); (ii) five vowel letter–sound relations (/a/, /e/, /i/, /o/, /u/); (iii) five final consonant letter–sound relations (/b/, /d/, /g/, /p/, /s/). Next, revision of the three phoneme sets (onsets, vowels, and final consonants) was undertaken, with each printed letter and letter sound occurring twice as the sample letter and sample sound within the block of 30 training trials. Word naming and word recognition tests for the 13 recombined CVC words (shown in Table 10.1) that could be formed from the trained phonemes (e.g., /top/, /his/, /mud/) followed.

Syllable training

Whole CVC words, the largest sized unit in this study to train letter–sound relations, were employed in this training condition. This was the shortest training condition for the children to complete. The children completed spoken-word-to-printed-word conditional discrimination training, printed-word-to-spoken-word symmetry training, and mixed CVC word testing for five different CVC words (/fox/, /hit/, /lad/, /sum/, /peg/). Spoken-word-to-printed-word and printed-word-to-spoken-word revision training blocks for the five trained CVC words were also undertaken.

For the word naming and word recognition tests, the 13 recombined CVC words tested (as shown in Table 10.1) incorporated the five explicitly trained CVC words alongside eight untrained CVC words. The previously mastered words were included in the tests to forge links with the earlier training.

Phase 3: Follow up post-tests

Post-tests to examine retention of word naming and recognition were administered one day, one week, and one month after each training condition. Once the monthly post-test had been completed, and following a one week interval, training commenced for the next training condition. The post-tests were identical in format to the previous tests; the children completed the word naming test, followed by the spoken-word-to-printed-word recognition test for the 13 words in each condition. Naming and recognition of the 30 control words was also measured, with the testing of 10 control words assigned to each training condition.

10.3 Results

When assessed at baseline, none of the participants could read aloud any of the 39 recombined words or control words presented in the word naming tests. Likewise, they did not recognise the corresponding printed words for any of the spoken test words or control words. Findings are discussed below for each participant.

10.3.1 Participant 1

Participant 1 was a ten year old male (age at start of current study) with mild learning difficulties. Table 10.3 provides a summary of performance on the reading skills baseline tasks for Participant 1.

Table 10.3 Performance on the reading skills tasks by Participant 1 at entry to the research. Percentage correct in parentheses.

<table>
<tr><td>Participant 1
Male
Mild learning difficulties</td><td>Age</td><td colspan="2">Letter–sound recognition correct/ 26</td><td colspan="2">Letter–name recognition correct/ 26</td><td colspan="2">Letter–sound production correct/ 26</td><td colspan="2">Letter–name production correct/ 26</td></tr>
<tr><td>Baseline April 2008</td><td>10 years 2 months</td><td colspan="2">Lowercase
5 (19)
Uppercase
5 (19)</td><td colspan="2">Lowercase
22 (85)
Uppercase
25 (96)</td><td colspan="2">Lowercase
4 (15)
Uppercase
4 (15)</td><td colspan="2">Lowercase
24 (92)
Uppercase
26 (100)</td></tr>
<tr><td>Letter–sound writing correct/ 26</td><td>Letter–name writing correct/ 26</td><td colspan="2">High frequency word naming correct/ 64</td><td colspan="2">Print exposure correct/ 17</td><td colspan="2">Regular and irregular word spelling correct/ 40</td><td colspan="2">Phonological/ orthographic neighbours correct/ 16</td></tr>
<tr><td>7 (27)</td><td>21 (81)</td><td colspan="2">14 (22)</td><td colspan="2">13 (76)</td><td colspan="2">3 (8)</td><td colspan="2">12 (75)</td></tr>
<tr><td>TROG standard score</td><td>Working memory span / 8</td><td colspan="8">Phonological awareness</td></tr>
<tr><td rowspan="2">88</td><td rowspan="2">5</td><td>Rime oddity correct/12</td><td colspan="2">Phoneme isolation correct/12</td><td colspan="2">Phoneme blending correct/15</td><td colspan="2">Alliteration correct/27</td><td>Rhyme awareness correct/23</td></tr>
<tr><td>8 (67)</td><td colspan="2">8 (67)</td><td colspan="2">11 (73)</td><td colspan="2">24 (89)</td><td>19 (83)</td></tr>
</table>

10.3.1.1 Onset and rime training

Participant 1 reached criterion for all of the training stages. Two 25-trial blocks were required to learn the five onset sound–letter relations, and only one block of onset letter-to-sound trials was necessary to reach criterion. He correctly matched almost all of the onset sound–letter pairs in the mixed onset test, demonstrating 95% accuracy.

Greater matching errors occurred for Participant 1 when learning the rime sound–letter relations. Errors occurred when choosing the printed letters for the rime sounds /id/ and /en/. He frequently selected ‘en’ after hearing /id/, and pointed to ‘id’ when /en/ was articulated. A total of three 25-trial blocks were completed before the rime sound-to-letter criterion was achieved. Fewer errors were evident in the rime letter-to-sound training, and Participant 1 successfully matched almost all of the rime letters to their respective –VC sounds within one block of trials. For the mixed rime test, 95% accuracy was shown by Participant 1 in matching the rime sound–letter pairs. The onset and rime revision stages were each passed within one block of trials.

Figure 10.1 shows word naming and recognition accuracy across the three training conditions for Participant 1. Following completion of the onset and rime training, Participant 1 successfully named all 13 recombined words and could select the corresponding printed words for all 13 recombined spoken word targets. There was no increase in the number of control words read aloud or recognised.

Participant 1 was absent on the day following training for the one day post-test, although he was present for the one week and one month post-tests. The number of recombined printed words recognised remained consistent, with all 13 recombined onset–rime printed words correctly selected during the one week and one month post-tests. There was a slight decrease in the number of recombined words read aloud. All of the recombined words were named aloud correctly apart from the words ‘lid’ read as /lad/, and ‘hid’ read as /had/.

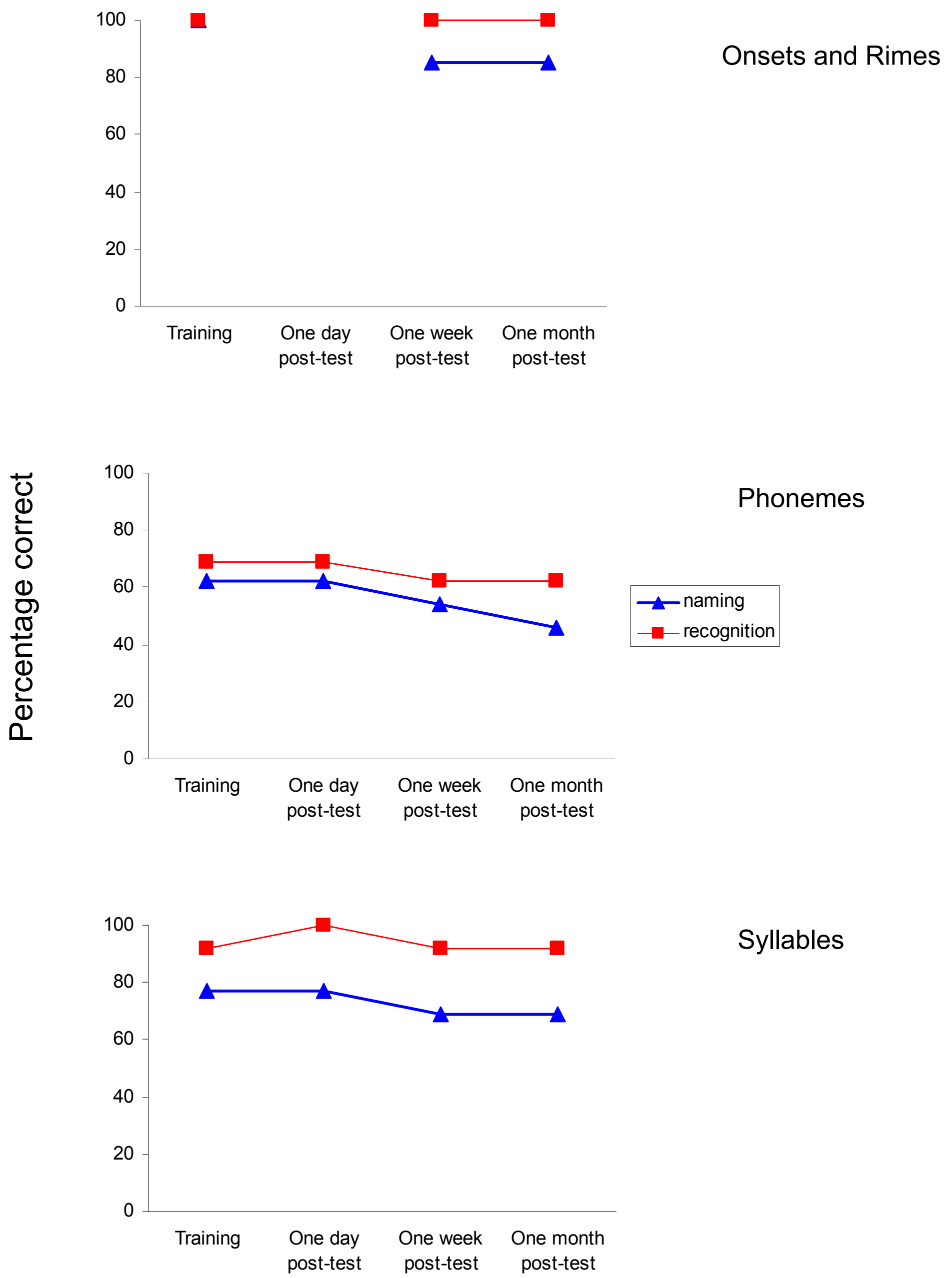


Figure 10.1 Accuracy in naming and recognising the recombined CVC words by Participant 1 following onset and rime, phoneme, and syllable training. Participant 1 was absent for the one day post-test following onset and rime training.

10.3.1.2 Phoneme training

Participant 1 passed the onset sound-to-letter training, letter-to-sound training, and mixed test trials, each within one block of trials, and could accurately match all five initial consonant sound–letter pairs. A greater number of training trials were required to reach criterion for the vowel training stages as difficulties were encountered in matching the vowel sounds to their printed letters. In particular, errors occurred when finding the printed letters for the sounds /u/ which was often matched with ‘o’, and /i/ which was associated with ‘e’. Three 25-trial blocks and two 25-trial blocks were required to pass the vowel sound-to-letter and letter-to-sound training respectively. Participant 1 showed 90% accuracy at his first attempt at the mixed vowel test, and could match nearly all of the vowel sound–letter pairs. Fewer errors occurred in matching the final consonant sound–letter pairs, and Participant 1 passed the final consonant training stages each within one 25-trial block. Similarly, only one block of trials was required to pass the sound-to-letter and letter-to-sound revision training, with 96% and 94% accuracy shown in matching the onset, vowel, and final consonant sound–letter pairs in these blocks respectively.

As shown in Figure 10.1, Participant 1 named aloud eight of the recombined phoneme words (62% naming accuracy) and recognised the printed words corresponding to nine spoken recombined words (69% recognition accuracy). He tended to select the incorrect printed comparison that shared the same initial consonant to the sample as opposed to the same vowel and final consonant (e.g., ‘tag’ was selected for /tud/, ‘rud’ for /rag/). None of the control words were named or recognised.

Naming and recognition of the printed recombined phoneme words was maintained for the one day post-test (8/13 words named, 9/13 words recognised) but decreased slightly for the one week (7/13 words named, 8/13 words recognised) and one month post-tests (6/13 words named, 8/13 words recognised).

10.3.1.3 Syllable training

Participant 1 passed the CVC word spoken-word-to-printed-word training, printed-word-to-spoken-word training, and mixed test, within two blocks, one block, and one block respectively. He could accurately match all five CVC spoken word–printed word pairs during the revision training blocks, showing 100% accuracy.

As can be seen in Figure 10.1, recognition was slightly better than naming of the recombined CVC words for Participant 1. He named all trained CVC words and five of the eight untrained words (/had/, /leg/, /lit/, /fit/, /sit/). Naming errors occurred for the words ‘sad’ read as /said/, ‘pit’ read as /put/, and ‘hum’ read as /him/. He recognised all trained CVC words and 7/8 of the untrained CVC words; accurately pointing out the printed words corresponding to all spoken words except the word /lit/, for which the word ‘lad’ was selected. The only control word named and recognised was the word ‘has’.

Naming accuracy remained relatively similar throughout the post-tests. All five trained words were named and recognised at the one day, one week, and one month post-tests. Five of the eight untrained words were named on the day following training. Four untrained words were named at the one week and one month post-tests. He recognised all eight untrained CVC words at the one day post-test, and recognised seven words at the one week and one month post-tests.

Overall, as can be seen in Table 10.3 (p. 214), prior to training, Participant 1 presented with good letter–name knowledge and showed awareness of a small number of letter–sound relations. This may help to explain why Participant 1 passed the training stages quite quickly in all training conditions. Participant 1 commenced training with quite a good foundation of reading skills. In particular, his phonological awareness skills were good, and he scored highly on the tasks measuring rime and phoneme awareness. Of all the children, he scored highest on the test measuring understanding of grammatical constructs and could already read aloud some of the high frequency words. Together with the MTS training procedures, his good baseline reading skills may have contributed to his performance on the word naming and recognition tests, as in all three training conditions he was able to read aloud and identify a high percentage of the untrained words. His ability to read aloud some high frequency words indicated that he was able to retain words, and along with Participant 2, he was one of two children who recalled the most colours in the working memory span task (see p. 199). In combination with his other entry reading skills, these factors may help to account for his good retention of the words across the post-tests.

10.3.2 Participant 2

Participant 2 was a nine year old male with mild learning difficulties. Table 10.4 presents the baseline reading skills scores for Participant 2.

Table 10.4 Baseline performance on the reading skills tasks by Participant 2. Percentage correct in parentheses.

<table>
<tr><td>Participant 2
Male
Mild learning difficulties</td><td>Age</td><td colspan="2">Letter–sound recognition correct/ 26</td><td colspan="2">Letter–name recognition correct/ 26</td><td colspan="2">Letter–sound production correct/ 26</td><td colspan="2">Letter–name production correct/ 26</td></tr>
<tr><td>Baseline
April 2008</td><td>9 years
1 month</td><td colspan="2">Lowercase
6 (23)
Uppercase
5 (19)</td><td colspan="2">Lowercase
24 (92)
Uppercase
26 (100)</td><td colspan="2">Lowercase
3 (12)
Uppercase
3 (12)</td><td colspan="2">Lowercase
26 (100)
Uppercase
26 (100)</td></tr>
<tr><td>Letter–sound writing correct/ 26</td><td>Letter–name writing correct/ 26</td><td colspan="2">High frequency word naming correct/ 64</td><td colspan="2">Print exposure correct/ 17</td><td colspan="2">Regular and irregular word spelling correct/ 40</td><td colspan="2">Phonological/ orthographic neighbours correct/ 16</td></tr>
<tr><td>4 (15)</td><td>26 (100)</td><td colspan="2">17 (27)</td><td colspan="2">11 (65)</td><td colspan="2">10 (25)</td><td colspan="2">10 (63)</td></tr>
<tr><td>TROG standard score</td><td>Working memory span / 8</td><td colspan="8">Phonological awareness</td></tr>
<tr><td rowspan="2">55</td><td rowspan="2">5</td><td>Rime oddity correct/12</td><td colspan="2">Phoneme isolation correct/12</td><td colspan="2">Phoneme blending correct/15</td><td colspan="2">Alliteration correct/27</td><td>Rhyme awareness correct/23</td></tr>
<tr><td>8 (67)</td><td colspan="2">9 (75)</td><td colspan="2">9 (60)</td><td colspan="2">25 (93)</td><td>18 (78)</td></tr>
</table>

10.3.2.1 Onset and rime training

For all three training conditions, Participant 2 did not require that many exposures to the training stages to meet the criteria. As can be seen from Table 10.4, prior to starting the MTS training, Participant 2 had good letter–name knowledge, and a little letter–sound knowledge, which may perhaps have influenced his relatively straightforward progression through the training stages.

The onset sound-to-letter and letter-to-sound training stages were each passed within two blocks. Participant 2 demonstrated 100% accuracy in the mixed onset test and could correctly match all five onset sound–letter pairs. When learning the rime sound–letter relations, two trial blocks were completed to reach the sound-to-letter criterion, and one trial block to achieve the letter-to-sound criterion. Participant 2 showed 95% accuracy in matching the rime sound–letter pairs in the mixed rime test. Similarly, accuracy was high for the onset and rime revision training, with Participant 2 showing 93% accuracy in matching the onset and rime letter–sound relations.

Figure 10.2 shows accuracy on the word naming and recognition tests across the three training conditions for Participant 2. Participant 2 read aloud all 13 recombined onset–rime words presented in the naming test and likewise, correctly identified the correct printed words corresponding to the 13 recombined words in the recognition test. He recognised the control word 'mat' and named the control word /ham/, but could not recognise or name any of the remaining control words.

For the post-tests, all 13 recombined words were named and recognised at the one day post-test. All 13 CVC words were read aloud at the one week post-test. Naming accuracy was 92% at the one-month post-test, with all words named except the word 'bid' which was read as /bend/. In the one week recognition test, the word 'bap' was selected for the spoken word /bid/. Otherwise all of the printed recombined words were correctly identified in the one week (12/13) and one month (13/13) post-tests.

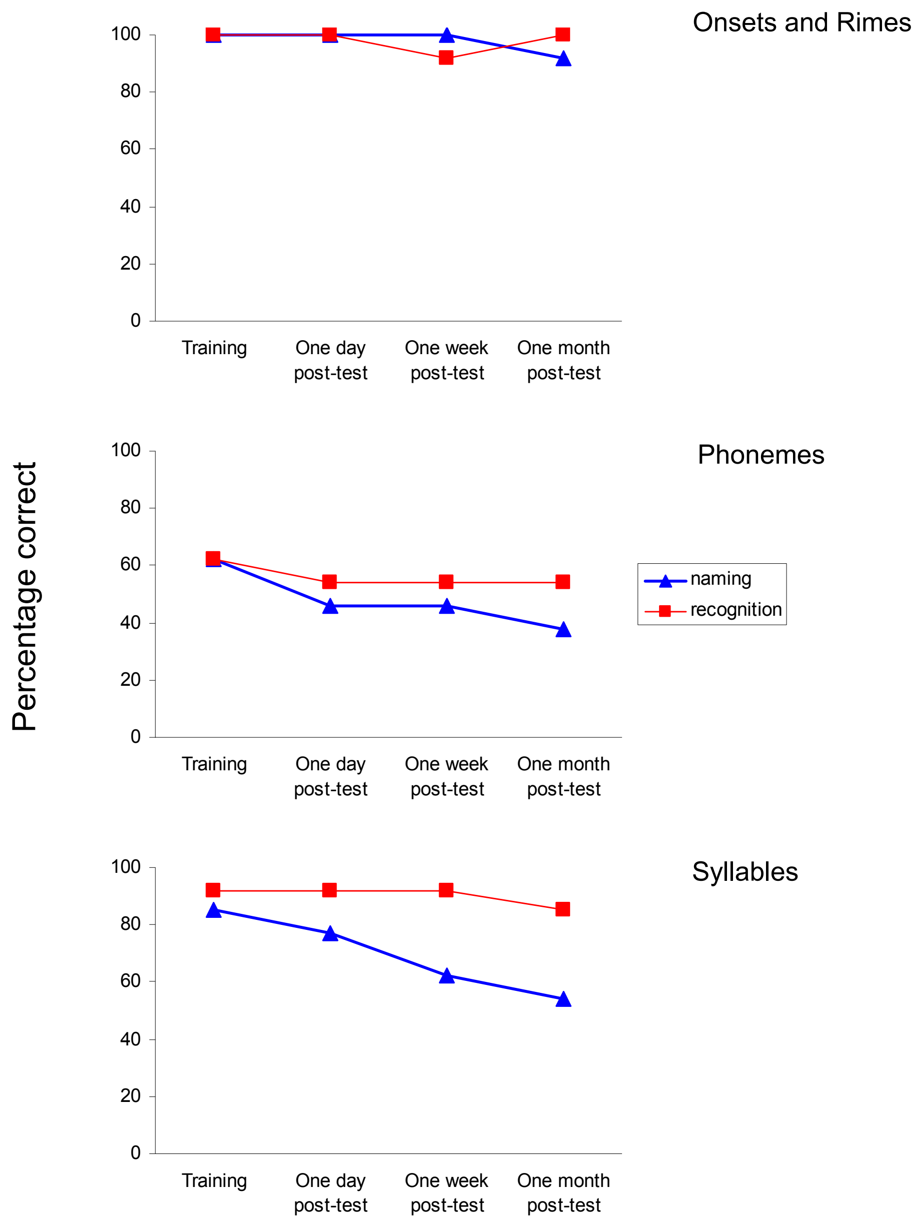


Figure 10.2 Accuracy in naming and recognising the recombined CVC words by Participant 2 following onset and rime, phoneme, and syllable training.

10.3.2.2 Phoneme training

Participant 2 successfully matched the five initial consonant sounds and letters to pass the onset sound-to-letter and letter-to-sound training, and mixed test, each within one trial block. He required a higher number of training trials when matching the vowel sounds and letters, and completed two blocks each in the sound-to-letter and letter-to-sound training stages. The mixed vowel test was passed at the first attempt. For the final consonant sound-to-letter, letter-to-sound, and mixed test, Participant 2 completed two blocks, one block, and one block respectively to achieve the criterion. He passed the two revision stages at the first attempt, demonstrating 90% accuracy in each stage.

Naming accuracy was 62%, with eight of the 13 recombined words named correctly (please see Figure 10.2). In the phoneme training, as in the other conditions, he attempted to sound out all recombined test words. Naming errors occurred for the words ‘wag’ read as /way/, ‘hag’ as /had/, ‘tud’ as /top/, ‘top’ as /tap/, and ‘web’ as /wed/. As can be seen from his word naming errors, usually it was only one printed letter (often the final consonant) that was mispronounced. Participant 2 recognised the printed words for eight spoken CVC test words (62% accuracy), and tended to choose the incorrect comparison that shared the same initial letter rather than rime as the sample spoken word. None of the control words were named or recognised.

For the one day, one week, and one month recognition post-tests, Participant 2 demonstrated 54% accuracy. There was a slight reduction in the percentage of words read aloud, with 46% of words (6/13) named at the one day and one week post-tests, and 38% of words (5/13) named at the one month post-test.

10.3.2.3 Syllable training

Two trial blocks were completed to pass the spoken-word-to-printed-word training, and the criterion for the printed-word-to-spoken-word training was met within one block. Participant 2 was accurate in matching the five explicitly trained CVC spoken word–printed word pairs, showing 95% accuracy when completing the mixed test trials. The spoken word–printed word revision training stages were each passed within one block, with 97% accuracy recorded in each stage.

As shown in Figure 10.2, naming and recognition accuracy for the recombined syllable words was high at 85% and 92% respectively. All five trained CVC words were named and recognised. The only two untrained recombined words not named correctly were ‘lit’ read as /like/, and ‘fit’ read as /fat/. In the recognition test, the untrained printed word ‘leg’ was chosen for the spoken word sample /lit/. None of the control words were named or recognised.

During the post-tests, naming accuracy decreased to 77%, 62%, and 54%, at the one day, one week, and one month tests respectively. Recognition accuracy persisted at 92% in the one day and one week post-tests, but was 85% in the one month post-test.

From the baseline reading tasks, it was clear that Participant 2 was making progress in his overall reading skills. Of all the children, he correctly read aloud the highest number of high frequency words and was able to spell the most words in the regular and irregular word task. Similarly, he performed well in identifying rimes or phonemes in the phonological awareness tasks. As with Participant 1, it is likely that these prior reading skills may have contributed to his ability to name and recognise a high percentage of words across the training conditions, but also to show good maintenance of the training in the post-tests.

10.3.3 Participant 3

Participant 3 was a ten year old female with mild learning difficulties. Table 10.5 reviews the baseline reading skills performance of Participant 3.

Table 10.5 Performance on the reading skills tasks by Participant 3 at entry to the research. Percentage correct in parentheses.

Participant 3 Female Mild learning difficulties	*Age*	*Letter–sound recognition correct/ 26*	*Letter–name recognition correct/ 26*	*Letter–sound production correct/ 26*	*Letter–name production correct/ 26*	
Baseline April 2008	9 years 11 months	Lowercase 3 (12) Uppercase 3 (12)	Lowercase 24 (92) Uppercase 26 (100)	Lowercase 2 (8) Uppercase 2 (8)	Lowercase 25 (96) Uppercase 23 (88)	
Letter–sound writing correct/ 26	*Letter–name writing correct/ 26*	*High frequency word naming correct/ 64*	*Print exposure correct/ 17*	*Regular and irregular word spelling correct/ 40*	*Phonological/ orthographic neighbours correct/ 16*	
2 (8)	24 (92)	8 (13)	8 (47)	3 (8)	13 (81)	
TROG standard score	*Working memory span / 8*	*Phonological awareness*				
78	4	*Rime oddity correct/12*	*Phoneme isolation correct/12*	*Phoneme blending correct/15*	*Alliteration correct/27*	*Rhyme awareness correct/23*
		6 (50)	6 (50)	7 (47)	22 (81)	14 (61)

10.3.3.1 Onset and rime training

Participant 3 completed three blocks of onset sound-to-letter trials and two blocks of onset letter-to-sound trials. There were some matching errors for the sounds /m/ and /h/ (e.g., if the sound /h/ was presented, the letter ‘m’ was often selected). Participant 3 correctly matched 90% of the onset sound–letter pairs in the mixed onset test. She met the criteria for the rime sound-to-letter, letter-to-sound, and mixed test within three blocks, two blocks, and one block respectively. On the first attempt at the onset and rime sound-to-letter revision training, Participant 3 recorded 83% accuracy, but after retraining, obtained the 90% criterion on the second attempt. The sound-to-letter and letter-to-sound revision training stages were passed each within one block of trials.

As shown in Figure 10.3, naming accuracy was 85% when presented with the recombined CVC test words. Eleven of the 13 recombined CVC printed words (85%) were correctly identified in the recognition test. Matching errors were shown for the words /lid/ and /bid/ for which the onset matching distractor words 'len' and 'ben' were incorrectly selected. None of the control words were named or identified.

Recognition accuracy was maintained at 85% across the three recognition post-tests. Although naming accuracy was unchanged at 85% in the one day post-test, there was a decrease in accuracy to 77% and 54% in the one week and one month post-tests.

10.3.3.2 Phoneme training

Participant 3 completed three blocks, two blocks and one block to reach criterion in the initial consonant sound-to-letter, letter-to-sound, and mixed test respectively. Greater difficulties were apparent in matching the vowel sound–letter relations. Although Participant 3 could accurately match the phoneme /a/ to the letter 'a', a high rate of errors occurred for the remaining four vowel sound–letter pairs. After completing four MTS trial type blocks for the vowel sound-to-letter trials using two and three choice comparison trials, Participant 3 had not yet reached the criterion. Thus, an exclusion type procedure was implemented using the known letter–sound relation for /a/, with one more unknown letter–sound pair, to facilitate learning of the other four vowel pairs. Once Participant 3 was correctly associating the vowel letter–sound pairs, the vowel sound-to-letter MTS trial block was reintroduced, and criterion was met within one block.

The vowel letter-to-sound training was passed within two trial blocks, and the criterion accuracy of 90% was met for the mixed vowel test. Participant 3 experienced little difficulties in matching the final consonant sound–letter pairs. The criteria for the final consonant sound-to-letter, letter-to-sound, and mixed test trials were reached within two blocks, two blocks and one block respectively. Two trial blocks were each completed in the revision training stages.

Naming accuracy was 46%, with six of the 13 recombined words presented read aloud (please see Figure 10.3). Some naming errors occurred in the pronunciation of the vowel sounds, for example, ‘mag’ was read as /mug/, ‘wag’ as /wig/. Alternatively, there were some errors in the pronunciation of the final consonant, for instance, ‘hag’ was read as /had/, ‘rud’ as /rug/. Recognition accuracy was also 46% for the recombined words. She named and recognised the control words ‘mat’ and ‘pat’

Post-test naming and recognition accuracy held constant at 46% on the one day post-test. However, naming accuracy decreased to 38% at the one week and one month post-tests. Recognition accuracy stayed at 46% when measured at the one week and one month post-tests.

10.3.3.3 Syllable training

In general, Participant 3 was accurate at matching the five CVC spoken word–printed word pairs. The spoken-word-to-printed-word, printed-word-to-spoken-word, and mixed test trials were passed in two blocks, one block, and one block respectively. The 90% criterion was met for the revision training stages each within one block.

Participant 3 could name all of the trained CVC words and four of the eight untrained CVC words. Sometimes she named the rime correctly but voiced the incorrect onset, for example, reading /fit/ for ‘lit’. Mostly she was able to say the correct first letter of the word but pronounced incorrect subsequent letters, (e.g., ‘fit’ was read as /from/). Recognition accuracy was 69%, with half (4/8) of the untrained CVC words and all five trained CVC words correctly identified. Recognition errors were mostly onset rather than rime matches, with Participant 3 selecting the incorrect comparison that shared the same onset as the target (e.g., choosing ‘hit’ for the target /had/). None of the control words were named or recognised.

Naming accuracy was maintained at 69% at the one day post-test, but decreased to 54% and 38%, at the one week and one month post-tests respectively. Similarly, recognition accuracy was maintained at 69% at the one day post-test, but fell to 62% at the one week post-test, and 54% at the one month post-test.

Across the three training conditions, immediately following training, Participant 3 could almost always name and identify at least half of the recombined test words. If we examine the baseline reading skills performance (Tables 9.9 and 9.10, pp. 199-200), Participant 3 was one of three participants (along with Participants 1 and 2) who demonstrated a little letter–sound knowledge, named a small proportion of the high frequency words, and scored highly on the phonological awareness measures. She also demonstrated a good awareness of grammatical constructs as evident by her score on the TROG; responding correctly to more items than all of the other participants except Participant 1. As with Participants 1 and 2, the potential contribution of these pre-training reading skills to these participants’ ability to name, recognise, and remember the recombined CVC words must be taken into account when analysing the data.

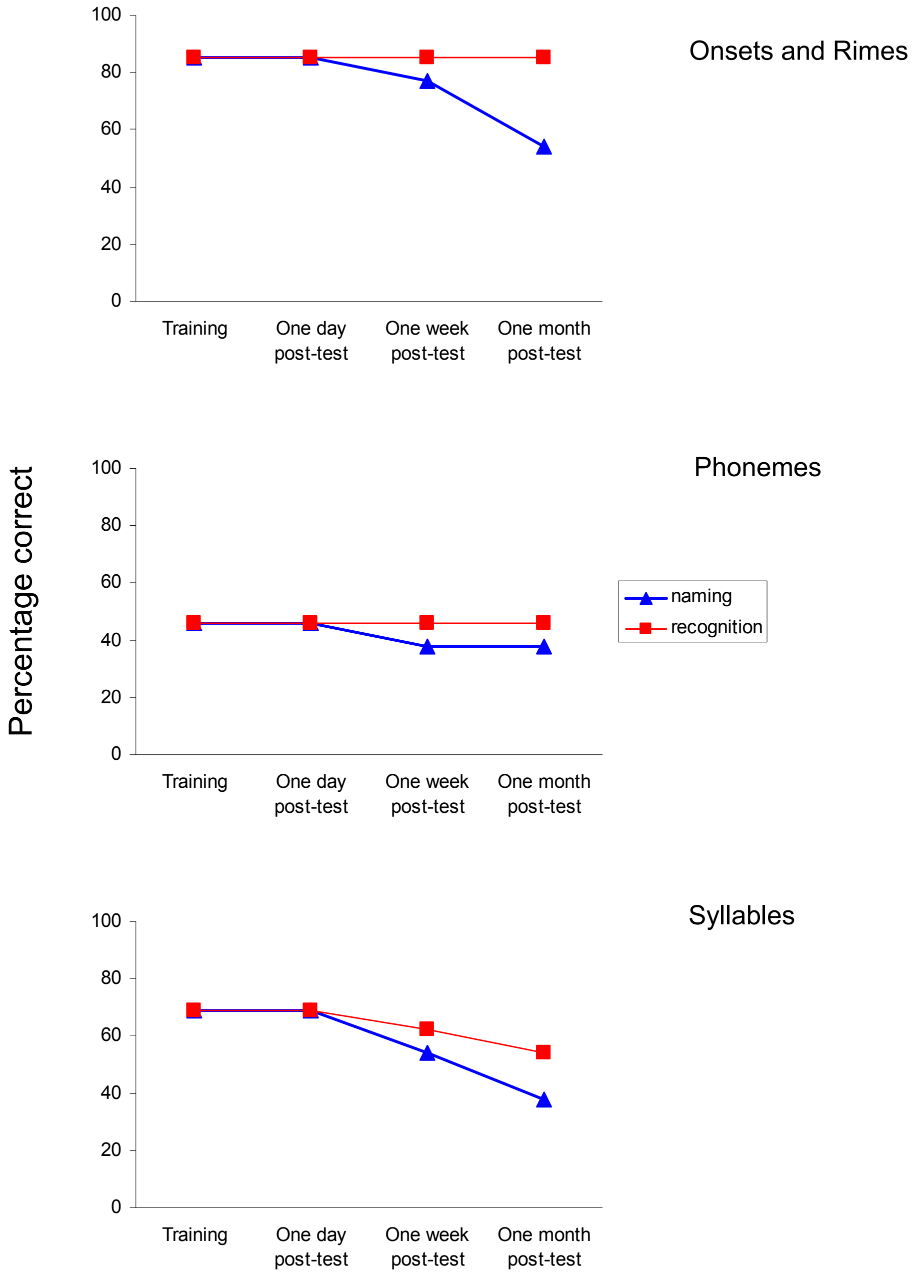


Figure 10.3 Accuracy in naming and recognising the recombined CVC words by Participant 3 following onset and rime, phoneme, and syllable training.

10.3.4 Participant 4

Participant 4 was a ten year old male with Down syndrome and mild learning difficulties. Table 10.6 lists the scores obtained by Participant 4 on the baseline reading skills measures.

Table 10.6 Baseline performance on the reading skills tasks by Participant 4. Percentage correct shown in parentheses.

<table>
<tr><td>Participant 4
Male
Mild learning difficulties
Down syndrome</td><td>Age</td><td>Letter–sound recognition correct/ 26</td><td>Letter–name recognition correct/ 26</td><td colspan="2">Letter–sound production correct/ 26</td><td>Letter–name production correct/ 26</td></tr>
<tr><td>Baseline April 2008</td><td>9 years
8 months</td><td>Lowercase
1 (4)
Uppercase
1 (4)</td><td>Lowercase
23 (88)
Uppercase
19 (73)</td><td colspan="2">Lowercase
0 (0)
Uppercase
0 (0)</td><td>Lowercase
24 (92)
Uppercase
21 (81)</td></tr>
<tr><td>Letter–sound writing correct/ 26</td><td>Letter–name writing correct/ 26</td><td>High frequency word naming correct/ 64</td><td>Print exposure correct/ 17</td><td colspan="2">Regular and irregular word spelling correct/ 40</td><td>Phonological/ orthographic neighbours correct/ 16</td></tr>
<tr><td>0 (0)</td><td>20 (77)</td><td>2 (3)</td><td>4 (24)</td><td colspan="2">0 (0)</td><td>2 (13)</td></tr>
<tr><td>TROG standard score</td><td>Working memory span / 8</td><td colspan="5">Phonological awareness</td></tr>
<tr><td rowspan="2">55</td><td rowspan="2">3</td><td>Rime oddity correct/12</td><td>Phoneme isolation correct/12</td><td>Phoneme blending correct/15</td><td>Alliteration correct/27</td><td>Rhyme awareness correct/23</td></tr>
<tr><td>4 (33)</td><td>3 (25)</td><td>5 (33)</td><td>8 (30)</td><td>10 (43)</td></tr>
</table>

10.3.4.1 Onset and rime training

Participant 4 reached the onset sound-to-letter criterion within four trial blocks. Errors were high when distinguishing the correct printed letter for the onset sound /l/ (e.g., if /l/ was the sample, he often pointed to ‘m’). Although he was able to choose between up to five comparisons in the onset sound-to-letter training, he found the onset letter-to-sound training trials more challenging and errors were high (e.g., choosing /b/ for the letter ‘t’). As a result only two comparisons (the correct comparison and one incorrect comparison) were presented to increase accuracy. Consequentially, the 90% criterion for the onset letter-to-sound training was met within four trial blocks, and the mixed onset test was passed within one block.

Three and two trial blocks were completed to reach the criterion for the rime sound-to-letter and letter-to-sound training respectively. Participant 4 often chose the letters or sound corresponding to ‘en’ when ‘id’ was the sample, and ‘id’ when ‘en’ was the sample. Participant 4 could match nearly all of the rime sound–letter pairs in the mixed rime test, and demonstrated 90% accuracy. The onset and rime revision stages were each passed within one block.

Figure 10.4 shows naming and recognition accuracy in the three training conditions for Participant 4. Participant 4 named 38% (5/13) of the recombined CVC words, but seemed to find the naming task quite challenging. When reflecting on his low scores for the majority of baseline reading measures (please see Table 10.6), particularly in terms of low letter–sound knowledge, the naming difficulties he experienced are perhaps not wholly unexpected. He was however accurate in pointing to the spoken word corresponding to a printed word sample, and showed 69% accuracy in the printed-word-to-spoken-word matching test which was employed as an alternative measure to the naming test. Printed word recognition accuracy was 69% (9/13). Errors occurred when he sometimes selected the incorrect comparison with the same rime as the sample, for example, ‘bap’ was chosen for /tap/, ‘map’ for /lap/. He could not name or recognise any of the control words.

His printed word recognition decreased to 62%, 54%, and 38%, for the one day, one week, and one month post-tests respectively. Printed-word-to-spoken-word matching accuracy remained at 69% for the one day post-test, but decreased to 54% on the one week post-test, and 46% on the one month post-test. Across the three post-tests, naming accuracy was 31%, 15%, and 0%, respectively.

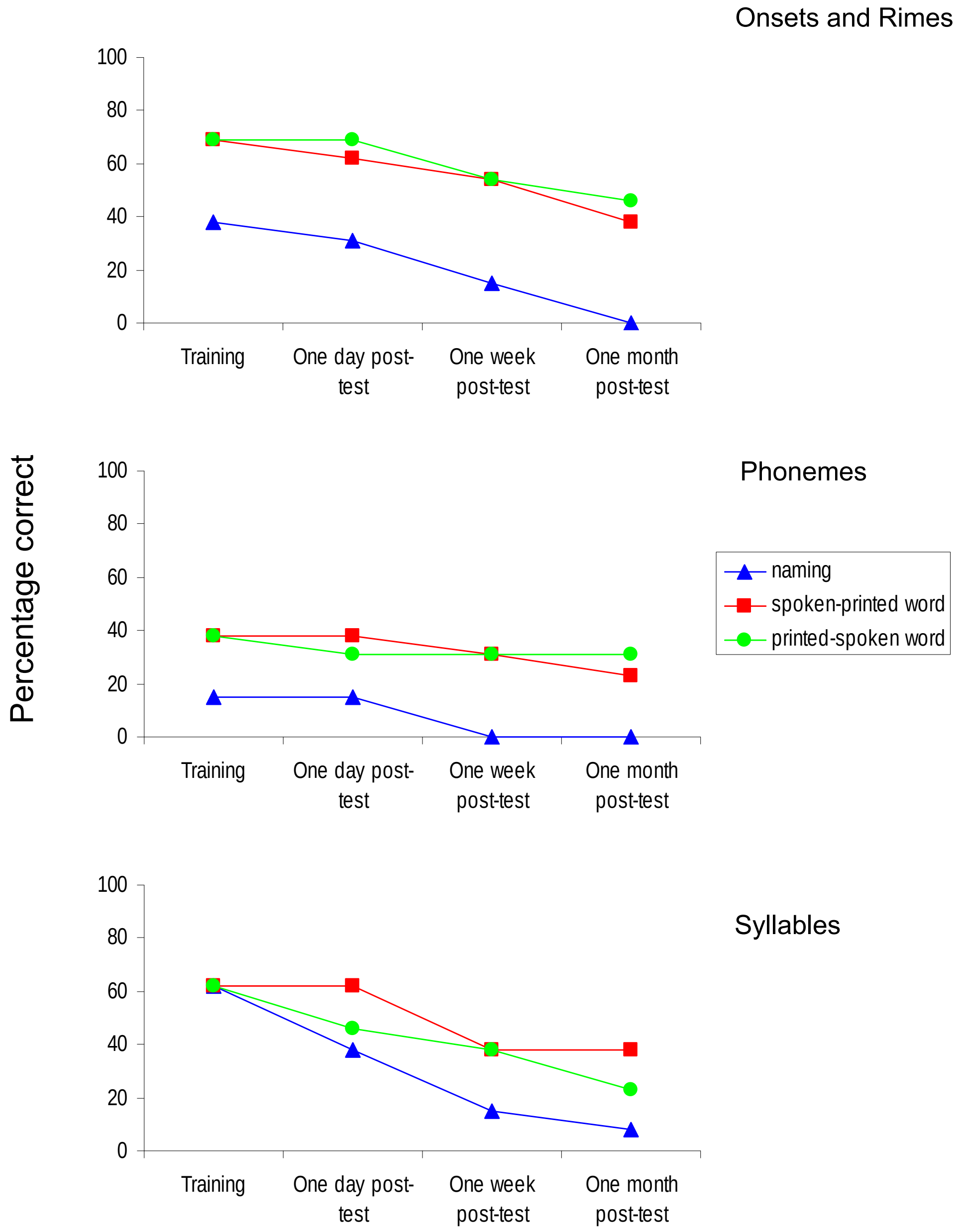


Figure 10.4 Accuracy in naming and recognising the recombined CVC words by Participant 4 following onset and rime, phoneme, and syllable training.

10.3.4.2 Phoneme training

Participant 4 made few errors when matching the five initial consonant letter–sound pairs, and passed the sound-to-letter, letter-to-sound, and mixed test trials, within two blocks, two blocks and one block respectively. However, a high error rate was evident when matching the vowel letter–sound pairs, and exclusion procedures were employed to train the vowel letter–sound relations, followed by presentation of the

MTS trial block. After completing the exclusion trials, the criterion for the vowel sound-to-letter, letter-to-sound, and mixed test trials, was achieved within two blocks, two blocks and one block respectively. Fewer difficulties were observed in matching the final consonant letters and sounds. Participant 4 passed the final consonant training stages within three MTS trial blocks, one block, and one block respectively. Three blocks of sound-to-letter revision training trials were completed before reaching the 90% criterion, and two blocks of letter-to-sound revision training trials were required to meet the criterion.

On the naming test, few of the recombined phoneme words were named. Participant 4 correctly named the words 'top' and 'hop' to record 15% naming accuracy. He successfully chose the spoken words corresponding to five printed words. Likewise for the recognition test, 38% of the recombined printed words were correctly identified. Often, errors occurred when Participant 4 selected the printed word that shared the same initial and final consonants as the sample spoken word, but that contained a different vowel (e.g., 'mup' was chosen for /mop/). None of the control words were named or recognised.

At the one day post-test, Participant 4 could still name the two words 'hop' and 'top'. However, he could not name any words at the one week or one month post-tests. There was a slight decrease in accuracy on the printed word-to-spoken word matching test, with accuracy measured at 31% for the three post-tests. Recognition accuracy was maintained at 38% for the one day post-test, but decreased to 31% and 23% for the one week and one month post-tests respectively.

10.3.4.3 Syllable training

Participant 4 completed four blocks of two choice training trials to reach the spoken-word-to-printed-word criterion. Errors were high when matching the spoken words

/fox/, /peg/, and /lad/ to their respective printed words. Similarly, four blocks of two choice printed-word-to-spoken-word training trials were completed to reach the 90% criterion. The number of incorrect comparisons presented in the mixed CVC word test was gradually increased, and criterion was met within two blocks. The revision training stages were each passed within two blocks.

Recombined printed word recognition accuracy was 62%. All trained CVC printed words and three untrained CVC printed words were identified. He named all five trained CVC words and the untrained words ‘had’, ‘sad’, and ‘sit’ to record a naming accuracy of 62%. Accuracy on the printed-word-to-spoken-word test was 62%. Participant 4 did not name or recognise any of the control words.

Accuracy in matching the printed-words-to-spoken-words was 46% at the one day post-test, 38% at the one week post-test, and 23% at the one month post-test. Naming accuracy decreased to 38%, 15%, and 8% in the one day, one week, and one month post-tests respectively. Participant 4 demonstrated 62% accuracy (one day post-test) and 38% accuracy (one week and one month post-tests) in choosing the correct printed words to match spoken word samples.

To summarise, in all of the training conditions, Participant 4 could only name a very small percentage of the untrained words. However, considering that at entry to the research he could only read aloud very few of the high frequency words, showed very little letter–sound knowledge, and produced quite low scores on the phonological awareness tasks, his difficulties in naming the words across the three training conditions were not unexpected. Furthermore, his low scores on the baseline reading tasks must also be taken into account when examining the decreases in word naming and recognition performance observed across the post-tests.

10.3.5 Participant 5

Participant 5 was a thirteen year old male with mild learning difficulties. Table 10.7 shows the baseline reading skills scores for Participant 5.

10.3.5.1 Onset and rime training

Participant 5 appeared to find it difficult to learn the sound–letter relations for the onsets and rimes, and required a greater number of training cycles than the other participants. This was not unexpected given his extremely low scores on the letter–sound and working memory span baseline measures (please see Table 10.7), which all suggested that he would need more intensive training to learn and remember the letter–sound relations. He completed six blocks of training trials (exclusion type trials followed by MTS trials once accuracy in matching the onset sound–letter relations reached 90%) in which the number of incorrect comparisons was gradually increased over the duration of MTS training from two to four incorrect comparisons before reaching the onset sound-to-letter criterion. Similarly, for the onset letter-to-sound training, the first block of trials attempted were exclusion trials, followed by two blocks of MTS training trials, after which the 90% criterion was met. The number of incorrect comparisons was gradually increased from two to four in the mixed onset test trials, and as such, two blocks of test trials were completed.

The same procedure used for the onset training stages was implemented for the rime training stages. Participant 5 completed two blocks of training trials in both the sound-to-letter and letter-to-sound revision training to reach the 90% criterion.

Table 10.7 Performance on the reading skills tasks by Participant 5 at entry to the research. Percentage correct shown in parentheses.

<table>
<tr><td>Participant 5
Male
Mild learning difficulties</td><td>Age</td><td colspan="5">Letter–sound recognition correct/ 26</td><td colspan="5">Letter–name recognition correct/ 26</td><td colspan="5">Letter–sound production correct/ 26</td><td colspan="5">Letter–name production correct/ 26</td></tr>
<tr><td>Baseline
April 2008</td><td>13 years
3 months</td><td colspan="5">Lowercase
1 (4)
Uppercase
1 (4)</td><td colspan="5">Lowercase
19 (73)
Uppercase
18 (69)</td><td colspan="5">Lowercase
1 (4)
Uppercase
1 (4)</td><td colspan="5">Lowercase
17 (65)
Uppercase
17 (65)</td></tr>
<tr><td>Letter–sound writing correct/ 26</td><td>Letter–name writing correct/ 26</td><td colspan="5">High frequency word naming correct/ 64</td><td colspan="5">Print exposure correct/ 17</td><td colspan="5">Regular and irregular word spelling correct/ 40</td><td colspan="5">Phonological/ orthographic neighbours correct/ 16</td></tr>
<tr><td>0 (0)</td><td>18 (69)</td><td colspan="5">3 (4)</td><td colspan="5">4 (24)</td><td colspan="5">0 (0)</td><td colspan="5">4 (25)</td></tr>
<tr><td>TROG standard score</td><td>Working memory span / 8</td><td colspan="20">Phonological awareness</td></tr>
<tr><td rowspan="2">55</td><td rowspan="2">3</td><td colspan="4">Rime oddity correct/12</td><td colspan="4">Phoneme isolation correct/12</td><td colspan="4">Phoneme blending correct/15</td><td colspan="4">Alliteration correct/27</td><td colspan="4">Rhyme awareness correct/23</td></tr>
<tr><td colspan="4">5 (42)</td><td colspan="4">4 (33)</td><td colspan="4">5 (33)</td><td colspan="4">11 (41)</td><td colspan="4">12 (52)</td></tr>
</table>

As is evident from Figure 10.5, Participant 5 named four of the 13 recombined onset–rime words (naming accuracy = 31%). In the alternative printed-word-to-spoken-word matching test, he correctly selected the corresponding spoken words for 62% of the printed word samples. Recognition accuracy in the spoken-word-to-printed-word test was also 62%. He did not name or recognise any control words.

For the post-tests, recognition accuracy decreased to 46%, 38%, and 15%, for the one day, one week, and one month post-tests respectively. There was a reduction in naming accuracy to 23% in the one day post-test, although none of the words were named in the one week and one month post-tests. When it became clear that Participant 5 was unable to read aloud the words, he was instead encouraged to say the letter names of the letters contained within the words. This was deemed to be a suitable alternative for Participant 5 because from the baseline measures (please see Table 10.7) it was clear that he had a well-established letter–name knowledge, and so would be able to successfully name the letters when unable to read aloud the test words. Likewise, decreases in accuracy for the printed-word-to-spoken-word matching test were also evident. At the one day, one week, and one month post-tests, accuracy was 54%, 46%, and 15%, respectively.

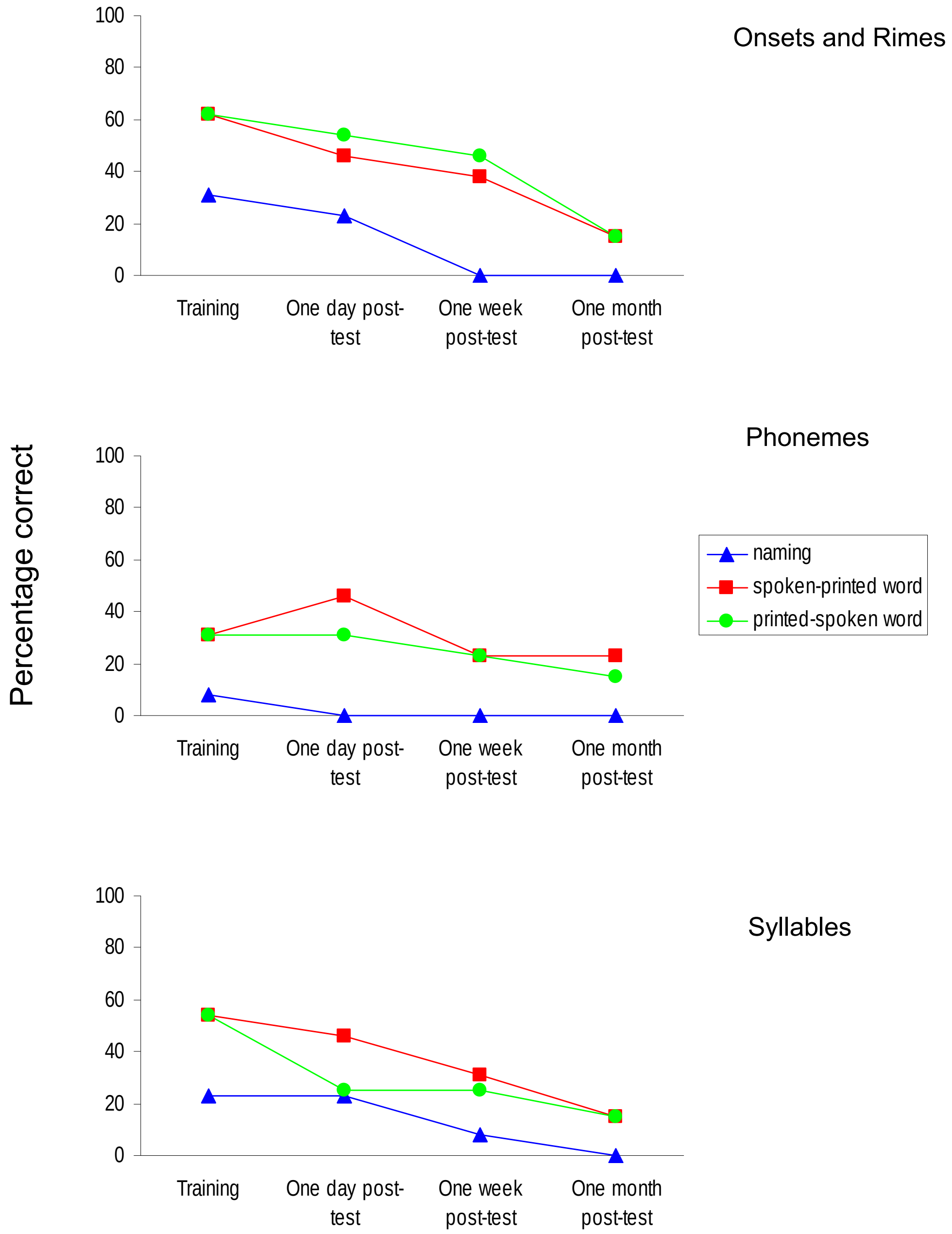


Figure 10.5 Accuracy in naming and recognising the recombined CVC words by Participant 5 following onset and rime, phoneme, and syllable training.

10.3.5.2 Phoneme training

The training procedure described in the onset and rime training condition in which exclusion type trials were utilised to learn the letter–sound relations followed by MTS training trials to further reinforce the associations was also used in the phoneme training condition for training with the initial consonants, vowels, and final consonants. The 90% criterion was reached in each of the training stages.

Naming and recognition accuracy percentages were quite low for Participant 5 (see Figure 10.5). The only word named correctly was 'his'. Given though that he struggled to read aloud or recognise even the high frequency words during the baseline reading skills tasks, and had almost no prior letter–sound knowledge, this might help to explain why he could not name or recognise many of the untrained words. Accuracy in identifying the spoken words corresponding to printed word samples was 31%, and errors occurred mainly when he selected the incorrect comparison that shared the same initial consonant as the sample rather than the same vowel or end consonant. Recognition accuracy in choosing the printed word equivalents for the spoken word samples was also 31%, and again, Participant 5 tended to choose the incorrect comparison sharing the same initial consonant as the sample.

For the three word naming post-tests, when unable to read aloud any of the test words, Participant 5 provided the letter names for all the letters that formed each word. There was a slight decrease in printed-word-to-spoken-word matching accuracy from the one day post-test (31%) to the one week (23%) and one month (15%) post-tests. Spoken-word-to-printed-word recognition accuracy stayed at 31% for the initial post-test, but was 23% at the one week and one month post-tests.

10.3.5.3 Syllable training

Participant 5 completed two blocks of exclusion trials and two blocks of MTS training trials to learn the spoken-word-to-printed-word relations. For the printed-word-to-spoken-word training, he completed one exclusion block followed by two MTS blocks before reaching the 90% criterion, and then proceeded to meet the 90% criterion after two blocks in the mixed test trials (the number of comparisons was gradually increased across the two test blocks). The revision training stages were each passed within one block.

Participant 5 could name the printed words ‘fox’, ‘lad’, and ‘hit’, which were three of the five explicitly trained CVC words, but he could not name any of the untrained CVC words. On the printed-word-to-spoken-word matching test, all trained CVC spoken words were correctly identified. The only untrained CVC words matched were ‘lit’ and ‘pit’. Participant 5 also recognised the printed words for these two spoken words in the spoken-word-to-printed-word recognition test, along with the five trained CVC words, to demonstrate 54% accuracy. Participant 5 did not recognise or name aloud any of the syllable control words.

Naming accuracy remained unchanged at 23% for the one-day post-test, but decreased to 8%, and then 0%, for the one week and one month post-tests. Across the three post-tests, printed-word-to-spoken-word matching accuracy was 25% at the one day and one week post-tests, and 15% at the one month post-test. There was a continual decrease in spoken-word-to-printed-word recognition accuracy from 46%, to 31%, to 15%, at the one day, one week, and one month post-tests respectively.

On the baseline reading measures (see Table 10.7), the scores produced by Participant 5 on the letter–sound and phonological awareness tasks in particular, were low. His performance on these tasks suggested that his letter–sound knowledge and ability to detect and manipulate sounds within words was not as developed as perhaps some of the other participants. Noticeably, his overall basic reading skills were considerably poorer than the other participants. For example, he often could not provide a response, even a guess, when encouraged to read aloud a word, and that was why the alternative letter naming measure was introduced for this participant. Potentially these differences may account for the smaller number of recombined CVC words that were named and recognised by Participant 5 following training, and then in the post-tests, irrespective of the training unit employed.

10.3.6 Participant 6

Participant 6 was a thirteen year old female with Down syndrome and mild learning difficulties. Table 10.8 presents the baseline reading skills scores for Participant 6.

Table 10.8 Performance on the entry reading skills tasks by Participant 6. Percentage correct shown in parentheses.

<table>
<tr><td>Participant 6
Female
Mild learning difficulties
Down syndrome</td><td>Age</td><td colspan="5">Letter–sound recognition correct/ 26</td><td colspan="5">Letter–name recognition correct/ 26</td><td colspan="5">Letter–sound production correct/ 26</td><td colspan="5">Letter–name production correct/ 26</td></tr>
<tr><td>Baseline
April 2008</td><td>13 years
4 months</td><td colspan="5">Lowercase
3 (12)
Uppercase
2 (8)</td><td colspan="5">Lowercase
25 (96)
Uppercase
24 (92)</td><td colspan="5">Lowercase
2 (8)
Uppercase
2 (8)</td><td colspan="5">Lowercase
24 (92)
Uppercase
23 (88)</td></tr>
<tr><td>Letter–sound writing correct/ 26</td><td>Letter–name writing correct/ 26</td><td colspan="5">High frequency word naming correct/ 64</td><td colspan="5">Print exposure correct/ 17</td><td colspan="5">Regular and irregular word spelling correct/ 40</td><td colspan="5">Phonological/ orthographic neighbours correct/ 16</td></tr>
<tr><td>3 (12)</td><td>20 (77)</td><td colspan="5">5 (8)</td><td colspan="5">5 (29)</td><td colspan="5">0 (0)</td><td colspan="5">7 (44)</td></tr>
<tr><td>TROG standard score</td><td>Working memory span / 8</td><td colspan="20">Phonological awareness</td></tr>
<tr><td rowspan="2">55</td><td rowspan="2">4</td><td colspan="4">Rime oddity correct/12</td><td colspan="4">Phoneme isolation correct/12</td><td colspan="4">Phoneme blending correct/15</td><td colspan="4">Alliteration correct/27</td><td colspan="4">Rhyme awareness correct/23</td></tr>
<tr><td colspan="4">6 (50)</td><td colspan="4">5 (42)</td><td colspan="4">6 (40)</td><td colspan="4">16 (59)</td><td colspan="4">13 (57)</td></tr>
</table>

10.3.6.1 Onset and rime training

All of the training trials followed a MTS format for Participant 6. When learning the onset sound–letter relations, the 90% criterion was met within four blocks, three blocks, and one block for the onset sound-to-letter, letter-to-sound, and mixed test trials respectively. When learning the rime sound–letter relations, she completed four blocks of sound-to-letter training, and two blocks of letter-to-sound training. On her first attempt at the mixed rime test trials, Participant 6 fell slightly below the necessary 90% criterion, demonstrating 80% accuracy. Retraining commenced again with the rime sound-to-letter trials. The criterion for the sound-to-letter trials and subsequent letter-to-sound trials was met each within one block of trials, and the mixed rime test was passed at the second exposure. Onset and rime revision training stages were passed within two blocks and one block respectively.

Figure 10.6 shows performance on the word naming and recognition tests in all training conditions for Participant 6. She accurately named 54% of the recombined CVC words presented, and identified the spoken word equivalents for 77% of the printed words tested. Printed word recognition accuracy was also 77%. From the baseline data (see Table 10.8), it is evident that Participant 6 commenced the MTS training with a little letter–sound knowledge, and performed reasonably strongly on the phonological awareness tasks; all of which may have positively contributed to her performance on the word naming and recognition tests. There were no changes in the reading or recognition of the control words.

Naming, spoken-word-to-printed-word, and printed-word-to-spoken-word recognition accuracy remained unchanged for the one day post-test. Decreases in accuracy for all test measures were observed in the one week and one month post-tests. Naming accuracy was 46% (one week) and 31% (one month). Printed-word-to-spoken-word accuracy was 62% (one week) and 31% (one month). In the one week and one month post-tests, spoken-word-to-printed-word accuracy was 69% and 46% respectively.

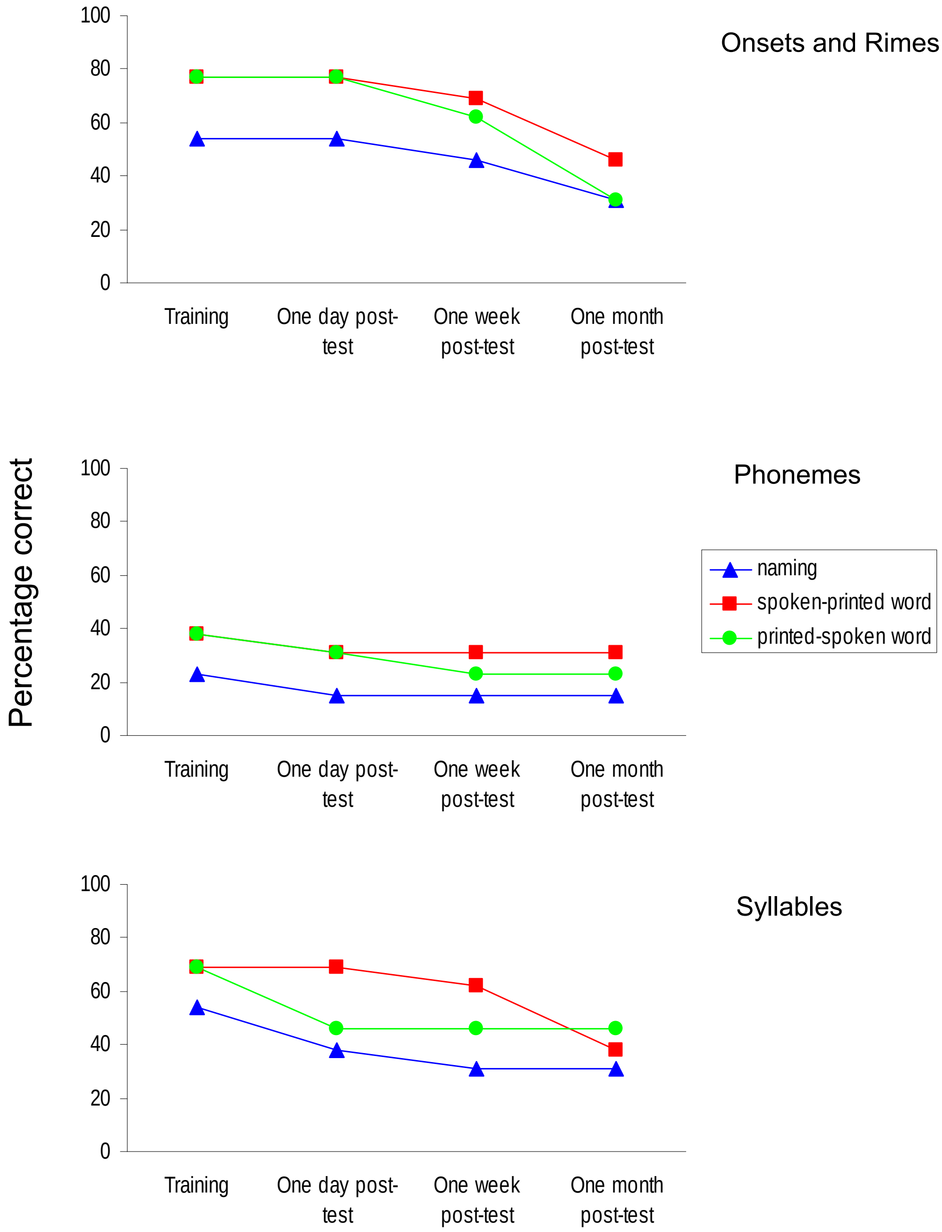


Figure 10.6 Accuracy in naming and recognising the recombined CVC words by Participant 6 following onset and rime, phoneme, and syllable training.

10.3.6.2 Phoneme training

When learning the initial consonant sound–letter associations, Participant 6 completed five blocks of sound-to-letter training, three blocks of letter-to-sound training, and achieved the 90% criterion in the mixed test within one block. As matching errors were high during the first MTS training block for the five vowel sound–letter pairs, Participant 6 undertook one block of two choice exclusion trials and one block of three choice exclusion trials. Once the 90% criterion was surpassed, she completed one block of three choice MTS trials and one block of five choice MTS trials to proceed to the vowel letter-to-sound training. Two MTS blocks of vowel letter-to-sound trials were completed to reach criterion, and the mixed vowel test was passed within one block. Although Participant 6 passed the final consonant sound-to-letter and letter-to-sound training stages within three blocks and one block respectively, her performance in the mixed final consonant test at 75% accuracy did not meet the criterion. Training recommenced therefore with final consonant sound-to-letter trials, and after meeting the criterion for the final consonant sound-to-letter and letter-to-sound trials each within one block, she attained the 90% criterion on the second exposure to the mixed test. Two blocks were required to pass the sound-to-letter revision trials, and one block to pass the letter-to-sound revision trials.

A small number of the recombined word were read aloud by Participant 6 (‘mop’, ‘top’, ‘hop’), with naming accuracy measured at 23% (see Figure 10.6). She often voiced many of the correct initial consonants but sometimes made errors when pronouncing the remaining letters, for example, ‘his’ was named as /hill/, ‘tag’ as /ten/. On some naming trials, she read aloud the words as high frequency words, (e.g., she read the target ‘wag’ as /egg/). She showed 38% accuracy in identifying the spoken words corresponding to printed word samples. Recognition accuracy in selecting the printed words to match a given spoken word sample was also 38%. She often chose the incorrect comparison that shared the same initial and final consonants as the target but a different vowel (e.g., /hag/ was matched to 'hug'). Recall that errors were high for Participant 6 when learning the vowel letter–sound relations. She did, however, name and recognise two of the control words.

Both naming and printed-word-to-spoken-word accuracy decreased in the post-tests. Naming accuracy fell to and remained at 15% across the three post-tests, while printed-word-to-spoken-word accuracy decreased to 31% (one day) and 23% (one week and one month post-tests). Accuracy in recognising the printed word equivalents was 31% across the three post-tests.

10.3.6.3 Syllable training

Participant 6 reached criterion for the spoken-word-to-printed-word, printed-word-to-spoken-word, and mixed CVC word test, within three blocks, three blocks, and one block respectively. She demonstrated 93% accuracy in matching the five CVC printed word–spoken word pairs in the revision training stages.

The five explicitly trained CVC words were read aloud accurately. The only untrained words correctly named were 'sad' and 'had' (naming accuracy = 54%). A small proportion of the untrained CVC words were read aloud as high frequency words, for example, 'leg' was named as /dog/, 'sit' as /said/. As shown in Figure 10.6, accuracy in pointing to the spoken words corresponding to a given printed word was slightly better, with four of the eight untrained recombined spoken words correctly identified (spoken word accuracy = 69%). She could also recognise 69% of the printed words shown, with errors occurring mainly when she selected the comparison containing an incorrect vowel, for example, for /pit/ the printed word 'put' was selected. None of the control words were named or recognised.

Naming accuracy decreased to 38% at the one day post-test, and was maintained at 31% across the remaining two post-tests. Printed-word-to-spoken-word matching accuracy was 46% in all post-tests. Spoken-word-to-printed-word accuracy was unchanged at 69% for the one day post-test, but was 62% for the one week post-test, and 38% for the one month post-test.

10.3.7 Participant 7

Participant 7 was a nine year old female with mild learning difficulties. Table 10.9 shows the baseline measure reading skills scores for Participant 7.

Table 10.9 Performance on the entry reading skills tasks by Participant 7. Percentage correct shown in parentheses.

<table>
<tr><td>Participant 7
Female
Mild learning difficulties</td><td>Age</td><td colspan="5">Letter–sound recognition correct/ 26</td><td colspan="5">Letter–name recognition correct/ 26</td><td colspan="5">Letter–sound production correct/ 26</td><td colspan="5">Letter–name production correct/ 26</td></tr>
<tr><td>Baseline
April 2008</td><td>9 years
2 months</td><td colspan="5">Lowercase
1 (4)
Uppercase
1 (4)</td><td colspan="5">Lowercase
20 (77)
Uppercase
19 (73)</td><td colspan="5">Lowercase
1 (4)
Uppercase
1 (4)</td><td colspan="5">Lowercase
18 (69)
Uppercase
18 (69)</td></tr>
<tr><td>Letter–sound writing correct/ 26</td><td>Letter–name writing correct/ 26</td><td colspan="5">High frequency word naming correct/ 64</td><td colspan="5">Print exposure correct/ 17</td><td colspan="5">Regular and irregular word spelling correct/ 40</td><td colspan="5">Phonological/ orthographic neighbours correct/ 16</td></tr>
<tr><td>1 (4)</td><td>19 (73)</td><td colspan="5">3 (4)</td><td colspan="5">5 (29)</td><td colspan="5">0 (0)</td><td colspan="5">2 (13)</td></tr>
<tr><td>TROG standard score</td><td>Working memory span / 8</td><td colspan="20">Phonological awareness</td></tr>
<tr><td rowspan="2">55</td><td rowspan="2">3</td><td colspan="4">Rime oddity correct/12</td><td colspan="4">Phoneme isolation correct/12</td><td colspan="4">Phoneme blending correct/15</td><td colspan="4">Alliteration correct/27</td><td colspan="4">Rhyme awareness correct/23</td></tr>
<tr><td colspan="4">3 (25)</td><td colspan="4">3 (25)</td><td colspan="4">4 (27)</td><td colspan="4">6 (22)</td><td colspan="4">7 (30)</td></tr>
</table>

10.3.7.1 Onset and rime training

Participant 7 achieved the 90% criterion in matching the five onset sound–letter relations in the sound-to-letter training, letter-to-sound training, and mixed test trials, within four blocks, two blocks and one block respectively. However, she did find it difficult to learn the rime sound–letter pairs. After two rime sound-to-letter training MTS trial blocks, exclusion trials were implemented and Participant 7 completed two blocks of two choice trials, and one block of three choice trials. After reaching 96% accuracy, Participant 7 undertook one block of three choice MTS trials and one block of five choice MTS trials (meeting the 90% criterion). Rime letter-to-sound training was passed within two blocks (five choice MTS trials) and the mixed rime test was passed at the first attempt. The 90% accuracy criterion for the onset and rime revision training was achieved at the first attempt.

Of the recombined words presented, Participant 7 named 38% (5/13) and recognised the spoken word equivalents for nine of the recombined words presented (accuracy = 69%). As shown in Figure 10.7, accuracy in matching the spoken words to corresponding printed words was also 69%. Not only for the onset and rime training, but across the training conditions, Participant 7 recorded higher scores in the word recognition tests compared to the word naming tests. However, it is important to highlight that Participant 7 did produce low scores in the high frequency word naming baseline task, which was the oral reading skills measure, and the letter–sound task (see Table 10.9), which possibly may be one reason as to why word recognition was better than word naming.

There was a slight decrease in naming accuracy to 31% (4/13), 15% (2/13), and 8% (1/13) across the three post-tests. Both recognition accuracy measures were maintained at the one day post-test. Printed-word-to-spoken-word accuracy decreased to 46% (one week) and 23% (one month). Accuracy in selecting the printed words to match spoken word samples was 54% (one week) and 23% (one month).

10.3.7.2 Phoneme training

Participant 7 appeared to learn the initial consonant sound–letter relations quite easily, requiring three blocks, one block and one block to pass the sound-to-letter, letter-to-sound and mixed test trials respectively. However, when presented with the vowel sound–letter relations, as only 12% accuracy was shown in the sound-to-letter training trials, the MTS training was replaced with exclusion type training trials. After completing two blocks of two choice and one block of three choice exclusion trials to criterion, Participant 7 completed one three choice MTS block and one five choice MTS block, before fulfilling the 90% criterion to proceed to the letter-to-sound training, which was passed within two blocks. The mixed vowel test was passed at the first attempt. Using MTS training trials, all of the final consonant training stages were passed, along with the revision training stages.

Participant 7 could not name any of the recombined phoneme words. Despite encouragement to look carefully at each of the words, she tended to produce unrelated high frequency words when attempting to read aloud the recombined words. For example, ‘mud’ was named as /up/, ‘top’ as /on/, and ‘wag’ as /go/. Similarly, in the spoken-word-to-printed-word and printed-word-to-spoken-word recognition tests, she identified few of the printed or spoken word equivalents (38% and 23% respectively). Initial consonant recognition was good as she often selected the incorrect comparison that shared the same initial consonant as the sample but that contained an incorrect vowel and final consonant (e.g., given the sample /mud/, the printed word ‘mop’ was chosen). Participant 7 did not name or recognise any of the control words presented.

None of the recombined words were named in any of the post-tests. Instead, Participant 7 was encouraged to say the names of the letters contained within the test words. Spoken-word-to-printed-word recognition accuracy decreased to 23% for the one day and one week post-tests, and 15% for the one month post-test. Printed-word-to-spoken-word accuracy remained at 23% for the one day post-test, but decreased to 15% at the one week and one month post-tests.

10.3.7.3 Syllable training

Participant 7 appeared to find it extremely difficult to remember the five CVC spoken word–printed word relations when first attempting the spoken-word-to-printed-word training trials. She seemed to be indiscriminately matching the spoken and printed words. For example, /sum/ was matched to ‘peg’, ‘hit’, and ‘lad’, but not matched to ‘sum’ in the first block of trials. The only pairing that Participant 7 grasped from the initial exposure was /fox/-‘fox’. From the baseline reading measures, she demonstrated an extreme lack of letter–sound knowledge (see Table 10.9), which may have exacerbated her difficulties in differentiating between the letter sounds and associated letters in the training stages.

It was deemed appropriate to employ exclusion type training trials with Participant 7 to build up knowledge of the spoken word–printed word relations, before reintroducing MTS training trials. For the spoken-word-to-printed-word training, Participant 7 completed two blocks of two choice exclusion trials (achieving 56% and 92% accuracy respectively), one block of three choice exclusion trials (showing 92% accuracy), one block of three choice MTS trials, and one block of five choice MTS trials. On this final training block, the 90% criterion required to pass the spoken word–printed word training was achieved. Two blocks of printed-word-to-spoken-word MTS training trials were completed, with Participant 7 achieving 88% accuracy on the first block and 96% accuracy on the second block. The 90% criterion for the revision training stages was reached on the first attempt.

Two of the five explicitly trained words ('lad', 'fox') were named by Participant 7. The untrained recombined word /leg/ was incorrectly named as /lad/. Some of the recombined words were named as words containing different letters. For example, 'peg' was named as /down/, 'lit' as /see/, and 'sit' as /you/. The words produced by Participant 7 are high frequency words and are included within the word lists used during her classroom reading activities. This may perhaps account for the use of these particular words that appeared removed from the training words (a similar pattern was also observed in the phoneme naming test). Participant 7 recognised the printed words and spoken words corresponding to the five taught CVC words, and recognised two of the eight untrained words ('pit' and 'leg'). All control words remained unnamed and unrecognised.

Naming accuracy was maintained at the one day post-test, but none of the words were named at the one week or one month post-tests. Printed-word-to-spoken-word accuracy decreased to 46% (one day) and 23% (one week and one month). Accuracy in matching the spoken word–printed word relations persisted at 54% for the one day post-test, but decreased to 46% and 23% for the one week and one month post-tests respectively.

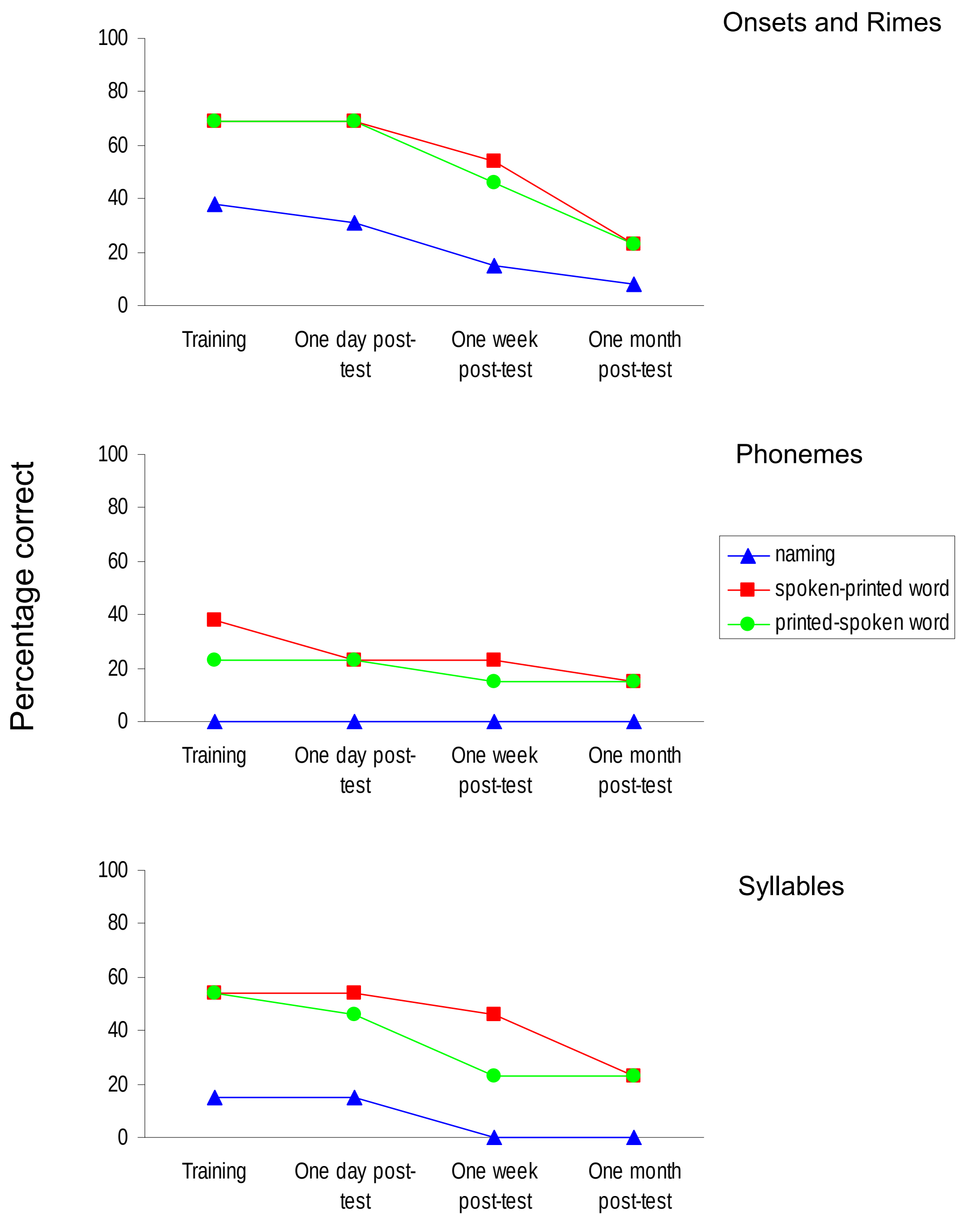


Figure 10.7 Accuracy in naming and recognising the recombined CVC words by Participant 7 following onset and rime, phoneme, and syllable training.

10.4 Discussion

For all of the children, onset and rime training appeared to be associated with the highest percentage of novel recombined words accurately read aloud and the greatest accuracy in matching the recombined spoken words and printed words in the word recognition tests. In general, the difference between word naming and recognition performance following phoneme training and syllable training was quite small for the majority of participants, although there was a slight advantage for syllable training over phoneme training in terms of the percentage of printed words recognised for most of the children. These results are in accordance with previous findings highlighting the important role of onsets and rimes for children learning to read (e.g., Ziegler & Goswami, 2005), although, training with each of the three units, be it onsets and rimes, phonemes, or syllables, did result in gains in word naming and word recognition for the participating children.

Taking into account that the training was brief (i.e., MTS training at each unit size took place during one day) and that there was no further training between the post-tests or corrective feedback provided during the post-tests, the gains that were maintained for some of the children were impressive. But generally, word naming and recognition did decrease across the post-test periods, especially for the children who could not read aloud many words (e.g., high frequency words) or obtained low scores on the baseline reading skills tasks to begin with. The very fact that the children did not receive any supplementary instruction to revise and consolidate their learning is the most likely explanation behind the decreases in word naming and recognition that were evident. Looking at how effective the single training session was for some of the children, there is a strong possibility that if training had been interspersed with testing, greater maintenance might have been seen.

From an ethical standpoint, questions can be raised if the children who could not name many of the words (e.g., Participants 4, 5, and 7) should have continued to complete the post-tests. To track their classroom reading progress, the children are accustomed to attempting to read word lists for their teachers (e.g., the Dolch word lists) which can often contain words that they are unable to read. In light of such testing being something that the children were familiar with from their classroom experiences, continuing with the post-tests was not deemed to be unreasonable. However, as described in the results section, to minimise any anxiety that might possibly occur from being unable to read aloud any of the words, the children were instead invited to name the letters contained within the words, something that the children had no difficulties in doing.

From the completion of the first study, it was clear that although the protocol did seem to be effective in facilitating the naming and recognition of unfamiliar words, there were some points of contention.

Firstly, the MTS format of the training trials was not suitable for all of the participants. Some of the children found it particularly difficult to learn and remember the letter–sound relations when completing the MTS training trials. It was therefore necessary to introduce exclusion type training trials to 'build up' the correct associations for these children relatively quickly, before returning to the MTS training trials as verification that the correct letter–sound pairings had been established. Perhaps though, these findings are not that surprising given that some researchers have found exclusion procedures rather than 'trial and error' techniques (an example of which would be a MTS procedure) to better facilitate learning of relations in visual–sound matching tasks (e.g., de Rose et al., 1996; Ferrari, de Rose, & McIlvane, 1993). One of the advantages of the training protocol is that it can be adapted to meet the needs of individual children. From the initial data, it seemed that there were four to five children who would certainly benefit from completing a mixture of exclusion and MTS training trials.

Secondly, the percentage of words read aloud was quite small for some of the participants, in particular, Participants 4, 5, and 7. From the baseline entry data it is clear that these three participants presented with the lowest scores on the various reading skills tasks administered (e.g., phonological awareness, letter–sound knowledge, print exposure) and perhaps, this may account somewhat for their test performances. Notably however, these three participants recognised over half of the recombined printed words or spoken words following onset and rime training, a finding that was encouraging given that they could not recognise any of the words at baseline. Participants 1 and 2 named and recognised the most recombined test words, and analysis of the baseline entry measures indicates that these two participants did have quite good letter–name knowledge, a little letter–sound knowledge of some dominant letter sounds (e.g., ‘a’ - /a/), and demonstrated more developed phonological awareness skills. All of these abilities have been identified as contributing factors influencing reading development (e.g., Byrne, 1998; Hulme et al., 2005; de Jong & Van der Leij, 1999) and may have influenced recombinative generalisation performance. The remaining five participants had less developed phonological awareness skills and possessed almost no letter–sound knowledge, but did demonstrate generally good letter–name knowledge. However following training, these participants were capable of naming and recognising some of the recombined words. This finding may lend further support to the effectiveness of the training protocol itself in facilitating recombinative generalisation in the absence of well developed letter–sound or phonological awareness skills. The presence of some phonological awareness skills and some letter–sound knowledge may also help recombinative generalisation performance. Further data is required to explore these issues.

In summary, all seven children entered this research with word reading and pseudoword reading skills assessed as extremely low, and were reported to be significantly underachieving in reading. From the initial collected data, if we compare the children's baseline and post training performance, all of the children demonstrated gains in word naming and recognition following the MTS training procedures. Regarding the size of the training unit, gains were generally largest when onsets and rimes were employed as the units to train the letter–sound correspondences. The basic protocol used as a single training procedure appeared to be an effective tool in promoting novel word naming and recognition for the participating children.

Chapter Eleven

Experiment 8C: Meaningfulness and Comprehension: Developing a New Stimulus Equivalence Matching-to-Sample Protocol

11.1 Introduction

Following completion of the initial research with the children, the question stood: how effective was the training protocol for these children? If we compare the children's baseline and post training performance, all of the children demonstrated some gains in word naming and recognition following the MTS training procedures. More specifically, it was the onset and rime training, as opposed to the phoneme or syllable training, which was associated with the greatest increases in the number of recombined words named and recognised. To this extent, the onset and rime protocol appeared to be the most effective for the children.

Noticeably though, three of the children (Participants 4, 5, and 7) did struggle somewhat to correctly read aloud the recombined words even after participating in the onset and rime training. It cannot be overlooked that these three children presented with the lowest scores on the entry reading skills measures (please see Tables 9.9 and 9.10, pp. 199-200). As was acknowledged in Chapter 10, perhaps these children's less developed letter–sound knowledge and phonological awareness skills might have contributed to their poorer performance in the recombinative generalisation tests. Based on the preliminary findings, it was felt that the procedures could be refined and further developed to try and improve word naming accuracy in the recombinative generalisation tests for all seven children. The final body of research with the children addressed this issue.

Training paradigms incorporating stimulus equivalence procedures have been shown to be effective in promoting reading skills (e.g., Connell & Witt, 2004; de Rose et al., 1992, 1996; de Souza et al., 2009; Lane & Critchfield, 1998; Mackay & Sidman, 1984; Sidman, 1971; Sidman & Cresson, 1973). By definition, three component relations must be evident for the term 'stimulus equivalence' to be applied. These relations are described as symmetry, transitivity, and reflexivity (Sidman, 1994; Sidman & Tailby, 1982).

A symmetrical relation is essentially a bidirectional relation. Thus, after learning to choose the printed word comparison 'cake' given the sample spoken word /cake/, if the printed word 'cake' was then presented as the sample, and the spoken word /cake/ was selected as the comparison, this would be a symmetrical relation (see de Rose et al., 1996). In order for transitivity to occur, a third stimulus must be introduced, for instance, a picture of a cake. Transitivity is apparent if after learning to relate the printed word comparison 'cake' to the spoken word sample /cake/, and learning to match the picture comparison of a cake to the spoken word sample /cake/, given then the printed word 'cake' as a sample, if (in the absence of any training) a participant selected the picture of a cake (as a comparison), transitivity has occurred (Sidman, 1994). Finally, if a participant can successfully match each of the three sample stimuli to its identical comparison stimuli (e.g., 'cake'[sample] – 'cake' [comparison], /cake/ – /cake/, etc.,), this is referred to as reflexivity (Sidman, 1994). Once these three relations have been observed, the stimuli involved - the printed word, spoken word, and picture - are said to have formed an 'equivalence class' (Mackay & Sidman, 1984). Furthermore, as the pictures are taken to exemplify the meaning of the associated spoken words and printed words, a participant who can, without any direct training, match a picture to its associated printed word (an instance of a transitive relation), is assumed to have demonstrated some comprehension of the meaning of the printed word (see Sidman, 1971). In this way, the successful emergence of equivalence has been acknowledged to provide a rudimentary measure of comprehension (Sidman, 1994).

One of the first researchers to highlight the benefits of stimulus equivalence methods in strengthening word naming was Sidman (1971). Working with participants defined as having severe mental retardation, MTS procedures were used to train the participants to match printed word comparisons to spoken word samples, to match picture comparisons to spoken word samples, and to name the pictures. Despite no further training, Sidman (1971) discovered that the participants were able to accurately match the printed words and corresponding pictures when the printed word-to-picture and picture-to-printed word relations were examined in the tests for equivalence. The participants could also read aloud a proportion of the printed words without the need for direct training.

When considering the data from the Mueller et al. (2000) study, it was only with the addition of a stimulus equivalence training component that increments in word naming were apparent for two of the typically developing children. Likewise, in the Saunders et al. (2003) investigation with adults with mental retardation, successful word naming was dependent on the completion of a stimulus equivalence phase.

In retrospect, the results from the study reported in Chapter 10, and the word naming difficulties experienced by Participants 4, 5, and 7, are perhaps not that unexpected given that no such stimulus equivalence procedure was incorporated into the preliminary protocol. Based on the available evidence, the addition of a stimulus equivalence component to the MTS protocol was purported to make a very likely valuable contribution to the children’s word recognition and naming. Such a stimulus equivalence component was included in the final procedure that was employed with the children and its utility in improving the children's word naming and identification was assessed.

Additionally, one anecdotal observation from Experiment 8B was that some of the children displayed a tendency to enquire about the meaning of a printed word. Upon viewing a printed word, sometimes a participant would ask "what's that?" For the current experiment, including a stimulus equivalence component in which the children learned to relate printed words, spoken words, and pictures, provided an opportunity for the children to potentially learn a little more about what the printed words and spoken words were referring to. In a sense, this amplified the meaningfulness of the task, which may be particularly suitable for children with LD who may struggle with abstract concepts (see Allor, Mathes, Robertsm Cheatham, & Champlin, 2010; van der Schuit, Peeters, Segers, van Balkom, & Verhoeven, 2009). Furthermore, as was indicated in Chapter 1, one of the goals that readers strive towards is comprehension of print. It may be suggested that an effective instructional procedure should ideally include some comprehension based components to try and enable the children to gain a sense of the meaning of words. A stimulus equivalence component is exactly suited for this purpose.

To extend the use of the protocol, the children were presented with regular, rime consistent words (i.e., words that can be pronounced through reference to letter–sound relations) and exception words (i.e., words in which a printed rime assumes a different pronunciation to how it is pronounced in other rime sharing words). Quite a large number of exception words are high frequency words that tend to be encountered early on in reading instruction (see Rayner et al., 2001). As there is a strong possibility that children will often be confronted with these words, it is important that they can accurately recognise exception words.

How can exception words be tackled? Returning to the dual-route models of word recognition (e.g., Coltheart et al., 1993, 2001), the defining characteristic of an exception word is that it cannot be correctly pronounced by application of letter–sound correspondences; the mechanism attributed to the indirect, sublexical route. Hence, exception words must be taught ‘by sight’ as whole words and will be recognised in their entirety by the direct route. In Experiment 7, the adults who completed the syllable training (i.e., trained to match whole CVC words) were more accurate in recognising the exception words than the onset and rime or phoneme trained participants. But conversely, when presented with the onset–consistent rime recombined words, it was the onset and rime and phoneme trained participants who were the most successful in identifying these words. In Chapter 8, it was suggested that perhaps the most effective protocol would be one in which a combination of whole word and onset and rime training procedures were used. If two routes are indeed required to read aloud regular and exception words, arguably it is logical that instructional practices should aim to reflect and complement these two routes.

Thus, for the final experiment, the protocol was modified as follows. A stimulus equivalence phase was added to train (as whole words) the exception words and a proportion of the rime consistent words. As exception words must be learned in some form as whole words (applying individual letter–sound mappings will result in an incorrect word pronunciation) such exception words may be suggested to be particularly suitable to be trained via a whole word stimulus equivalence training procedure. On the other hand, rime consistent words can be accurately read aloud by reference to letter–sound correspondences. Thus, the inclusion of such rime consistent words within the procedure afforded the opportunity to test for recombinative generalisation. Novel recombined words were formed by combining different onsets with the consistent rimes. In the current study, the children were exposed to the consistent rimes within the context of whole words in the stimulus equivalence training. Additionally, as part of the general procedure, the children were also trained with the individual onset and rime sub-word units prior to the start of the stimulus equivalence training. The findings from Experiment 8B highlighted the benefits of such onset and rime training, hence the retention of this training component in the revised procedure.

In summary, the current study sought to determine if the revised stimulus equivalence protocol was effective in improving the children's word naming and recognition of explicitly trained whole words (exception words and rime consistent words). A further aim was to explore if any such gains also extended to the untrained novel words formed from recombinations of onsets and consistent rimes.

11.2 Method

All seven children completed the training and testing procedures. Prior to the start of training, the children's general reading skills were assessed utilising the tasks outlined in Chapter 9 to measure each child's current progress in these domains. These assessments were undertaken during April 2009 to June 2009.

In terms of overall reading progress, class teacher reports, together with the ongoing school visits carried out by the researcher, indicated that Participant 2 had made considerable progress with his reading development. Although many of the other children had also made individual progress, the improvements in reading ability were particularly evident for Participant 2. For example, he could generally sound out words accurately and recognised an expanding number of words quickly by sight. Participant 2 continued to participate in the current experiment as it was felt that completing the training would still be beneficial for him. It is important to acknowledge this difference in reading ability between Participant 2 and the other children when inspecting the following data.

11.2.1 Stimuli

To reduce memory demands, all of the words used in the experiment were monosyllable words. Training and test words were nouns, verbs, or adjectives predominantly comprised of four letters, although some test words contained five letters. Because the training words needed to be represented pictorially for the stimulus equivalence phase, this restricted the words that could be included.

Four exception words were chosen ('wash', 'have', 'give', and, 'foot'). These words are exception words as each contains a printed rime that requires a pronunciation that differs from how the rime is usually pronounced in other words also containing the same printed rime. These four words have been employed and classified as high frequency exception words in previous studies (e.g., Pexman et al., 2005; Plaut et al., 1986). Rime consistency percentages were computed for each inconsistent rime using the formula described in Chapter 8 (p. 140) to ensure that as far as possible the rime consistencies were not too dissimilar. The inconsistent rimes 'ash', 'ave', 'ive', and 'oot' yielded consistency percentages of 85%, 61%, 69%, and 87% respectively.

For each exception word, lists were prepared of possible rime sharing monosyllable words. These were words that shared the same printed rime as the exception word, but across these words, the printed rime was always pronounced in the same way. Two of the rime sharing words that could be illustrated by picture were chosen to be trained alongside the exception word as whole words in the stimulus equivalence training phase. The remaining rime sharing words were presented as novel, untrained words during the reading aloud and recognition generalisation tests that occurred after the training.

Four high frequency consistent rime words were chosen to be trained as whole words in the stimulus equivalence training. As a consistent rime word, the rime was pronounced identically across monosyllable words which possessed the rime. The consistent rime words chosen for the study were ‘cake’, ‘nest’, ‘sing’, and ‘cold’. These words matched the exception words in terms of the rimes utilising similar initial vowels (/a/, /e/, /i/, /o/). Again, lists of rime consistent monosyllable words were assembled for each consistent rime.

The four exception words, four consistent rime words and associated rime sharing words were organised into eight word sets. There were four exception word sets. Each set contained one exception word (e.g., ‘foot’) and two rime sharing words (‘boot’, ‘root’) that were explicitly trained, and between two to six rime sharing words (e.g., ‘hoot’, ‘loot’) that were untrained. The other four word sets each contained one consistent rime word (e.g., ‘cake’) and two consistent rime sharing words (e.g., ‘lake’, ‘rake’) that were directly trained, together with two to six rime sharing words (e.g., ‘bake’, ‘make’, ‘take’) that were not trained. Particular care was taken when selecting the untrained words that whenever possible, the words were printed words that the children were unlikely to have encountered in print before, or have received explicit instruction in how to read.

Table 11.1 shows the eight word sets, and indicates the trained exception words, trained rime consistent words, and untrained test words presented in each set. Where available, frequency ratings for all words employed across the eight sets were obtained from the Children's Printed Word Database developed by Masterson et al. (2003). There were no significant differences in frequency ratings between the four high frequency exception words (mean frequency = 875.33) and the four high frequency consistent rime words (mean frequency = 833.33) trained in the stimulus equivalence stage, $t(6) = .052$, $p = .960$. Likewise, no significant differences were found between the frequency ratings for all of the words presented in the four exception word sets (mean frequency = 255) and the words featured in the four rime consistent word sets (mean frequency = 281.37), $t(45) = -.160$, $p = .874$. As shown in Table 11.1, the percentage of nouns, verbs, and adjectives contained in the four exception word sets compared to the four rime consistent word sets was similar.

Table 11.1 The eight word sets (four exception word sets and four rime consistent word sets) presented. Percentage of adjectives, nouns and verbs shown in parentheses.

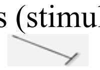
Word Sets		*Stimulus Equivalence Training*		*Word naming and Word Recognition Tests*	*Part of Speech*
	Inconsistent rime	*Trained exception word*	*Trained rime sharing words*	*Untrained rime sharing words*	*Total number/23*
1	ash	wash	cash, mash	bash, dash, gash, sash	*Adjectives* 2 (9%)
2	ave	have	cave, wave	gave, save, brave	*Nouns* 11 (48%)
3	ive	give	dive, hive	five, drive	*Verbs*
4	oot	foot	boot, root	hoot, loot	10 (43%)
	Consistent rime	*Trained consistent rime word*	*Trained rime sharing words*	*Untrained rime sharing words*	*Total number/27*
5	ake	cake	lake, rake	bake, make, sake, take, wake, brake	*Adjectives* 2 (8%)
6	est	nest	rest, vest	best, test, west	*Nouns* 12 (44%)
7	ing	sing	ring, wing	ding, ping, bring	*Verbs* 13 (48%)
8	old	cold	fold, gold	hold, sold, told	

11.2.2 Outline of training and test procedures

The procedure was comprised of four stages as follows: (i) pretests; (ii) onset and rime training; (iii) stimulus equivalence training and recombinative generalisation testing for word sets 1 to 8; (iv) one day and one week follow up post-tests for word sets 1 to 8.

Stage one was completed during September 2009 to November 2009. From January 2010 to June 2010, during weekly sessions, the children completed stages two, three, and four. An overview of the stages can be seen in Table 11.2.

Table 11.2 Stages completed in the stimulus equivalence MTS protocol.

<table>
<tr><td colspan="2">Stage 1: Word Naming and Printed Word Recognition Pretests</td></tr>
<tr><td colspan="2">Baseline accuracy in reading aloud and recognising printed words for the 50 words presented across the word sets.</td></tr>
<tr><td colspan="2">Stage 2: Onset and Rime Training</td></tr>
<tr><td>(i) Onset training (14 onsets)
sound-to-letter relations e.g., /b/ - ‘b’
letter-to-sound relations e.g., ‘b’ - /b/</td><td>(ii) Rime training
4 consistent (/ake/, /est/, /ing/, /old/)
4 inconsistent rimes (/ash/, /ave/, /ive/, /oot/)
sound-to-letter relations e.g., /ake/ - ‘ake’
letter-to-sound relations e.g., ‘ake’ - ‘ake’</td></tr>
<tr><td colspan="2">Stage 3: Stimulus Equivalence Training and Recombinative Generalisation Testing for Word Sets 1 – 8</td></tr>
<tr><td colspan="2">(i) Train spoken-words-to-printed-words
e.g., /rake/ - ‘rake’; /lake/ - ‘lake’; /cake/ - ‘cake’
(ii) Test printed-words-to-spoken-words (symmetry)
e.g., ‘rake’ - /rake/; ‘lake’ - /lake/; ‘cake’ - /cake/
(iii) Train pictures-to-spoken-words
e.g.,  - /rake/
(iv) Test spoken-words-to-pictures (symmetry)
e.g., /rake/ - 
(v) Test printed-words-to-pictures (stimulus equivalence test)
e.g., ‘rake’ - 
(vi) Test pictures-to-printed-words (stimulus equivalence test)
e.g.,  - ‘rake’
Recombinative Generalisation Tests
Three trained words (e.g., /rake/, /lake/, /cake/)
Untrained recombined words (e.g., /bake/, /make/, /sake/, /take/, /wake/, /brake/)</td></tr>
<tr><td>(i) Printed word naming test</td><td>(ii) Spoken-word-to-printed-word recognition test</td></tr>
<tr><td colspan="2">Stage 4: One day and one week follow up post-tests</td></tr>
<tr><td>(i) Printed word naming test</td><td>(ii) Spoken-word-to-printed-word recognition test</td></tr>
</table>

Stage 1: Word naming and printed word recognition pretests

Initially, the children completed a word naming pretest, followed one week later by a word recognition pretest. These assessments measured each child's baseline accuracy in reading aloud and identifying the 50 words included in the word sets. The pretests were identical in format to those reported in Chapter 10 (p. 208).

Stage 2: Onset and rime training

Given the effectiveness of the onset and rime training in Experiment 8B, training with the onset and rime sub-word units that formed the word set words was included as the first training stage.

To begin with, it was ensured that the participants could correctly recognise each of the 14 onset letter–sound relations (/b/, /c/, /d/, /f/, /g/, /h/, /l/, /m/, /n/, /p/, /r/, /s/, /t/, /w/) featured across the 50 words. Sound-to-letter trials were attempted first. To progress to the letter-to-sound trials, at least 95% accuracy was required. Each onset letter or sound was presented twice as the sample within a block of 28 training trials.

Depending on individual ability, some participants completed MTS trials in which the target letter or sound was accompanied by three or four incorrect letter or sound comparisons. Alternatively, exclusion trials in which the number of comparisons was gradually increased from two to four comparisons were undertaken. Generally, this stage was completed quickly by the majority of participants who had made gains in their letter–sound knowledge (i.e., only one block each of sound-to-letter and letter-to-sound trials was needed to fulfil the criterion).

Next, the four inconsistent rime (/ash/, /ave/, /ive/, /oot/) and four consistent rime (/ake/, /est/, /ing/, /old/) letter–sound relations were trained. Exclusion trials were used to minimise response errors and thus build up knowledge of the printed rimes and associated pronunciations. At first, this was a spoken rime-to-printed rime two-choice task between the following inconsistent–consistent rimes: /ash/–/ake/; /ave/–/est/; /ive/–/ing/; /oot/–/old/. Six trials were assigned to each pair. The consistent rime in each pair was presented three times as the sample sound (e.g., /est/ as in /nest/). There were two possible pronunciations for each inconsistent rime; the exception word pronunciation (e.g., /ave/ as in /have/) and the pronunciation in other rime sharing words (e.g., /ave/ as in /gave/, /save/). Of the three trials assigned to each inconsistent rime, for one trial the exception word rime pronunciation was used as the sample; while the alternative rime pronunciation was employed as the sample in the other two trials. Thus, the participants were exposed to the two possible pronunciations for each inconsistent rime.

Starting with the first rime pair (/ash/-/ake/), participants needed to select the correct printed rime comparison to match a given spoken rime sample on all six trials before the next rime pair (/ave/-/est/) was introduced. Participants had to respond correctly to all six trials for each rime pair before the next rime pair was presented. After all four rime pairs had been presented, participants completed a printed rime-to-spoken rime two-choice exclusion task. This task was identical to the previous task, except that the printed rimes were presented as the samples and the spoken rimes as the comparisons.

Lastly, a three-choice MTS task was undertaken to revise all of the rime letter–sound relations. Twenty-four trials were presented in a quasi-random order; 12 spoken rime-to-printed rime and 12 printed rime-to-spoken rime trials. Each rime (/ash/ [as in /cash/], /ash/ [as in /wash/], /ave/ [as in /save/], /ave/ [as in /have/], /ive/ [as in /five/], /ive/ [as in /give/], /oot/ [as in /boot/], /oot/ [as in /foot/], /ake/ [as in /cake/], /est/ [as in /nest/], /ing/ [as in /ring/], /old/ [as in /cold/]) was presented once as the sample. On each trial, the correct comparison (e.g., /oot/) appeared with two incorrect comparisons; one of which almost always started with the same vowel as the correct comparison (e.g., /old/ and /est/). Given accuracy of at least 90% from one block of 24 trials, participants were ready to commence the stimulus equivalence training.

All participants achieved the criterion to pass the onset and rime training.

Stage 3: Stimulus equivalence training and recombinative generalisation testing for word sets 1 to 8

All seven children completed training with the eight word sets (four exception word sets and four consistent rime word sets). The order in which the sets were attempted differed for each participant. Each session concentrated on one particular word set. There were three spoken words, three printed words, and three corresponding pictures trained in each set. Typically a word set was trained and tested within a 20 to 30 minute session.

The stimulus equivalence training for the three words was divided into six phases as follows: (i) training spoken-words-to-printed-words; (ii) testing printed-words-to-spoken-words; (iii) training pictures-to-spoken-words; (iv) testing spoken-words-to-pictures; (v) testing printed-words-to-pictures; (vi) testing pictures-to-printed-words. All trials were MTS trials. The format of the spoken word–printed word trials essentially adhered to the specifications outlined in Chapter 10 (p. 206), for example, in terms of the use of stars to mark the screen location of sounds etc. Any differences are described in the following sections. Further details on the new picture–spoken-word–printed-word trials are included below. Feedback as described in Chapter 10 was generated by the researcher for training trials, but omitted for test trials.

Training spoken-words-to-printed-words

Each block was comprised of 12 trials. The three words included in the designated word set each appeared four times as the sample (e.g., /cake/, /rake/, /lake/). For each trial, after the sample word had been spoken by the researcher, the three printed words were presented across the computer screen from left to right as three comparisons (e.g., 'cake', 'rake', 'lake'). The position of the correct comparison occurred equally in each of the three screen locations (e.g., left, middle, right). At least 11 correct responses from one block of 12 trials were necessary to proceed to the next phase. A block of trials was repeated until the criterion was achieved.

Testing printed-words-to-spoken-words

This phase was identical to the preceding phase, apart from the use of the three printed words for the word set as samples, and the three associated spoken words as comparisons. No feedback was provided. A minimum of 11 of the 12 test trials needed to be responded to correctly to advance to the next phase.

Training pictures-to-spoken-words

Figure 11.1 is included as an example of a typical picture-to-spoken-word trial. Trials were structured as follows. Three different coloured stars appeared down the left-hand side of the screen. The target picture was located in the centre of the screen. First, to ensure that the participant was attending to the picture the researcher pointed to the picture and said "look at this picture (pause to verify that the child was looking at the computer screen) is it ….". Then, starting with the first coloured star, the researcher pointed to the first star and pronounced one of the words (e.g., /lake/). Next, the researcher pointed to the middle star and said a second word (e.g., /cake/), and lastly, pointed to the bottom star and said the third word (e.g., /rake/). The colours of the stars were random and changed with each trial. However trials were organised to ensure that the correct spoken word comparison occurred equally in each of the three possible screen locations.

To signal their response, a participant touched the star (i.e., spoken word) that he or she thought was the correct match for the target picture. Twelve picture-to-spoken-word trials were presented in one block. The criterion to proceed to the subsequent phase was set at 11 of 12 correct responses from one block.

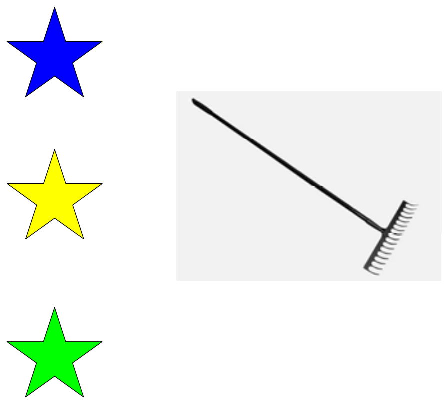


Figure 11.1 Screenshot of a picture-to-spoken-word trial. Each of the coloured stars is named in sequence from top to bottom by the researcher (e.g., /lake/, /cake/, /rake/). The participant points to the star (i.e., spoken word) that matches the sample picture.

Testing spoken-words-to-pictures

Twelve spoken-word-to-picture trials were presented. As shown in Figure 11.2, for each trial, the three pictures (e.g., rake, lake, and cake) appeared on screen. Across the trial block, the correct picture comparison appeared four times in each of the three screen locations. For each trial, the researcher asked the participant “which one is (rake)?” The participant touched the screen to indicate their response. Criterion was established at 11 correct responses from one block to progress to the next phase.

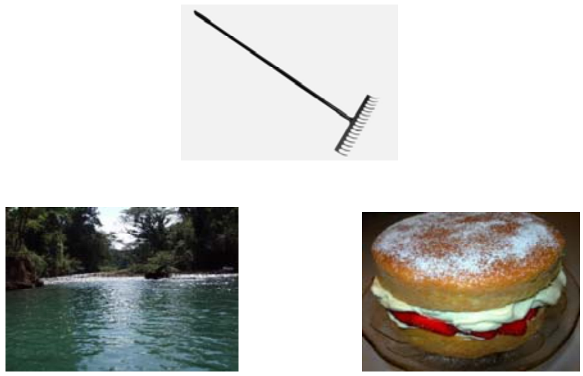


Figure 11.2 Screenshot of a typical spoken-word-to-picture trial. The sample spoken word is articulated by the researcher as part of the phrase "which one is (rake)?" Participants point to the picture comparison that matches the sample spoken word.

Testing printed-words-to-pictures

This phase was included to test for stimulus equivalence by examining if the participants could match the printed words and pictures; the printed word–picture relations were the derived, untaught, transitive relations. Participants attempted nine trials. Each of the three set words (e.g., 'rake', 'cake', 'lake') appeared three times as the sample word. Figure 11.3 illustrates a typical trial in this phase. On each trial, the sample printed word appeared in the middle of the screen, surrounded by three picture comparisons. The researcher underlined the printed word with their finger, and asked the participant to "look at this word (pause), which one is it?" Participants pointed to the picture that matched the sample printed word.

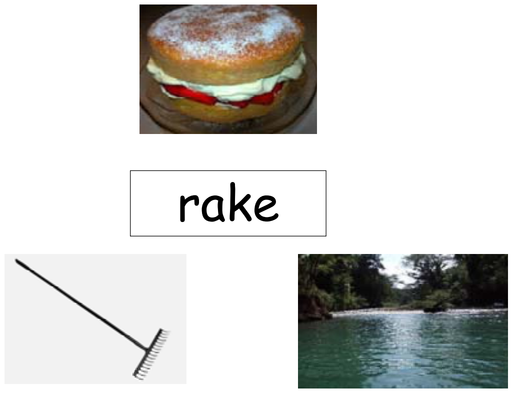


Figure 11.3 Screenshot of a printed-word-to-picture trial. After looking at the printed word, a participant touched the picture comparison that represented the printed word sample.

Testing pictures-to-printed-words

Figure 11.4 shows a picture-to-printed-word trial. This phase was incorporated as a further test for stimulus equivalence; testing emergence of the untaught picture-to-printed-word relations. As in the previous phase, participants completed nine trials, with the three pictures each representing one of the three set words functioning three times as the sample picture. In all trials, the sample picture appeared. Below the picture, the three printed words were presented. Participants pointed to the printed word that matched the sample picture.

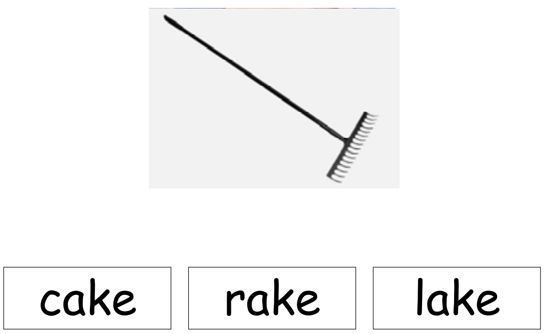


Figure 11.4 Screenshot of a picture-to-printed-word trial. Participants pointed to the printed-word comparison that corresponded to the sample picture.

Recombinative generalisation testing

Immediately following the stimulus equivalence tests, the participants firstly completed a reading aloud test, and then, a spoken-word-to-printed-word recognition test.

For each word set, the tests encompassed the three trained set words. These three words were always presented in the first three test trials in both the reading aloud and recognition tests. Untrained words that also shared the same rime pronunciation as two of the trained words (but not the exception word in an exception word set) were also presented after the trained words to test for recombinative generalisation. Such novel words were included to explore if the participants could independently employ their letter–sound and rime knowledge to read aloud and recognise the untaught recombined onset–consistent rime words.

For the reading aloud test, participants attempted to read aloud each individual word as it appeared on screen. Trained words were tested first (e.g., ‘cake’, ‘rake’, ‘lake’), followed by untaught recombined words (e.g., ‘bake’, ‘make’, ‘sake’, ‘take’, ‘wake’, ‘brake’). The number of untaught words varied depending on the word set under investigation.

Next, in the recognition test, as the researcher pronounced each word (e.g., /lake/), the participant selected a printed word from a choice of four printed word comparisons. At least one of the comparisons shared the same onset as the sample to preclude responses based on onset alone (e.g., ‘lake’, ‘late’). Another comparison shared the same rime as the sample (e.g., ‘lake’, ‘rake’). A third comparison was a combination of the incorrect onset and rime (e.g., ‘rate’) or if this was not possible due to the formation of a nonword, another rime sharing comparison was utilised (e.g., ‘bake’).

Stage 4: One day and one week follow up post-tests for word sets 1 to 8

Following the completion of each word set, on the next day, and then exactly one week after the training, post-tests were administered to monitor word retention. The post-tests were identical in format to the reading aloud and recognition recombinative generalisation tests. Training with the next word set commenced usually one week after the post-tests for the previous word set had been concluded.

11.3 Results

The following analyses focus on each child's performance in the stimulus equivalence training phases and the recombinative generalisation tests for the eight word sets.

11.3.1 Performance on the stimulus equivalence training protocol

The training phases were successfully completed by all participants. Tables 11.3, 11.4, and 11.5, show the number of correct responses for participants on the training phases, including performance on the equivalence tests.

With the exception of Participants 5 and 7, the other participants consistently met the criterion for the training phases within one to three blocks of MTS trials. For some of the word sets, on the first block of trials, it was noted that Participants 5 and 7 responded correctly to only a very small number of the MTS trials. Given the high error rate shown by these participants, blocks of two-choice exclusion trials were employed as an alternative to the MTS trials. Using the exclusion trials, the number of correct responses increased as the participants accurately matched the three spoken words and printed words. After accuracy reached at least 90%, the three-choice spoken-word-to-printed-word MTS trials were reintroduced to ensure that the two participants could recognise and discriminate between the three words. To maintain high accuracy, for some of the word sets, following the spoken-word-to-printed-word MTS trials, Participants 5 and 7 completed two-choice printed-word-to-spoken-word exclusion trials. Accuracy was always at least 90% before the MTS trials were presented. As these two participants scored lower than the other children on the letter–sound knowledge assessments (please see Tables 11.10 and 11.12), their need for further exclusion training to learn the printed word–spoken word relations is not wholly unexpected. However, Participants 5 and 7 could accurately match the picture–spoken word relations and responded to a sufficiently high number of MTS trials correctly to pass the phases training and testing the picture–spoken word relations without the need for exclusion training.

11.3.2 Emergence of stimulus equivalence

Most importantly, all participants demonstrated stimulus equivalence. After explicit training in the printed word–spoken word and picture–spoken word relations, all of the children matched the untrained printed word–picture relations to varying accuracy. As shown in Tables 11.3, 11.4, and 11.5, accuracy was very high in the equivalence tests for Participants 1, 2, 3, and 4. Participants 1 and 2 persistently demonstrated 100% accuracy in the equivalence tests for all eight word sets. Accuracy for Participants 3, 4, and 6 ranged between 89% and 100% across the eight sets. Participants 5 and 7 showed slightly lower accuracy in matching the untrained printed word–picture relations. For Participant 5 accuracy was between 56% and 89%; and for Participant 7 accuracy ranged between 67% and 100%. Bearing in mind that Participants 5 and 7 entered the study with less developed reading skills than the other participants, this could potentially account for the slight difference in equivalence performance.

Table 11.3 Performance of Participants 1, 2, and 3 on the stimulus equivalence protocol. Percentage correct is shown in parentheses.

	Set	*Spoken-to-printed-word correct/12*	*Printed-to-spoken-word correct/12*	*Picture-to-spoken-word correct/12*	*Spoken-word-to-picture correct/12*	*Printed-word-to-picture (test for equivalence) correct/9*	*Picture-to-printed-word (test for equivalence) correct/9*
Participant 1	1	11 (92)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	2	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	3	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	4	11 (92)	11 (92)	12 (100)	12 (100)	9 (100)	9 (100)
	5	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	6	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	7	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	8	11 (92)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
Participant 2	1	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	2	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	3	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	4	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	5	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	6	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	7	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	8	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
Participant 3	1	11 (92)	11 (92)	12 (100)	12 (100)	9 (100)	9 (100)
	2	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	3	11 (92)	12 (100)	12 (100)	12 (100)	8 (89)	9 (100)
	4	11 (92)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	5	11 (92)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	6	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	7	10 (83), 12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	8	12 (100)	11 (92)	12 (100)	12 (100)	9 (100)	9 (100)

Note. The asterisk denotes that two-choice exclusion trials were used.

Table 11.4 Performance of Participants 4 and 5 on the stimulus equivalence protocol. Percentage correct is shown in parentheses.

	Set	*Spoken-to-printed-word correct/12*	*Printed-to-spoken-word correct/12*	*Picture-to-spoken-word correct/12*	*Spoken-word-to-picture correct/12*	*Printed-word-to-picture (test for equivalence) correct/9*	*Picture-to-printed-word (test for equivalence) correct/9*
Participant 4	1	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	2	9 (75), 12 (100)	6 (50), 11 (92)	5 (42), 11 (92)	12 (100)	8 (89)	9 (100)
	3	12 (100)	12 (100)	10 (83), 12 (100)	12 (100)	9 (100)	8 (89)
	4	7 (58), 10 (83), 12 (100)	9 (75), 11 (92)	12 (100)	12 (100)	9 (100)	9 (100)
	5	11 (92)	11 (92)	11 (92)	12 (100)	9 (100)	8 (89)
	6	10 (83), 12 (100)	11 (92)	12 (100)	12 (100)	8 (89)	8 (89)
	7	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	8	10 (83), 12 (100)	11 (92)	12 (100)	11 (92)	9 (100)	9 (100)
Participant 5	1	2 (17), 9 (75)*, 12 (100)*, 11 (92)	12 (100)*, 12 (100)	12 (100)	12 (100)	7 (78)	7 (78)
	2	5 (42), 11 (92)*, 12 (100)	11 (92)*, 12 (100)	12 (100)	12 (100)	7 (78)	6 (67)
	3	3 (25), 10 (83)*, 11 (92)	12 (100)*, 11 (92)	11 (92)	11 (92)	6 (67)	6 (67)
	4	3 (25), 9 (75)*, 12 (100)*, 12 (100)	9 (75)*, 11 (92)*, 11 (92)	9 (75), 11 (92)	11 (92)	5 (56)	6 (67)
	5	4 (33), 11 (92)*, 11 (92)	11 (92)*, 11 (92)	11 (92)	12 (100)	6 (67)	7 (78)
	6	4 (33), 10 (83)*, 11 (92)	10 (83)*, 10 (83), 12 (100)	10 (83), 12 (100)	11 (92)	6 (67)	6 (67)
	7	9 (58), 10 (83), 12 (100)	8 (67), 11 (92)	12 (100)	12 (100)	8 (89)	8 (89)
	8	5 (42), 11 (92)*, 11 (92)	11 (92)*, 12 (100)	9 (75), 12 (100)	11 (92)	8 (89)	8 (89)

Note. The asterisk denotes that two-choice exclusion trials were used.

Table 11.5 Performance of Participants 6 and 7 on the stimulus equivalence protocol. Percentage correct is shown in parentheses.

	Set	*Spoken-to-printed-word correct/12*	*Printed-to-spoken-word correct/12*	*Picture-to-spoken-word correct/12*	*Spoken-word-to-picture correct/12*	*Printed-word-to-picture (test for equivalence) correct/9*	*Picture-to-printed-word (test for equivalence) correct/9*
Participant 6	1	8 (67), 8 (67), 11 (92)	11 (92)	12 (100)	11 (92)	8 (89)	9 (100)
	2	5 (42), 8 (67) 11 (92)	10 (83), 12 (100)	11 (92)	12 (100)	8 (89)	8 (89)
	3	8 (67), 10 (83), 12 (100)	7 (58), 10 (83), 12 (100)	12 (100)	12 (100)	8 (89)	8 (89)
	4	7 (58), 11 (92)	11 (92)	12 (100)	11 (92)	9 (100)	8 (89)
	5	10 (83), 12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
	6	11 (92)	12 (100)	12 (100)	12 (100)	9 (100)	8 (89)
	7	10 (83), 11 (92)	11 (83)	12 (100)	11 (92)	8 (89)	8 (89)
	8	12 (100)	12 (100)	12 (100)	12 (100)	9 (100)	9 (100)
Participant 7	1	4 (33), 12 (100)*, 11 (92)	11 (92)*, 11 (92)	12 (100)	12 (100)	8 (89)	8 (89)
	2	9 (75), 12 (100)	9 (75), 11 (92)	12 (100)	12 (100)	8 (89)	8 (89)
	3	5 (42), 11 (92)*, 11 (92)	12 (100)*, 12 (100)	12 (100)	12 (100)	6 (67)	9 (100)
	4	8 (67), 10 (83) 11 (92)	11 (92)	11 (92)	12 (100)	9 (100)	9 (100)
	5	9 (75), 9 (75), 12 (100)	9 (75), 10 (83), 12 (100)	12 (100)	12 (100)	7 (78)	8 (89)
	6	5 (42), 12 (100)*, 12 (100)	12 (100)*, 12 (100)	10 (83), 12 (100)	11 (92)	7 (78)	7 (78)
	7	4 (33), 10 (83)*, 12 (100)*, 12 (100)	12 (100)*, 12 (100)	8 (67), 12 (100)	10 (83), 12 (100)	8 (89)	9 (100)
	8	8 (67), 11 (92)	11 (92)	12 (100)	12 (100)	9 (100)	9 (100)

Note. The asterisk denotes that two-choice exclusion trials were used.

11.3.3 Word naming and recognition

11.3.3.1 Participant 1

Table 11.6 presents the scores obtained by Participant 1 on the reading skills tasks completed at baseline (September 2007 to April 2008) and prior to the start of the current study (April 2009 to June 2009). Increments in letter–sound knowledge and phonological awareness were apparent. Participant 1 was also able to correctly spell a larger number of the regular words in the spelling task and read aloud a greater number of the high frequency words. With the current measures, it was observed that Participant 1 made more attempts to sound out the task words; a reading strategy that was not so evident when he was assessed at the start of the research.

Table 11.6 Performance on the reading skills tasks by Participant 1 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

<table>
<tr><td>Participant 1
Male
Mild learning difficulties</td><td>Age</td><td>Letter–sound recognition correct/ 26</td><td colspan="2">Letter–name recognition correct/ 26</td><td>High frequency word naming correct/ 64</td><td>Print exposure correct/ 17</td><td>Regular and irregular word spelling correct/ 40</td></tr>
<tr><td>Baseline
April 2008</td><td>10Y 2M</td><td>Lowercase
5 (19)
Uppercase
5 (19)</td><td colspan="2">Lowercase
22 (85)
Uppercase
25 (96)</td><td>14 (22)</td><td>13 (76)</td><td>3 (8)</td></tr>
<tr><td>Pretraining
June 2009</td><td>11Y 4M</td><td>Lowercase
26 (100)
Uppercase
26 (100)</td><td colspan="2">Lowercase
26 (100)
Uppercase
26 (100)</td><td>26 (41)</td><td>16 (94)</td><td>14 (35)</td></tr>
<tr><td rowspan="2">Participant 1
Male
Mild learning difficulties</td><td rowspan="2">Age</td><td rowspan="2">Working memory span</td><td colspan="5">Phonological Awareness</td></tr>
<tr><td>Rime oddity correct/ 12</td><td>Phoneme isolation correct/ 12</td><td>Phoneme blending correct/ 15</td><td>Alliteration correct/ 27</td><td>Rhyme awareness correct/ 23</td></tr>
<tr><td>Baseline
April 2008</td><td>10Y 2M</td><td>5</td><td>8 (67)</td><td>8 (67)</td><td>11 (73)</td><td>24 (89)</td><td>19 (83)</td></tr>
<tr><td>Pretraining
June 2009</td><td>11Y 4M</td><td>5</td><td>12 (100)</td><td>12 (100)</td><td>14 (93)</td><td>27 (100)</td><td>23 (100)</td></tr>
</table>

Figure 11.5 shows the percentage of words read aloud and recognised across the word sets by Participant 1. As is evident from Figure 11.5, Participant 1 could

accurately name a small proportion of the words from sets 2, 4, 5, and 8 prior to training. At baseline, he could recognise two or three of the printed words from each set. Because Participant 1 demonstrated a high level of letter–sound knowledge during the initial assessments, it is perhaps unsurprising that he was able to successfully name and recognise some of the words.

Increases in word naming and recognition were apparent following completion of the MTS training. Aside from sets 1, 3, and 7, Participant 1 could accurately read aloud the three explicitly trained words and all of the untrained rime sharing words in the remaining word sets. It was only in sets 1, 3, and 7, that there was a slight reduction in word naming accuracy to 86%, 80%, and 83% respectively. Although even in these three sets, he read aloud all of the words apart from one of the untrained words, and in sets 3 and 7 it was the more challenging consonant blend words (e.g., ‘drive’ and ‘bring’) that he could not name.

Participant 1 could correctly identify the printed words corresponding to all trained and untrained spoken words, achieving 100% recognition accuracy across the eight sets.

Word naming and recognition accuracy was usually maintained at the one day post-test. There were however one or two untrained words that were not named or recognised at the one week post-test for some of the word sets, which resulted in a slight decrease in accuracy. Across the eight sets, at the one week post-test, the mean accuracy for Participant 1 was 78% and 94% for word naming and recognition respectively.

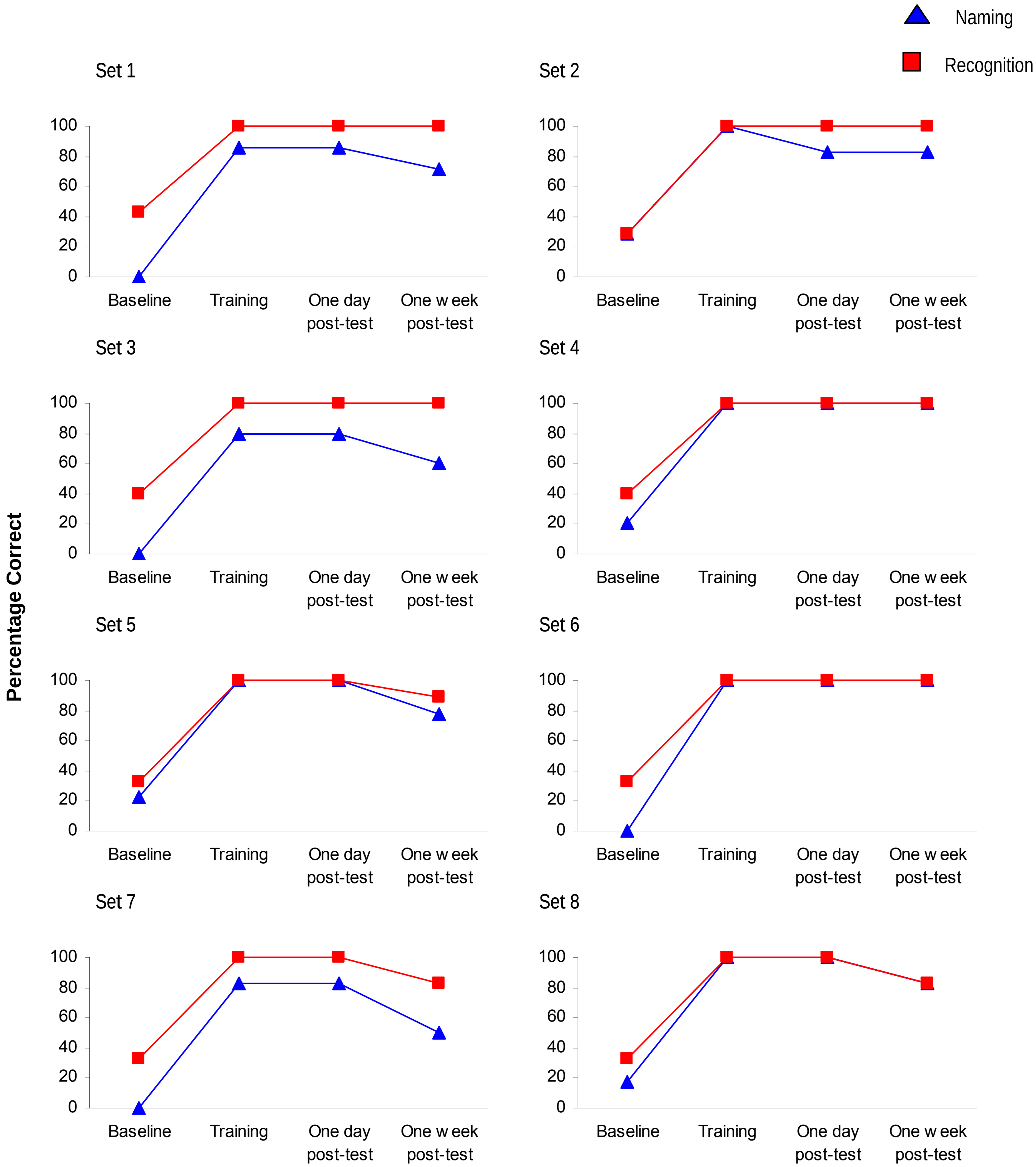


Figure 11.5 Performance of Participant 1 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

11.3.3.2 Participant 2

As discussed in the Method (p. 259), of all the participants, Participant 2 was reported by his class teacher to have made the greatest progress in his reading development. The data from the reading skills assessment for the current study are also indicative of gains in letter–sound knowledge, phonological awareness, naming of high frequency words, and use of letter–sound knowledge to spell regular words (please see Table 11.7).

Table 11.7 Performance on the reading skills tasks by Participant 2 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

Participant 2 Male Mild learning difficulties	*Age*	*Letter–sound recognition correct/ 26*	*Letter–name recognition correct/ 26*	*High frequency word naming correct/ 64*	*Print exposure correct/ 17*	*Regular and irregular word spelling correct/ 40*
Baseline April 2008	9Y 1M	Lowercase 6 (23) Uppercase 5 (19)	Lowercase 24 (92) Uppercase 26 (100)	17 (27)	11 (65)	10 (25)
Pretraining June 2009	10Y 3M	Lowercase 26 (100) Uppercase 26 (100)	Lowercase 26 (100) Uppercase 26 (100)	49 (77)	17 (100)	24 (60)

Participant 2 Male Mild learning difficulties	*Age*	*Working memory span*	*Phonological Awareness*				
			Rime oddity correct/ 12	*Phoneme isolation correct/ 12*	*Phoneme blending correct/ 15*	*Alliteration correct/ 27*	*Rhyme awareness correct/ 23*
Baseline April 2008	9Y 1M	5	8 (67)	9 (75)	9 (60)	25 (93)	18 (78)
Pretraining June 2009	10Y 3M	5	12 (100)	12 (100)	15 (100)	27 (100)	23 (100)

Taking into account the overall improvement in reading skills demonstrated by Participant 2, it was expected that he might be able to name and recognise some of the set words at the baseline assessment. This proved to be the case. Across the eight sets 29% to 67% word naming accuracy, and 50% to 80% recognition accuracy, was shown. Despite these scores, training continued in a bid to further increase naming and recognition.

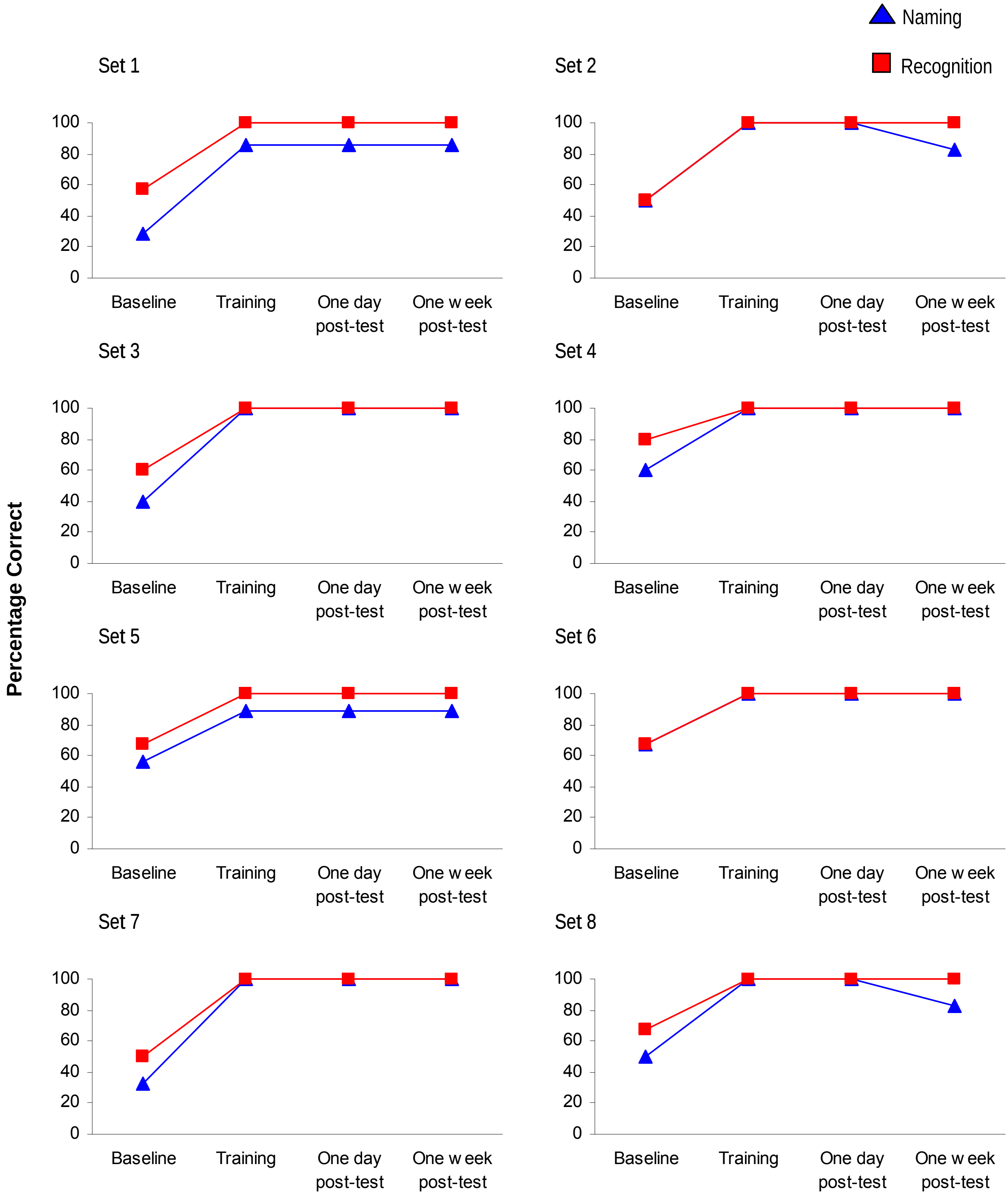


Figure 11.6 Performance of Participant 2 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

As shown in Figure 11.6, following training, recognition accuracy did increase to 100% for all word sets. Similar increases were evident in his word naming accuracy. Excluding sets 1 and 5, Participant 2 correctly read aloud all of the presented set words. In sets 1 and 5, it was only his inability to name one of the untrained words that resulted in a slight reduction in accuracy to 86% and 89% respectively. Both naming and recognition accuracy were maintained at the one day post-test. There was a small decrease in naming accuracy in sets 2 and 8 from 100% to 83% at the one week post-test. However, naming and recognition accuracy remained unchanged from training in the other sets, with 100% recognition accuracy always shown.

11.3.3.3 Participant 3

The reading skills assessment revealed that Participant 3 demonstrated a good knowledge of letter–sound mappings; producing a considerably higher score than when previously tested. Additionally, she read aloud a greater number of the high frequency words accurately, and could spell a larger proportion of the regular words. Table 11.8 summarises her performance on the reading skills measures.

As can be seen from Figure 11.7, before training, Participant 3 named and recognised only one or two words in some sets. Baseline accuracy ranged between 0% to 40% for naming, and between 14% to 44% for recognition. Following training, naming accuracy increased to 67% in sets 7 and 8, 86% in set 1, 89% in set 5, and 100% in the other four sets. Participant 3 performed well on the recognition tests. She could recognise the printed words corresponding to almost all of the spoken word samples. In sets 1 to 6, 100% recognition accuracy was achieved. Accuracy fell to 83% in sets 7 and 8, when one of the untrained words in each set was not recognised.

Table 11.8 Performance on the reading skills tasks by Participant 3 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

Participant 3 Female Mild learning difficulties	*Age*	*Letter–sound recognition correct/ 26*	*Letter–name recognition correct/ 26*	*High frequency word naming correct/ 64*	*Print exposure correct/ 17*	*Regular and irregular word spelling correct/ 40*
Baseline April 2008	9Y 11M	Lowercase 3 (12) Uppercase 3 (12)	Lowercase 24 (92) Uppercase 26 (100)	8 (13)	8 (47)	3 (8)
Pretraining June 2009	11Y 1M	Lowercase 24 (92) Uppercase 24 (92)	Lowercase 26 (100) Uppercase 26 (100)	23 (36)	15 (88)	12 (30)

Participant 3 Female Mild learning difficulties	*Age*	*Working memory span*	*Phonological Awareness*				
			Rime oddity correct/ 12	*Phoneme isolation correct/ 12*	*Phoneme blending correct/ 15*	*Alliteration correct/ 27*	*Rhyme awareness correct/ 23*
Baseline April 2008	9Y 11M	4	6 (50)	6 (50)	7 (47)	22 (81)	14 (61)
Pretraining June 2009	11Y 1M	4	10 (83)	10 (83)	13 (87)	26 (96)	20 (87)

Overall, there was little change in naming accuracy at the one day post-test. Only in sets 1, 4, and 6, was one fewer word named correctly than was named immediately following training. No changes in recognition accuracy were seen at the one day post-test. There were, however, some decreases in both naming and recognition accuracy at the one week post-test. Participant 3 always named and recognised all of the explicitly trained words, but errors were produced when she was tested with some of the untrained words. Mean naming accuracy was 73% (range, 50% to 83%) after one week compared to 89% (range, 67% to 100%) at training. Mean recognition accuracy was 85% (range, 67% to 100%) at the one week post-test compared to 96% (range, 83% to 100%) at training.

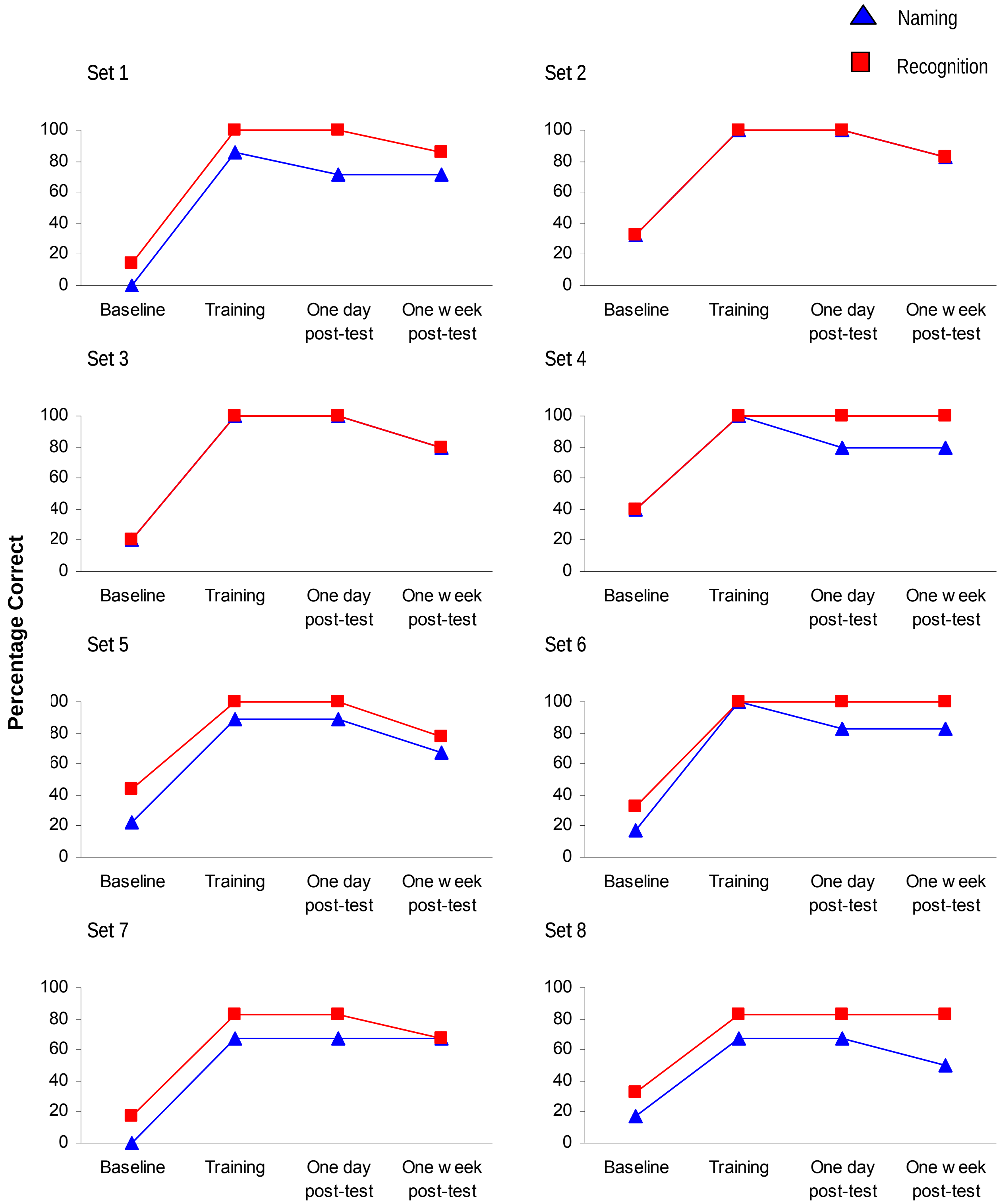


Figure 11.7 Performance of Participant 3 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

11.3.3.4 Participant 4

Table 11.9 summarises the performance of Participant 4 on the reading skills tasks. Participant 4 correctly recognised the printed letters corresponding to nearly all letter sounds. This was a marked improvement from his previous entry performance when he identified very few sound–letter relations. However, Participant 4 still named only a small percentage of the high frequency words tested. There were some gains in the scores obtained on the phonological awareness measures.

Table 11.9 Performance on the reading skills tasks by Participant 4 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

<table>
<tr><td>Participant 4
Male
Mild learning difficulties
Down syndrome</td><td>Age</td><td>Letter–sound recognition correct/ 26</td><td colspan="5">Letter–name recognition correct/ 26</td><td colspan="5">High frequency word naming correct/ 64</td><td colspan="5">Print exposure correct/ 17</td><td colspan="5">Regular and irregular word spelling correct/ 40</td></tr>
<tr><td>Baseline
April 2008</td><td>9Y 8M</td><td>Lowercase
1 (4)
Uppercase
1 (4)</td><td colspan="5">Lowercase
23 (88)
Uppercase
19 (73)</td><td colspan="5">2 (3)</td><td colspan="5">4 (24)</td><td colspan="5">0 (0)</td></tr>
<tr><td>Pretraining
June 2009</td><td>10Y 10M</td><td>Lowercase
21 (81)
Uppercase
20 (77)</td><td colspan="5">Lowercase
26 (100)
Uppercase
25 (96)</td><td colspan="5">9 (14)</td><td colspan="5">10 (59)</td><td colspan="5">2 (5)</td></tr>
<tr><td rowspan="2">Participant 4
Male
Mild learning difficulties
Down syndrome</td><td rowspan="2">Age</td><td rowspan="2">Working memory span</td><td colspan="20">Phonological Awareness</td></tr>
<tr><td colspan="4">Rime oddity correct/ 12</td><td colspan="4">Phoneme isolation correct/ 12</td><td colspan="4">Phoneme blending correct/ 15</td><td colspan="4">Alliteration correct/ 27</td><td colspan="4">Rhyme awareness correct/ 23</td></tr>
<tr><td>Baseline
April 2008</td><td>9Y 8M</td><td>3</td><td colspan="4">4 (33)</td><td colspan="4">3 (25)</td><td colspan="4">5 (33)</td><td colspan="4">8 (30)</td><td colspan="4">10 (43)</td></tr>
<tr><td>Pretraining
June 2009</td><td>10Y 10M</td><td>3</td><td colspan="4">7 (58)</td><td colspan="4">9 (75)</td><td colspan="4">9 (60)</td><td colspan="4">16 (59)</td><td colspan="4">15 (65)</td></tr>
</table>

During the baseline tests, Participant 4 named only two of the 50 set words (‘cake’ and ‘have’). Often he would provide a word starting with the same letter as the target word and usually, the words he generated were high frequency words. For example, ‘boot’ was read as ‘but’, ‘save’ as ‘some’, ‘nest’ as ‘nice’. Participant 5 recognised less than 20% of the words in each word set. Sometimes he selected the incorrect printed word comparison that contained an incorrect vowel letter to the sample spoken word. For instance, ‘mush’ was chosen for /mash/, ‘sang’ for /sing/.

Figure 11.8 shows the percentage of words named and recognised correctly by Participant 4. After training, in all eight sets, he always accurately named the three trained words and at least one of the untrained words. Naming accuracy across the sets ranged between 67% and 100%, with a mean naming accuracy of 84%. Recognition accuracy was also high for Participant 4. In five sets he correctly matched all of the trained and untrained spoken word samples to the corresponding printed words. Across the eight sets his mean recognition accuracy was 95% (range, 83% to 100%).

At the one day post-test, for some of the sets, there was a small decrease in naming accuracy but not in recognition accuracy. Although he correctly read aloud all of the trained words in each set, he was sometimes unable to name as many of the untrained words as he had managed to name directly following training. Thus, his mean naming accuracy was 75% (range, 67% to 100%) at the one day post-test.

There were further decreases in naming and recognition accuracy at the one week post-test. Mean accuracy was 61% (range, 43% to 83%) and 89% (range, 57% to 100%) for naming and recognition respectively. He could, however, name the three words in each set that had been explicitly trained.

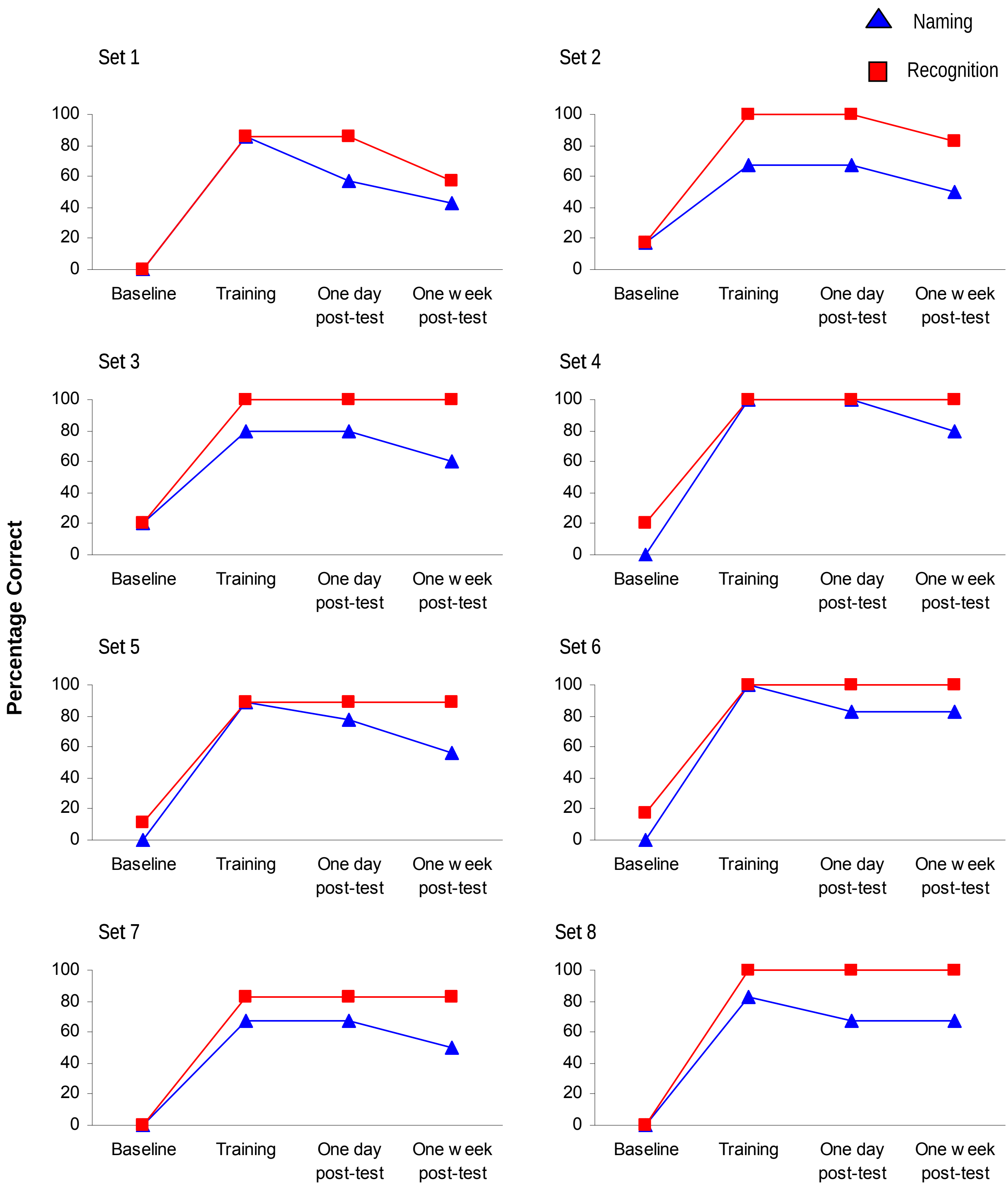


Figure 11.8 Performance of Participant 4 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

11.3.3.5 Participant 5

As shown in Table 11.10, low scores were obtained by Participant 5 in the reading skills tasks. He did recognise more of the letter–sound relations than at entry to the research, yet he still scored lowest on the letter–sound task when compared to the other participants. Additionally, he could read aloud only four of the high frequency words. There were only very small changes in his phonological awareness skills from when previously assessed.

Table 11.10 Performance on the reading skills tasks by Participant 5 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

Participant 5 Male Mild learning difficulties	*Age*	*Letter–sound recognition correct/ 26*	*Letter–name recognition correct/ 26*	*High frequency word naming correct/ 64*	*Print exposure correct/ 17*	*Regular and irregular word spelling correct/ 40*
Baseline April 2008	13Y 3M	Lowercase 1 (4) Uppercase 1 (4)	Lowercase 19 (73) Uppercase 18 (69)	3 (4)	4 (24)	0 (0)
Pretraining June 2009	14Y 5M	Lowercase 12 (46) Uppercase 10 (38)	Lowercase 24 (92) Uppercase 22 (85)	5 (7)	7 (41)	0 (0)

Participant 5 Male Mild learning difficulties	*Age*	*Working memory span*	*Phonological Awareness*				
			Rime oddity correct/ 12	*Phoneme isolation correct/ 12*	*Phoneme blending correct/ 15*	*Alliteration correct/ 27*	*Rhyme awareness correct/ 23*
Baseline April 2008	13Y 3M	3	5 (42)	4 (33)	5 (33)	11 (41)	12 (52)
Pretraining June 2009	14Y 5M	3	6 (50)	4 (33)	6 (40)	11 (41)	14 (61)

Participant 5 could not name or recognise any of the set words at baseline. Figure 11.9 shows accuracy on the naming and recognition tests for Participant 5. Following training, Participant 5 could correctly name and recognise the three trained words in each set. However, very few of the untrained words were named or recognised. It was only in sets 1 and 8 that one untrained word was named, and in set

5 that two untrained words were named. Given his low scores on the pretraining reading skills measures, potentially his less developed letter–sound knowledge might be one possible explanation to account for his inability to name as many of the untrained words as the other participants. Apart from set 7, in all other sets, Participant 5 recognised one untrained word alongside the three trained words. Across the eight sets, mean naming accuracy was 63% (range, 50% to 67%), and mean recognition accuracy was 67% (range, 50% to 80%).

There were decreases in both naming and recognition accuracy at the one day and one week post-tests. Participant 5 could recognise the three trained words in each set, but he rarely recognised any of the untrained words at the two post-tests. His mean recognition accuracy was 58% (range, 43% to 80%) and 53% (range, 43% to 80%), at the one day and one week post-tests respectively.

A different result emerged in the naming post-tests. Even very few of the trained words in each set were read aloud in the post-tests and none of the untrained words were named. At the one day post-test mean naming accuracy was 32% (range, 14% to 50%). This decreased to a mean naming accuracy of 21% (range, 0% to 40%) at the one week post-test. It should be noted that Participant 5 was identified by his class teacher as one of the students who had difficulties in retaining vocabulary following reading instruction sessions. Thus his decreases in naming accuracy at the post-tests must be considered in light of these observations.

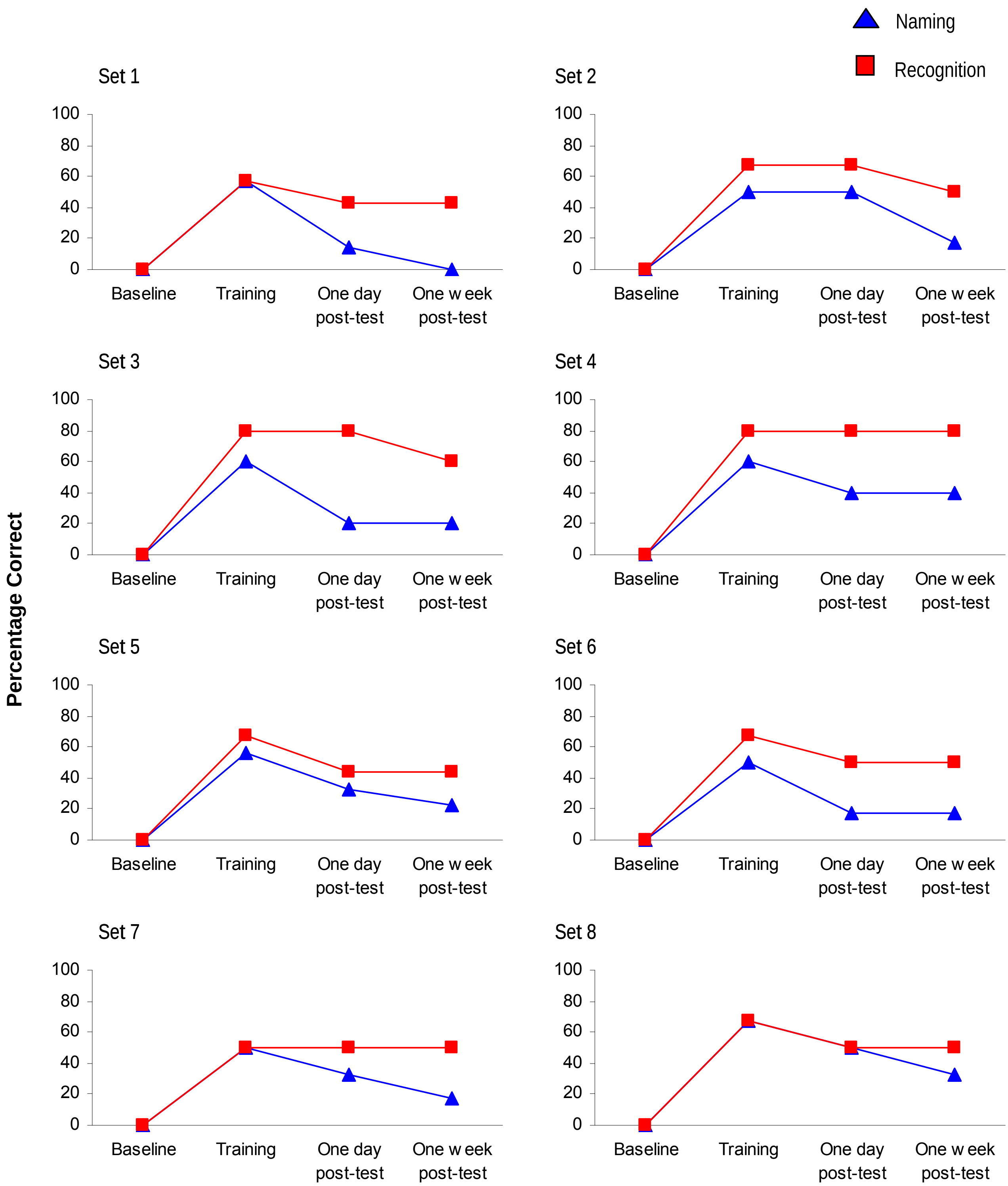


Figure 11.9 Performance of Participant 5 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

11.3.3.6 Participant 6

During the pretraining measures, Participant 6 demonstrated considerable improvements in her scores on the letter–sound task. She was able to correctly identify nearly all of the printed letters corresponding to the letter sounds (please see Table 11.11). Higher scores were also achieved by Participant 6 on the phonological awareness tasks.

Table 11.11 Performance on the reading skills tasks by Participant 6 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

Participant 6 Female Mild learning difficulties Down syndrome	*Age*	*Letter–sound recognition correct/ 26*	*Letter–name recognition correct/ 26*	*High frequency word naming correct/ 64*	*Print exposure correct/ 17*	*Regular and irregular word spelling correct/ 40*
Baseline April 2008	13Y 4M	Lowercase 3 (12) Uppercase 2 (8)	Lowercase 25 (96) Uppercase 24 (92)	5 (8)	5 (29)	0 (0)
Pretraining June 2009	14Y 6M	Lowercase 24 (92) Uppercase 24 (92)	Lowercase 26 (100) Uppercase 26 (100)	17 (27)	11 (65)	3 (8)

Participant 6 Female Mild learning difficulties Down syndrome	*Age*	*Working memory span*	*Phonological Awareness*				
			Rime oddity correct/ 12	*Phoneme isolation correct/ 12*	*Phoneme blending correct/ 15*	*Alliteration correct/ 27*	*Rhyme awareness correct/ 23*
Baseline April 2008	13Y 4M	4	6 (50)	5 (42)	6 (40)	16 (59)	13 (57)
Pretraining June 2009	14Y 6M	4	10 (83)	8 (67)	11 (73)	18 (67)	15 (65)

Prior to training, Participant 6 named four of the 50 set words, and could recognise one or two words from the majority of sets; demonstrating a mean recognition accuracy of 21%.

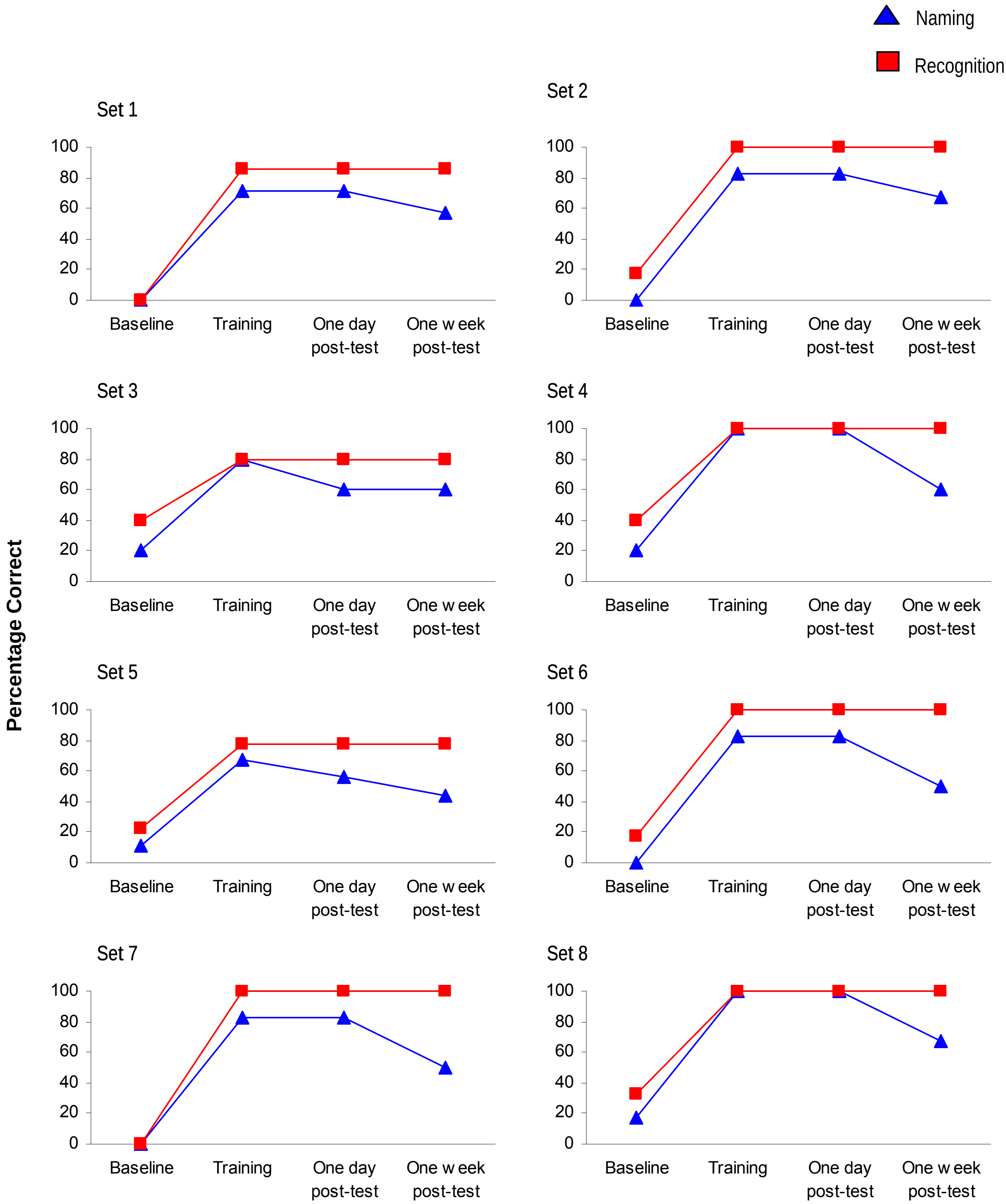


Figure 11.10 Performance of Participant 6 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

Figure 11.10 indicates that for Participant 6 both naming and recognition accuracy increased following completion of the training protocol. In each of the eight sets, Participant 6 successfully named all three trained words, and often, two of the untrained words in each set. Her mean naming accuracy was 84% (range, 67% to 100%). Similarly, recognition accuracy was also high. In five sets, she demonstrated 100% accuracy in recognising the printed words. Mean recognition accuracy was 93% (range, 78% to 100%).

The high recognition accuracy shown by Participant 6 in identifying many of the trained and untrained printed words remained unchanged at the one day post-test. For sets 3 and 5, Participant 6 named one less untrained word than was named in the previous tests. Hence, mean naming accuracy was 80% (range, 56% to 100%). Likewise, at the one week post-test, although all three trained words in each set were named, fewer of the untrained words were named across the sets. Mean naming accuracy was 57% (range, 44% to 67%). There was no change in recognition accuracy. All words recognised immediately following training were recognised again one week later.

11.3.3.7 Participant 7

Table 11.12 presents the pretraining scores for Participant 7 on the reading skills tasks. Gains can be seen in letter–sound knowledge; with a greater number of letter–sound relations correctly identified than at entry to the research. Errors were high on the word reading task during which very few of the high frequency words were read aloud correctly. Participant 7 tended to say other high frequency words when attempting to read aloud the task words.

Table 11.12 Performance on the reading skills tasks by Participant 7 at entry to the research and prior to the start of the current study. Percentage correct in parentheses.

Participant 7 Female Mild learning difficulties	*Age*	*Letter–sound recognition correct/ 26*	*Letter–name recognition correct/ 26*	*High frequency word naming correct/ 64*	*Print exposure correct/ 17*	*Regular and irregular word spelling correct/ 40*
Baseline April 2008	9Y 2M	Lowercase 1 (4) Uppercase 1 (4)	Lowercase 20 (77) Uppercase 19 (73)	3 (4)	5 (29)	0 (0)
Pretraining June 2009	10Y 4M	Lowercase 15 (58) Uppercase 15 (58)	Lowercase 26 (100) Uppercase 26 (100)	6 (9)	7 (41)	0 (0)

Participant 7 Female Mild learning difficulties	*Age*	*Working memory span*	*Phonological Awareness*				
			Rime oddity correct/ 12	*Phoneme isolation correct/ 12*	*Phoneme blending correct/ 15*	*Alliteration correct/ 27*	*Rhyme awareness correct/ 23*
Baseline April 2008	9Y 2M	3	3 (25)	3 (25)	4 (27)	6 (22)	7 (30)
Pretraining June 2009	10Y 4M	3	5 (42)	4 (33)	4 (27)	8 (30)	8 (35)

Figure 11.11 shows performance on the word naming and recognition tests by Participant 7. Prior to training, none of the set words were named or recognised. Sometimes words that shared an onset with the set word were read aloud instead of the set word, but often the words were unrelated. For example, ‘cake’ was read as /can/, but ‘rake’ was named as /she/.

Increases in word naming and recognition were demonstrated following training. In each word set, Participant 7 could always read aloud the three trained words. She correctly named one untrained word and four untrained words in sets 3 and 5 respectively. When attempting to read aloud the untrained words, she often named them as one of the three trained words for that particular set. For example, in set 2, ‘gave’ was read aloud as /cave/. Word naming accuracy was 43% in set 1, 50% in sets 2, 6, 7, and 8, 60% in set 4, 78% in set 5, and 80% in set 3 (mean naming accuracy = 58%). Although only a very small number of the untrained words were named, a greater number of untrained words were recognised across the sets. At least one untrained word was recognised in each set. In three sets, 100% recognition accuracy was shown. Across all sets, mean recognition accuracy was 87% (range, 67% to 100%).

There were decreases in naming and recognition accuracy at the one day post-test. Participant 7 could recognise the three trained words in each set, but could not always correctly name the three trained words. Mean naming accuracy fell to 34% (range, 14% to 50%), while mean recognition accuracy was 71% (range, 57% to 100%).

Likewise, decreases in the number of set words named and recognised were evident at the one week post-test. Mean naming accuracy was 24% (range, 0% to 40%) and mean recognition accuracy was 63% (range, 50% to 83%). Participant 7 could recognise all of the explicitly trained words at the one week post-test.

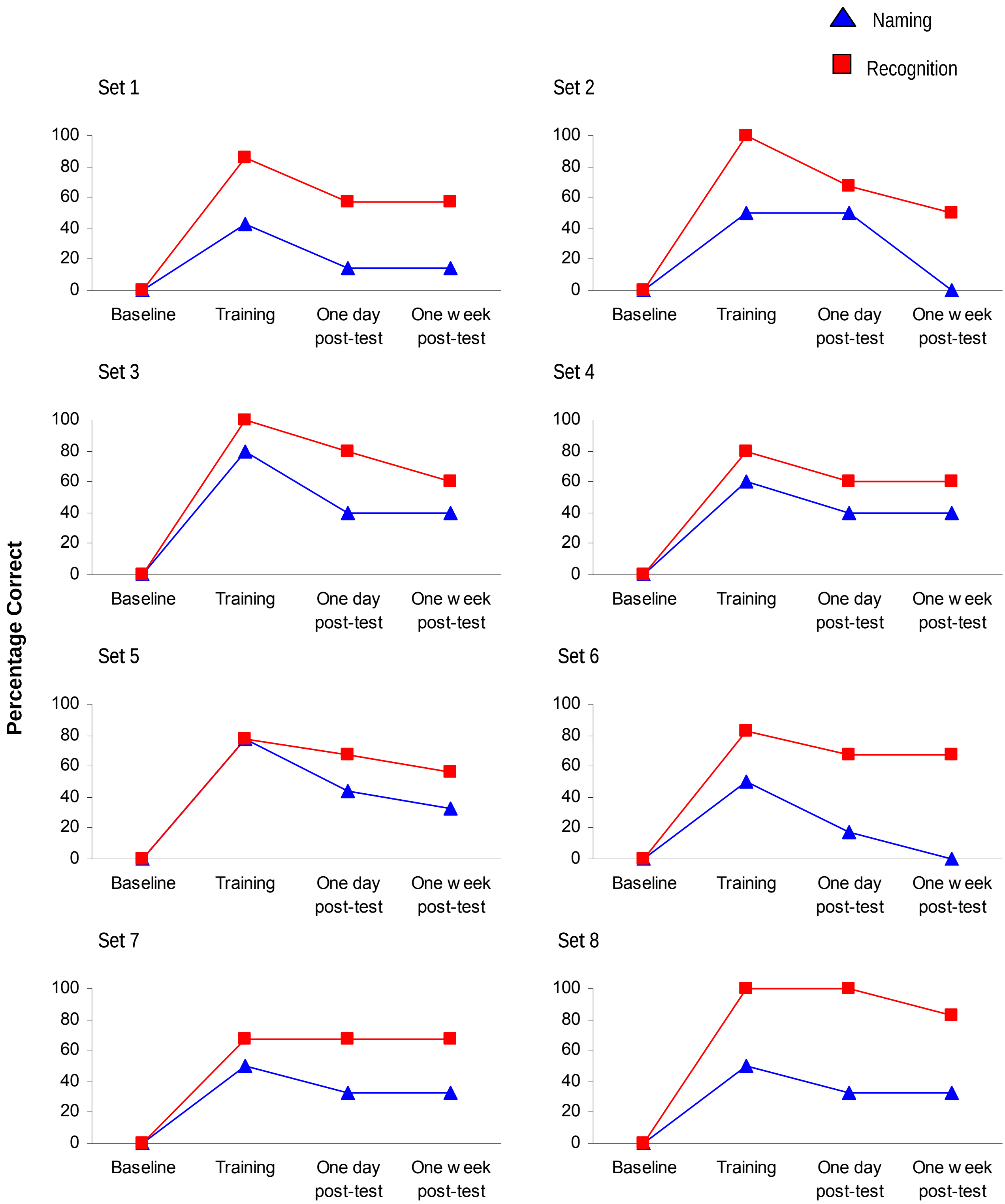


Figure 11.11 Performance of Participant 7 on the word naming tests (blue lines) and spoken-word-to-printed-word recognition tests (red lines) for sets 1 to 8, at baseline, after training, at the one day post-test, and the one week post-test.

11.4 Discussion

In the current experiment, a training protocol incorporating stimulus equivalence training procedures was developed and implemented with the seven children. Primarily, the aim of the study was to try and improve the children's word naming and recognition accuracy; building on the data and information about each individual child's training and testing performance gleaned from Experiment 8B.

Baseline measures were obtained to record the pretraining word naming and spoken-word-to-printed-word matching accuracy of the participants. It should be noted that some of the participants (those who scored highly on the reading skills assessments) could read aloud and recognise a small percentage of the 50 trained and untrained set words prior to the start of the stimulus equivalence training. Apart from Participant 2, however, pretraining naming and recognition accuracy was low (e.g., naming accuracy was less than 18% for all 50 set words). Participants 5 and 7 could not name or recognise any of the set words at baseline.

The stimulus equivalence training was successfully completed by all participants. All of the children learned to match spoken-word–printed-word relations and spoken-word–picture relations. Equivalence was demonstrated by all children as they could all match the printed words to their corresponding pictures; the untrained relation. Following the stimulus equivalence training, all seven participants could both name and recognise the printed word comparison for the three trained words across the eight word sets. Notably, all exception words were always read aloud correctly, despite sharing the same printed rime as the set words.

In particular, given that Participants 5 and 7 could not name or recognise these words prior to the stimulus equivalence training, these gains in word naming and recognition which were repeated across the word sets, point to the benefits of the stimulus equivalence training for these participants. These two participants performed poorly on the high frequency word naming reading skills measure (please see Tables 11.10 [p. 288] and 11.12 [p. 294]), and were also unable to read aloud many of the recombined onset–rime words in Experiment 8B (please see p. 236 and p. 249). Being able to read aloud the 24 words trained via stimulus equivalence therefore represents a considerable achievement for these two participants.

A slightly different finding emerged for the untrained recombined words. Participants 5 and 7 named and recognised very few of the untrained recombined words. Similar findings were reported in Experiment 2 of the de Rose et al. (1996) study. Although all four children demonstrated high accuracy in reading aloud the explicitly trained words in the de Rose et al. (1996) investigation, only one of the four children could name some of the generalisation words.

But again, in the current study, we cannot overlook the fact that Participants 5 and 7 scored lower on the reading skills measures than the other five participants. Although their letter–sound knowledge had improved, nonetheless, they were not as proficient as the other five participants in recognising the letter–sound relations. Such letter–sound knowledge is vital when tackling unfamiliar words (Share, 1995). Hence, the participants with the more developed letter–sound knowledge may have been at an advantage when faced with the untrained words.

Participants 1, 2, 3, 4, and 6, were all able to name and recognise a high number of the untrained words. Not discounting the achievements of Participants 1, 2, and 3, perhaps, most impressive was the performance of Participants 4 and 6. Participants 1, 2, and 3, performed well on the onset and rime training protocol, and also scored highly on all the reading skills measures. Completion of the stimulus equivalence protocol was beneficial for these participants as they all showed increases in their word naming and recognition accuracy. However, Participants 4 and 6 did not name many of the set words in the baseline assessments (please see Figures 11.8 and 11.10). But following the stimulus equivalence training, they were able to name some of the untrained words in each set. The training itself, together with their improved letter–sound knowledge, may have contributed to their ability to read aloud and recognise the untrained recombined words.

The current findings are congruent with earlier findings (e.g., Sidman, 1971; de Rose et al., 1996; Mueller et al., 2000; Saunders et al., 2002) denoting the effectiveness of stimulus equivalence procedures in which equivalence classes are formed between printed words, spoken words, and picture referents, in facilitating oral reading skills and printed word identification.

The current findings extended the research in this area by showing how such procedures could be used to support the naming and recognition of exception words and rime consistent words. By their very nature, exception words may prove something of a pitfall for beginning readers as they cannot be pronounced correctly through application of letter–sound mappings. The current study demonstrated how some exception words can potentially be included within a stimulus equivalence framework, and how following training, accurate word naming and recognition of these exception words may emerge.

Five of the seven children were also able to accurately name and recognise a high percentage of the untrained words that were formed from combining onset sounds with the consistent rimes. Four of these participants could not name any of the untrained words prior to completing the training protocol. In the main, the untrained printed words were words that the children would not normally encounter in their classroom reading instruction. Arguably then, the current data are indicative that the procedure described and used was effective in helping these children to read aloud and recognise novel printed words.

Why was the stimulus equivalence protocol particularly effective for these children? In the protocol described in Chapter 10, it may be suggested there was an element of rehearsal involved, in the sense that the sub-word units were being ‘drilled’ in quite an abstract, arbitrary manner. However, in the current protocol, through the use of pictures as visual representations of what the spoken words and printed words were referring to, this added to the meaningfulness of the task. It was observed in Experiment 8B that many of the children questioned what was meant by some of the spoken words. Through the stimulus equivalence training, it was possible to convey to the children easily what was meant by the spoken and printed words.

Children with LD often encounter difficulties in acquiring abstract concepts (see van der Schuit et al., 2009). Furthermore, research has indicated that when reading instruction is presented in a concrete and meaningful context this is a particularly conducive format for children with LD to make progress in their reading development (e.g., Katims, 2000; Koppenhaver & Erickson, 2003; Koppenhaver, Evans, & Yoder, 1991). Indeed, this appeared to be the case in the current study. Forging links between the spoken words, printed words, and what they were referring to through use of the pictures, made the task more concrete and relevant for the children in that they could potentially relate the pictures to instances or objects within their own real life experiences.

Moreover, the children also seemed to enjoy completing the stimulus equivalence protocol. Their interest and attention was sustained more throughout the trials, especially when faced with the spoken-word–picture trials. Motivation to complete a task and interest in a task are important factors to be considered when planning procedures to be used with children with LD on account that some children with LD may find it difficult to sustain concentration and attention to complete a task.

Noticeably absent from the current study was the inclusion of a control group of children with LD. It is acknowledged that employing such a control group would have strengthened the research by increasing confidence in the effectiveness of the procedures. There were two primary reasons underpinning the decision not to include a second group of children with LD to act as a comparison group.

Firstly, it was felt that it would not be ethically appropriate to have a control group of children with LD who did not complete the MTS training procedures. Essentially, the children who took part in this research were already very vulnerable in terms of finding it difficult to learn how to read. The participating children were all older children. At the start of the research the youngest child was nine years old. Thus, the children had already experienced at least three years of formal literacy instruction, and were still continuing to find reading a difficult task to master. Extreme care needed to be taken throughout this research not to do anything that could potentially adversely affect the children's reading development any further. Hence, the significance placed on the research with the adults. From the adult research, the basic procedure had proved to be extremely effective in facilitating recombinative generalisation, and as a result, there was greater certainty that the procedures would also very likely be beneficial for the children. Ethically speaking, to use the protocol with some children and not with others, would not be acceptable. There was a good chance that the children who completed the MTS training procedures would at least be able to, if not always name, at least recognise, some of the printed words following training. The results from the current study and the earlier unit size study, proved this to be correct, even for the children with the lowest scores on the entry reading skills measures. A control group of children with LD, who would also have been identified by their class teachers as failing to make progress in learning to read, might be unlikely to recognise any words in the test sessions. Under such circumstances, to continually test the children with little likelihood of success would be unfair on the children. Additionally, even from the research visits, it was clear that the older children are more conscious and aware of what other children are doing. The research tasks were all undertaken within the classroom as part of the ongoing routine. Using the same training procedures with all of the children avoided any potential difficulties that might arise from one child completing the training and another child not completing similar training and noticing this.

Secondly, there were practical reasons as to why a control group was not used. We were extremely fortunate to be given parental consent and permission from the school authorities to come into the school and work with these seven children on the basis that the research would be enjoyable and potentially beneficial for the children. All research tasks were completed with the children within their classrooms. Access to a larger number of children may have potentially caused too much of a disturbance to the ongoing school routine and may have been difficult to obtain permission for.

It is important to address the retention of the children's word naming and recognition accuracy as a further limitation of the study. Although not applicable to all of the children, as some did show good maintenance in word naming and recognition skills, the one day and one week post-tests often revealed a decrease in naming and recognition accuracy. The largest declines in naming and recognition were seen for Participants 5 and 7. Yet it is equally important to point out that Participants 5 and 7 were known from within their classroom settings to experience difficulties in retaining vocabulary after literacy instruction. As discussed in Chapter

10, the most likely explanation as to why naming and recognition accuracy did diminish was that there was no consolidation or revision training following the completion of each word set.

In all, this was a relatively short instructional procedure. Although the stage one onset and rime training required a longer period of time for the children to complete, generally each word set was trained within 30 minutes. The procedure needed to be this length firstly, so as to be successfully acclimatised within the classroom routine, and secondly, to ensure that the children's attention levels were not overburdened. Supplementary training to the stimulus equivalence training, for example, follow-up training with the onset and rime units, would provide additional practice and foster greater familiarity with the letters and sounds from which the recombined words are formed. From a dual-route perspective of word recognition, it is this orthographic and phonological knowledge of letter strings (e.g., rimes) and associated sounds that is vital for reading. Practice in identifying words (and by extension the sub-word units i.e., rimes contained within the words) is believed to strengthen the lexical and phonological representations of these words in the lexicon, thereby enabling words containing certain known rime sequences to be recognised quickly and efficiently via the direct route (see Rayner et al., 2001).

Lastly, it should be acknowledged that although in the current study some exception and rime consistent words were trained successfully, one drawback of the procedure is that there are constraints on the words that can be included for training because all words must be able to be represented pictorially. Providing that the words can be illustrated, the current data lend further support to the effectiveness of the stimulus equivalence paradigm in facilitating word naming and recognition skills for children with LD. All seven children showed improvements in their ability to accurately read aloud and identify printed words that had been trained using a stimulus equivalence protocol. Five of the participants were also able to name and recognise a greater number of untrained recombined words following completion of the training procedures.

Chapter Twelve

General Discussion

12.1 Overview

When embarking on this research, one of the primary aims was to develop an effective instructional procedure to promote printed word recognition skills, most notably, the recognition of novel, untrained words. To this end, a training procedure was designed to facilitate the emergence of one particular productive reading skill – recombinative generalisation – a skill that will potentially allow an individual to read new words that have not been taught directly.

Derived from behavioural enquiries into the area of facilitated recombinative generalisation, MTS procedures have been shown to be particularly conducive to promoting recombinative generalisation (e.g., de Rose et al., 1996; de Souza et al., 2009; Keaveney, 2005; Mueller et al., 2000; Saunders et al., 2003). Given the importance of developing effective methods to help teach early literacy skills such as recombinative generalisation, this is an area of research that merits further investigation. Thus, a revised MTS training protocol was developed for use in the current research. As reported in the first part of the thesis (Chapters 2 – 8), a series of experiments were conducted with adult participants to comprehensively test the effectiveness of the amended protocol. Additionally, the current thesis aimed to extend the use of MTS procedures by exploring ways in which such procedures could perhaps be applied to help support word recognition skills for the broad variety of words encountered by beginning readers (e.g., consonant blend words, regular and exception words).

After validating the effectiveness of the new protocol, a further aim was to see if the protocol could be used as a remedial tool to support the word naming and word recognition skills of a specific group of children with mild LD who were struggling to learn to read. Research was undertaken with seven children with LD to determine if the protocol could be of any help to these children as used within an applied classroom setting. These findings formed the second part of the thesis (Chapters 9 – 11). Some of the key outcomes to emerge from the adult and child research will be discussed separately in the following sections.

12.2 Research with adult participants

12.2.1 Key findings and implications

As a starting point, a modified MTS protocol was developed, incorporating sound-to-symbol conditional discrimination training, symbol-to-sound symmetry training, and mixed sound-to-symbol, symbol-to-sound symmetry testing, for separate onset and rime sub-word units. Adult participants who completed the revised MTS protocol were all capable of recognising novel CVC and CVCVC words composed from recombinations of the explicitly taught onsets and rimes. The data further underlined the suitability and robustness of MTS procedures in promoting recombinative generalisation, thereby replicating the findings of earlier MTS studies (e.g., de Rose et al., 1992, 1996; Mueller et al., 2000; Saunders et al., 2003).

One of the first steps when learning to read is that beginning readers need to learn how the printed letters of their written script correspond to units of sound within their spoken language (Ziegler & Goswami, 2005). The findings from Experiment 2 once more emphasised the importance of learning these print–sound mappings for productive reading (see also Byrne & Fielding-Barnsley, 1998; Dodd & Carr, 2003;

Foy & Mann, 2006; Share, 1995). By separately removing each of the training components utilised within the MTS protocol in Experiment 2, it was possible to show that it was the basic conditional discrimination training in which participants learned how the sounds related to the symbols, that was vital to producing the recombinative generalisation effect. These findings are consistent with the view that the ability to recognise novel words ultimately stems from a comprehensive knowledge of how printed symbols (i.e., letters) relate to sounds (Ehri, 1999; Rayner et al., 2001; Share, 1995).

Learning these print–sound correspondences can occur at various grain sizes (Goswami, 2002; Ziegler & Goswami, 2005). The findings from Experiment 6 indicated how the size of the training unit employed to teach the relations between sounds and symbols could influence recombinative generalisation performance. It was observed that, compared to the onset and rime and phoneme trained participants, the syllable trained participants (trained with whole CVC words) were the least successful in correctly identifying the novel recombined CVC words. From a behavioural perspective, perhaps the syllable trained participants who learned to relate whole CVC spoken words and symbol sequences did not acquire sufficient control of the minimal textual units necessary for recombinative generalisation. Sidman (1994) proposed that one of the prerequisites for control by minimal units is that participants recognise the correspondences between sounds and minimal textual units, something that may be largely left to chance when whole word practices are employed. Because, in Experiment 6, the onset and rime and phoneme trained participants were explicitly taught the associations between the smaller textual units and corresponding sounds, they did not have to deduce these correspondences for themselves. Consequently, this may have facilitated their performance on the recombinative generalisation tests.

If we are to compare the findings of Experiment 6 with what is known in the wider reading literature about the effectiveness of different types of reading instruction, the findings yield a similar picture. When whole word practices are used, accuracy in identifying directly trained words is high. Accuracy is severely compromised though, when novel untrained words are introduced (e.g., Bhattacharya & Ehri, 2004; Ehri et al., 2001; Seymour & Elder, 1986). Measures of unfamiliar word naming (used to assess decoding skills) additionally show that children who have received phonics-centred instruction outperform children who have been taught to read using whole word approaches (Bruck & Treiman, 1992).

Where then does the current research fit into the debate concerning whether whole word or phonics-based techniques should be used to teach reading? (See Rayner et al., 2001). In order to answer this question it is necessary to consider the properties of the orthographic script that is being taught. As was discussed in Chapter 1, certain cognitive theories of reading (e.g., the psycholinguistic grain size theory, Ziegler and Goswami, 2005) place a strong emphasis on how the word reading process is influenced by the orthography that a beginning reader will learn to read. Within the current research, the novel training script from which the recombined words were composed initially simulated a shallow alphabetic type script in which each symbol was consistently associated with only one sound. Later in Experiment 7, the training script was modelled on a deep alphabetic type script (such as English) characterised by inconsistency in its sound–symbol relations. According to Ziegler and Goswami (2005), such inconsistency requires flexibility in the size of print–sound mappings that are taught to beginning readers. Essentially, beginning readers of inconsistent scripts are predicted to benefit from learning print–sound mappings at multiple grain sizes (e.g., phonemes, onsets and rimes, syllables, whole words).

Evidence supporting the psycholinguistic grain size theory was obtained in Experiment 7. Training at single grain sizes (either with onsets and rimes or phonemes or syllables) proved to be insufficient for participants to cope proficiently with *both* consistent words (i.e., words adhering to expected sound–symbol mappings) and inconsistent words (i.e., words deviating from expected sound–symbol mappings).

The findings from Experiment 7 are also in line with predictions arising from the dual-route models of word recognition (e.g., Coltheart et al., 1993; 2001), which advocate that there are two separate processes by which words can be identified. One process relies on accessing whole words stored within the orthographic lexicon (i.e., the direct route). The other process depends on translating graphemes into their associated phoneme sounds (i.e., the indirect route). One key prediction of the dual-route models is that exception or 'enemy' words can only be correctly read aloud through the direct route (i.e., as whole words). Consistent with this claim, in Experiment 7, the syllable trained participants who learned to match whole CVC spoken words and symbol sequences, were the most adept of all the participants in identifying the enemy words. One might argue that the reason for this was that the syllable trained participants were the only participants explicitly taught the enemy words as whole words. In this way, the training was directly linked to the process believed to be involved in the recognition of such enemy words as presented in the dual-route models of reading. By contrast, the onset and rime and phoneme trained participants were largely inaccurate in recognising the enemy words. These participants learned the smaller sized symbol–sound mappings. Such small grain mappings are used by the indirect route (the route that cannot accurately cope with exception words) and this may account for the failure of the onset and rime and phoneme trained participants to recognise as many enemy words as the syllable trained participants. Likewise the same rationale can be applied to account for the differences in consistent word recognition between the different training types. By training only with whole words (i.e., tapping into the direct route), the syllable trained participants appeared to lack the more fine grained sound–symbol knowledge required to decode the novel consistent words, and were noticeably poorer than the onset and rime or phoneme trained participants in recognising the consistent words.

However, it remains unclear the extent to which learning how letters correspond to sounds is contingent upon explicit instruction (see Byrne, 1991; Rayner et al., 2001; Thompson et al., 1996). According to advocates of whole word instruction methods, explicit letter–sound training is viewed as unnecessary as it is proposed that letter–sound knowledge will be inferred incidentally (Ehri, 1998). Although the current training was only a short training procedure, the findings did suggest that without explicit training at the smaller grain sizes (phonemes, onsets and rimes), the syllable trained participants struggled to recognise the novel consistent words. Over a longer training period it remains to be seen if there would be any change in this position, but in terms of immediate gains to novel word recognition, the syllable trained participants were at a disadvantage when it came to identifying the novel recombined consistent words. Overall, the results point to the benefits of directly teaching the associations between sounds and symbols when the aim is to facilitate novel word recognition. Such training arguably establishes a good foundation of sound–symbol knowledge which can be employed to tackle novel words. These findings are in accordance with empirical evidence showing that when children specifically learn the correspondences between letters and sounds, they are more proficient at reading unfamiliar words (e.g., Bhattacharya & Ehri, 2004; Ehri et al., 2001; Seymour & Elder, 1986).

As to whether phonics-based or whole word instructional strategies are most effective for beginning readers, the current data are in line with the recent position that the dichotomy between the two approaches is misleading (Kirby et al., 2008; Rayner et al., 2001; Snow & Juel, 2005). Recognition of novel consistent words was facilitated by the use of smaller grain sizes (e.g., onsets and rimes, phonemes) to train the sound–symbol relations. These findings mirror data from beginning readers of more consistent scripts (who can reliably use small sized phoneme–grapheme relations to decode words) who repeatedly perform better than age matched beginning readers of inconsistent scripts on measures of novel word reading (e.g., Ellis & Hooper, 2001; Goswami et al., 1998; Spencer & Hanley, 2003). However, in terms of promoting word recognition in inconsistent scripts, training exclusively at only one grain size (e.g., phonemes or syllables) appears to be insufficient. An instructional approach incorporating phonics (e.g., letter–sound) *and* whole word training will arguably be the most powerful and effective for developing word recognition skills in inconsistent scripts. Through the research with the children with learning difficulties, one possible integrated training protocol was developed and used, with encouraging results.

12.2.2 A more effective protocol? Connecting behavioural training procedures with cognitive theories of word recognition

Having an effective instructional practice is essential. The findings from the current research strongly point out that behavioural strategies provide a reliable means of facilitating recombinative generalisation and novel word recognition. However, one of the main implications of the current research is that it demonstrates how cognitive theories of reading, such as the psycholinguistic grain size theory (Ziegler & Goswami, 2005), or the dual-route models of reading (e.g., Coltheart et al., 1993, 2001), can positively inform the use of behavioural training approaches. By considering how cognitive theories might influence the use of behavioural strategies, a more coherent picture of how to potentially facilitate novel word recognition is arguably provided.

For example, in Experiment 6, it was possible to explore how varying the grain size of the unit employed to train the sound–symbol mappings may affect the accuracy with which participants are able to recognise novel recombined words. Debate regarding how the size of the orthographic unit used to teach beginning readers print–sound correspondences may influence reading acquisition (e.g., small-units versus large-units) has been a source of controversy in the cognitive reading literature (e.g., Bowey, 2002; Duncan et al., 1997; Goswami, 2002; Hulme et al., 2002). Therefore it was important in the current research to compare recombinative generalisation performance following MTS training with various sized units to determine if grain size was one factor that did need to be considered when designing and implementing the MTS training protocol.

As detailed in Chapter 7, grain size did impact on recombinative generalisation performance. If we subscribe to the cognitive views of learning to read in English, that successful word recognition results from the use of various grain sizes (i.e., psycholinguistic grain size theory), this can help to explain why a MTS protocol training *only* small unit letter–sound correspondences or *only* large unit printed-word–spoken-word relations might not be the best option. Such a single unit training protocol based on one grain size alone does not adequately reflect or capture the cognitive processes (e.g., direct retrieval of whole words, application of grapheme–phoneme mappings) predicted to be involved in word recognition for the various types of words that will be encountered in an inconsistent script such as English.

Overall, the implication of the findings is that it is important not to overlook how cognitive factors implicated in reading acquisition, such as grain size or the consistency of the orthography, may influence performance on a behavioural training protocol. Indeed, the common theme running throughout this research is how the behavioural approach and cognitive theory can complement each other. These experiments actually do show how the MTS protocol can easily be refined to accommodate and connect with cognitive views of the processes involved in word recognition, which ultimately, should result in a more effective training procedure.

12.2.3 Limitations of the adult research

One of the criticisms that can be levelled against the first seven experiments is the fact that literate adults participated. Undoubtedly, this is a limitation of the experiments that deserves discussion.

Throughout the adult experiments, every effort was made to try and strengthen the ecological validity of the procedures by relating the protocol to the types of reading tasks and actual words (e.g., CVC words, consonant blend words) that children learning to read would likely encounter. The results obtained using the MTS protocol with the adults were promising in terms of the participants continually showing high accuracy in the novel word recognition tasks. Based on these data alone, however, it is only possible to speculate that the procedures would be effective as an instructional support to help children with LD struggling to learn to read for the first time. This was why the applied research with the children with LD was so important.

As discussed in Chapter 9, before the adults commenced the MTS training, they were already capable of matching letter–sound relationships in at least one language, so training the novel sound–symbol relations at whichever grain size, was probably facilitated by this. Children learning to read may not be proficient in this relational process. Thus, we cannot be certain that the procedures will be similarly effective for actual beginning readers of English.

One might even argue that the results and responses obtained are more similar to those that might be observed when someone is learning a new language (i.e., second language acquisition), rather than if someone is learning to read for the very first time.

However, the research with the children with LD did show that the protocol could be used as a remedial tool to help support oral word reading skills in children with LD who were experiencing difficulties in learning to read in their first language. This research helped to show that the protocol did work, and that the results accrued from the adult studies did not simply reflect a relational history of matching arbitrary sounds and symbols (although this may have helped their progression through the training), but could be attributed to the actual procedure.

As highlighted in Chapter 11, the children taking part in this research were already very vulnerable in terms of finding it difficult to learn how to read. It would be remiss to start working with the children using an approach that is not likely to result in successful results and be of benefit for the children. Yes, the protocol could be tailored to the specific abilities and needs of each child, but from the extensive research with the adults, we were relatively confident that the basic procedure was very likely to be effective for the children, and this was important given their past reading histories.

12.3 Research with children with learning difficulties

12.3.1 Key findings and implications

The seven children who took part in this research were all encountering difficulties in learning to read. Thus, the research was undertaken to answer the key question: could the MTS protocol be of any help to these children in improving their word naming and word recognition skills?

The answer to this question is yes. Comparing baseline and post-training performance, all of the children did show increases in the number of novel words that were read aloud or correctly recognised. However, the gains in word naming and recognition were larger for some children than for others. It is suggested that these differences can be traced back to the children's performance on the entry skills reading tasks. Primarily, the children who scored highest on the tasks designed to measure letter–name knowledge, print exposure, high frequency word reading, and phonological awareness, also tended to show the greatest improvements in naming and recognising the untrained recombined words following training. Whereas the children who knew fewer letter names, read aloud almost none of the high frequency words, or did not score as highly on the phonological awareness tasks, did not read aloud or recognise as many of the untrained test words. Phonological awareness, letter–sound and letter–name knowledge, have all been emphasised as factors influencing reading acquisition (e.g., Goswami & Bryant, 1990; Foy & Mann, 2006; Nation, 2008; Roberts, 2003; Share, 1995), and so perhaps it is unsurprising that differences in these reading related skills may have contributed to differences in performance on the recombinative generalisation tests. Nonetheless, it is crucial to stress that the children with the less developed reading skills were able to successfully name and recognise some of the novel words. For these children, any gain in word naming or printed word recognition, no matter how small, is important.

One of the implications of the current research is that it highlights why it is important not to overlook the role of prior reading skills when designing instructional reading tools to be used with children with LD. When used as a single training procedure (as in these studies), rather than a more intensive, long term training procedure, the protocol appeared to work best for the children who had some reading skills to begin with (see also Conners et al., 2006). Further research is needed to determine whether the effects of the entry reading skills would be balanced out if the children received multiple training sessions interspersed with tests to track progress, rather than just one training session for each word set, as was the case in the current research.

When assessing the impact of modifications to the size of unit employed to train the letter–sound correspondences, for all of the children the largest number of untrained words correctly named or recognised occurred following training with onsets and rimes. These findings are consistent with data highlighting the effectiveness of onset and rime training procedures for typically developing children (Christenson & Bowey, 2005; Savage et al., 2003; Walton & Walton, 2002), children with Down syndrome (Cupples & Iacono, 2002), and children with learning difficulties (e.g., Greaney et al., 1997; Hines, 2009; O'Shaughnessy & Swanson, 2000).

Slightly more untrained words were read aloud and identified following the training with syllables compared to the phonemes. Reasonably one might expect that if a child can match all of the letters to their associated sounds, he or she might also be able to read aloud words containing these letters and sounds. Training in the current study was to criterion, meaning that the children could not attempt the recombinative generalisation word naming and recognition tests until they had demonstrated proficiency in matching the letter–sound relations. Why then were the children generally least successful in naming and recognising the CVC words following the phoneme training? Just because letter–sound relations can be identified in isolation, it cannot be taken for granted that a child will be able to recognise words containing these letters and sounds. The current data were informative in documenting how some children may have difficulties in transferring letter discrimination skills to discrimination tasks involving whole words, which is something that needs to be considered and addressed in future studies.

One of the main drawbacks of the initial protocol used with the children was that the training was quite abstract in nature. Reading instruction for all children needs to be meaningful, but perhaps even more so for children with learning difficulties who can find abstract concepts quite problematic to cope with (e.g., Allor et al., 2010; van der Schuit et al., 2009). By adding the stimulus equivalence component to the protocol, the children were provided with a rudimentary level of comprehension as to what it was that the words were referring to. Along with decoding, comprehension is an essential component of reading. That being said, it was important to try and encompass a comprehension component within the training protocol so that the children were not simply reading aloud the words, but hopefully had some awareness of the meaning of the words (i.e., in the sense that the printed words could be matched to appropriate picture referents). Positive results were found when the stimulus equivalence protocol was used in an attempt to facilitate naming and recognition of consistent and inconsistent words. Even the children who scored lowest on the baseline reading skills measures demonstrated equivalence, were able to name all of the explicitly trained words, and name a proportion of the untrained recombined words.

Overall, the research with the children with LD indicated that there is much to be gained from incorporating stimulus equivalence methods into the training procedures. Integrating both MTS and stimulus equivalence training components arguably provides a more balanced approach to teaching literacy skills. The MTS training procedures help to establish the letter–sound knowledge required to successfully decode novel words, while the stimulus equivalence procedures may help a child to advance from simply reading aloud and identifying words, to reading with some comprehension as to the 'meaning' of those words. In this way, the two core components of reading (decoding and comprehension) are encompassed within the training procedure at a level suitable for beginning readers.

The effectiveness of stimulus equivalence methods in teaching components of reading is well established (e.g., Connell & Witt, 2004; de Rose et al., 1996; Mackay & Sidman, 1984; Sidman, 1971). The current data further extends the literature by showing how such stimulus equivalence procedures can be employed in a novel way, not only to facilitate recognition of novel, recombined (consistent) words, but also to facilitate recognition of inconsistent, exception words, a special class of words frequently appearing within English and in other languages, and thus requiring particular attention. Behavioural practices are particularly suitable for teaching literacy skills to children who may experience difficulties in learning to read as they allow rigorous control over the presentation of trials (i.e., providing suitable exposure and practice with stimuli) and the feedback provided (i.e., feedback is immediate to strengthen learning of the correct response). Most importantly, as shown in the current research, such behavioural methods are especially effective for use with children with LD because of the individualisation that they also allow.

Perhaps though, the greater significance of the findings with the children lies in actually showing, as with the adult research, how behavioural methods, such as the stimulus equivalence training paradigm, can be used in conjunction with cognitive theories of word recognition. Behavioural training procedures can be adapted to directly connect with, and tap into, some of the cognitive processes and mechanisms believed to contribute to successful word recognition (e.g., phonological recoding, sight word reading), in order to support word naming and recognition of the types of words (e.g., consistent words, enemy words) that beginning readers will be confronted with. Crucially, the current research demonstrates how one such integrated protocol can realistically be employed in an applied setting with children with LD. Moreover, the integrated protocol appeared to be of benefit for these children. Estimates that only one in five children with mild or moderate learning difficulties will acquire even basic reading skills (Katims, 2001) underlines why there is a real need for such applied research with children from this population.

12.3.2 Limitations of the research with the children

Some caution must be observed when drawing conclusions from the current data, especially given the small number of children taking part. These were only preliminary studies in the sense that the protocols were developed for use with a small sample of specific children with particular strengths and needs. The central objective was to see if the protocol could be of any aid to these children. Bearing in mind that children with learning difficulties do vary in their abilities (see Bergeron & Floyd, 2006; Verhoeven & Vermeer, 2006), it is possible that the protocol might not be as effective with other children from this population. Hence, there is a definite need to investigate the effectiveness of the protocols developed for this research with a larger group of children with LD. On a more positive note, the procedures are flexible in terms of adapting the training to meet individual needs (for instance, introducing simpler or more complex words varying in CV structure, print–sound consistency) and they could be amended to optimise the protocol for different children, capitalising on their individual strengths.

Furthermore, although all of the children had an educational classification of mild learning disabilities (i.e., IQ between 50 and 70), it must be acknowledged that the children differed with regard to their entry reading skills at the start of the research. As mentioned throughout the analyses, the differences in overall reading skills must be taken into account as the imbalance in reading related skills may well have influenced the results. On the other hand, as previously discussed, the research does suggest how individual differences in these skills may impact on recombinative generalisation performance. When analysing each child's training and test performance, particular attention was paid to the child's individual scores on the baseline reading tasks. By referring back to the baseline reading skills data, this helped to explain why some of the children could or could not name, recognise, or retain as many of the words compared to some of the other children.

It could be suspected that the protocol was effective primarily because the instruction was one-to-one for each child. With encouragement and feedback from the researcher, the children may have been more motivated to learn, more focused to remain on-task, which could have contributed to the gains seen. If the effectiveness of the protocol is linked to the one-to-one instruction, this would be a severe drawback for the applied utility of the procedure. Unfortunately, given the current climate in

Ireland which has resulted in reductions to the number of special needs assistants working with children with learning difficulties, many children with learning difficulties may not always have access to such one-to-one instruction. What is needed then is to test whether a fully interactive computerised protocol would be as effective as the one-to-one instruction. Few problems can be envisaged in developing such a protocol. Nearly all of the children who took part in the current research are accustomed to using computers. The computerised protocol could also be modified to incorporate words related to interests and preferences of the children (providing that a subset of the words can be represented visually), which again would make the task more meaningful for the children.

As noted in Chapter 11, it was not possible on ethical and logistical grounds, to include a control group of children with LD in the current research. Still, the prevalent finding from the extensive prior tests of the protocol conducted with the adult participants was that the protocol was a robust and effective technique that reliably facilitated recombinative generalisation. The research with the children with LD did prove that the basic protocol (with some slight modifications e.g., the addition of exclusion trials) could actually be used as a remedial aid to support the word naming and printed word recognition skills of the participating children, and as with the adult research, encouraging results were seen.

Finally, the current procedures utilised with the children aimed to strengthen their oral reading skills for single words presented in isolation. Yet the ability to accurately read aloud individual words is only one component skill of reading. Martens, Daly, Begeny and van der Heyden (in press) stated that there are at least two ways in which stimulus generalisation can occur for oral reading. Firstly, children should be able to name novel, untrained words that were not purposefully taught as part of an instructional procedure. Secondly, children should be able to accurately read aloud previously taught words when presented in novel texts. That is, the child generalises their word reading skills to new stimulus conditions. For example, reading a sentence containing trained words joined together in an unfamiliar sequence. Only the first form of oral reading stimulus generalisation was targeted in the current research. Future studies could instead examine whether following training, children are able to read aloud and recognise the trained and untrained recombined printed words in other contexts. Trained and recombined words could be included in books, or the trained words could be embedded in simple sentences with other high frequency words that the child can already read. These are just a handful of some of the possible ways in which the research could be extended, but the scope for further applied research in this area is wide-ranging.

When learning to read, children need to be involved in learning experiences that make sense to them (Basil & Reyes, 2003), and as discussed in Chapter 11, meaningfulness was an important issue to arise from working with the children with LD. Acknowledging the importance of meaningful reading instruction is one thing. It is quite another matter to actually make reading instruction meaningful, particularly for a child with LD. The current research further highlights how stimulus equivalence procedures can help to meet this aim, promoting meaningfulness in a way that is accessible and enjoyable for children with LD.

12.4 Concluding remarks

Learning to read requires the ability to tackle novel words. Training procedures that target and do facilitate this component of reading are therefore invaluable. Over a series of adult studies, the efficacy of one such procedure, a MTS training protocol that was designed to promote recombinative generalisation was examined. These experiments were some of the first to extend the use of the protocol and to test its effectiveness in facilitating within-unit and across-unit recombinative generalisation, and in facilitating recognition of not just monosyllabic words, but disyllabic words, and words varying in letter-to-sound consistency; thereby contributing to the literature concerning the potential value of such MTS procedures in teaching productive reading skills. Additionally, these experiments illustrate how behavioural strategies can complement and be used in tandem with cognitive theories of reading to maximise the potential benefits of the training. Traditionally in reading research, the behavioural and cognitive domains may have worked independently, but the current body of research is suggestive of how there is much to be potentially gained from integrating aspects (e.g., theory and practice) of the two disciplines.

The procedures have been thoroughly tested with adult participants garnering promising results. When the procedures were employed as a remedial support with a small group of children with learning difficulties in a classroom setting, all of the children showed some gains in word naming and printed word recognition for trained words, but most impressively, for words that had not been taught directly. Together these findings bode well for the use of similar training procedures as an aid to reading for any child who might be finding the task of learning to read challenging.

References

Adams, M. J. (1990). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT Press.

Allor, J. H., Mathes, P. G., Roberts, J. K., Cheatham, J. P., & Champlin, T. M. (2010). Comprehensive reading instruction for students with intellectual disabilities: Findings from the first three years of a longitudinal study. *Psychology in the Schools, 47*, *5,* 445-466.

Alloway, T. P., Gathercole, S. E., Willis, C., & Adams, A. M. (2005). Working memory and special educational needs. *Educational and Child Psychology, 22*, 56-67.

Al Otaiba, S., & Fuchs, D. (2002). Characteristics of children who are unresponsive to early literacy intervention. *Remedial and Special Education, 23*, 300-316.

Anthony, J. L., Lonigan, C. J., Driscoll, K., Phillips, B. M. & Burgess, S. R. (2003). Phonological sensitivity: A quasi-parallel progression of word structure units and cognitive operations. *Reading Research Quarterly, 38,* 470-487.

Ashby, J., Treiman, R., Kessler, B., & Rayner, K. (2006). Vowel processing during silent reading: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32, 2,* 416-424.

Balota, D. A., Pilotti, M., Cortese, M. J. (2001). Subjective frequency estimates for 2,983 monosyllable words. *Memory and Cognition, 29, 4*, 639-647.

Barron, R. W. (1986). Word recognition in early reading: A review of the direct and indirect access hypotheses. *Cognition, 24,* 93-119.

Basil, C. & Reyes, S. (2003). Acquisition of literacy skills by children with severe disability. *Child Language, Teaching and Therapy, 19, 1*, 27-45.

Bayliss, D. M., Jarrold, C., Baddeley, A. D., & Leigh, E. (2005). Differential constraints on the working memory and reading abilities of individuals with learning difficulties and typically developing children. *Journal of Experimental Child Psychology, 92*, 76-99.

Berent, I., & Perfetti, C. A. (1995). A rose is a REEZ: The two-cycles model of phonological assembly in reading English. *Psychological Review, 102,* 146-184.

Bergeron, R., & Floyd, R. G. (2006). Broad cognitive abilities of children with mental retardation: An analysis of group and individual profiles. *American Journal on Mental Retardation, 111, 6*, 417-432.

Berninger, V. W., Abbott, R. D., Vermeulen, K., & Fulton, C. M. (2006). Paths to reading comprehension in at-risk second-grade readers. *Journal of Learning Disabilities, 39, 4*, 334-351.

Besner, D., O'Malley, S., & Robidoux, S. (2010). On the joint effects of stimulus quality, regularity and lexicality when reading aloud: New challenges. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36, 3*, 750-764.

Bhattacharya, A., & Ehri, L. C. (2004). Graphosyllabic analysis helps adolescent struggling readers read and spell words. *Journal of Learning Disabilities, 37*, 331-348.

Bishop, D. V. M. (2003). *Test for Reception of Grammar – Version 2*. London: Psychological Corporation.

Borgwaldt, S. R., Hellwig, F. M., & de Groot, A. M. B. (2005). Onset entropy matters – letter-to-phoneme mappings in seven languages. *Reading and Writing, 18*, 211-229.

Bowey, J. A. (2002). Reflections on onset–rime and phoneme sensitivity as predictors of beginning word reading. *Journal of Experimental Child Psychology, 82*, 29-40.

Bowey, J. A., & Muller, D. (2005). Phonological recoding and rapid orthographic learning in third-grade children's silent reading: a critical test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 92*, 203-219.

Bowey, J. A., Vaughan, L., & Hansen, J. (1998). Beginning readers use of orthographic analogies in word reading. *Journal of Experimental Child Psychology, 68*, 108-133.

Bradley, L., & Bryant., P. E. (1983). Categorizing sounds and learning to read – a casual connection. *Nature, 301*, 419-421.

Brand, M., Giroux, I., Puijalon, C., & Rey, A. (2007). Syllable onsets are perceptual reading units. *Memory and Cognition, 35, 5*, 966-973.

Browder, D. M., Wakeman, S. Y., Spooner, F., Ahlgrim-Delzell, L., & Algozzine, R. (2006). Research on reading instruction for individuals with significant cognitive disabilities. *Exceptional Children, 72,* 392-408.

Browder, D. M., & Xin, Y. P. (1998). A meta-analysis and review of sight word research and its implications for teaching functional reading to individuals with moderate and severe disabilities. *The Journal of Special Education, 32*, 130-153.

Brown, P., & Besner, D. (1987). The assembly of phonology in oral reading: A new model. In M. Coltheart (Ed.), *Attention and performance: The psychology of reading, Vol. 12* (pp. 471–489). Hillsdale, NJ: Erlbaum.

Brown, G., & Deavers, R. (1999). Units of analysis in nonword reading: Evidence from children and adults. *Journal of Experimental Child Psychology, 73*, 208-242.

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Experimental Child Psychology, 50, 1*, 156-178.

Burgess, C. & Livesay, K. (1998). The effect of corpus size in predicting reaction time in a basic word recognition task: Moving on from Kucera and Francis. *Behavior Research Methods, Instruments, & Computers, 30*, 272-277.

Byrne, B. (1991). Experimental analysis of the child's discovery of the alphabetic principle. In L. Rieben & C. A. Perfetti (Eds.), *Learning to read: Basic research and its implications* (pp. 75-84), Hillsdale, NJ: Lawrence Erlbaum.

Byrne, B. (1998). *The foundation of literacy: The child's acquisition of the alphabetic principle.* Hove, UK: Psychology Press.

Byrne, B., & Fielding-Barnsley, R. (1989). Phonemic awareness and letter knowledge in the child's acquisition of the alphabetic principle. *Journal of Educational Psychology, 81,* 313-321.

Calhoon, J. A. (2001). Factors affecting the reading of rimes in words and nonwords in beginning readers with cognitive disabilities and typically developing readers: Explorations in similarity and difference in word recognition cue use. *Journal of Autism and Developmental Disorders, 31,* 491-504.

Caravolas, M. (2005). The nature and causes of dyslexia in different languages. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading: A Handbook.* (pp. 336-355). Malden, MA: Blackwell Publishing.

Carr, T. H., & Pollatsek, A. (1985). Recognizing printed words: A look at current models. In D. Besner, T. J. Waller, & G. E. MacKinnon (Eds.), *Reading research: Advances in theory and practice,* (pp. 1-82). Orlando, FL: Academic Press.

Cawley, J. F., & Parmar, R. S. (1995). Comparisons in reading and reading-related tasks among students with average intellectual ability and students with mild mental retardation. *Education and Training in Mental Retardation Developmental Disabilities, 30,* 118-129.

Chapman, J. W., Tunmer,W. E., & Prochnow, J. E. (2001). Does success in the Reading Recovery program depend on developing proficiency in phonological-processing skills? A longitudinal study in a whole language instructional context. *Scientific Studies of Reading, 5, 2*, 141−176.

Christensen, C. A., & Bowey, J. A. (2005). The efficacy of orthographic rime, grapheme-phoneme correspondence, and implicit phonics approaches to teaching decoding skills. *Scientific Studies of Reading, 9, 4*, 327-349.

Coltheart, M. (2005). Modeling reading: The dual route approach. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading: A Handbook* (pp. 6-23). Malden, MA: Blackwell Publishing.

Coltheart, M. (2006). Dual route and connectionist models of reading: An overview. *London Review of Education*, *4*, 5-17.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 100*, 589-608.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108,* 204-256.

Connell, J. E., & Witt, J. C. (2004). Applications of computer-based instruction: Using specialized software to aid letter–name and letter–sound recognition. *Journal of Applied Behavior Analysis, 37*, 67-71.

Conners, F. A. (2003). Reading skills and cognitive abilities of individuals with mental retardation. In L. Abbeduto (Ed.), *International review of research in mental retardation*, *Vol. 27* (pp. 191-229). San Diego: Academic Press.

Craig, C. H., Kim, B., Rhyner, P. M. P., & Chirillo, T. K. (1993). Effects of word predictability, child development, and aging on time-gated speech recognition performance. *Journal of Speech and Hearing Research, 36, 4*, 832-841.

Conners, F. A., Rosenquist, C. J., Sligh, A. C., Atwell, J. A., & Kiser, T. (2006). Phonological reading skills acquisition by children with mental retardation. *Research in Developmental Disabilities, 27,* 121-137.

Cunningham, A. E., Perry, K. E., Stanovich, K. E., & Share, D. L. (2002). Orthographic learning during reading: Examining the role of self-teaching. *Journal of Experimental Child Psychology, 82*, 185-199.

Cupples, L., & Iacono, T. (2002). The effects of whole word versus analytic reading instruction for children with Down syndrome. *Reading and Writing: An Interdisciplinary Journal, 15*, 549-574.

Daly, E., Chafouleas, S. III., Persampieri, M., Bonfiglio, C., & La Fleur, C. (2004). Teaching phoneme segmenting and blending as critical early literacy skills: An experimental analysis of minimal textual repertoires. *Journal of Behavioral Education, 13,* 165-178.

de Jong, P. F. (2007). Phonological awareness and the use of phonological similarity in letter–sound learning. *Journal of Experimental Child Psychology, 98,* 131-152.

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology, 91,* 450-476.

Department for Education and Employment. (1998). *The National Literacy Strategy Framework for Teaching*. Sudbury: DfEE Publications.

Department of Education and Science (1999). *Guidelines for the English Primary School Curriculum*. Dublin: Government of Ireland.

de Rose, J. C., de Souza, D. G., & Hanna, E. S. (1996). Teaching reading and spelling: Exclusion and stimulus equivalence. *Journal of Applied Behavior Analysis, 29*, 451-469.

de Rose, J. C., de Souza, D. G., Rossito, A. L., & de Rose, T. M. S. (1992). Stimulus equivalence and generalization in reading after matching-to-sample by exclusion. In S. C. Hayes & L. J. Hayes (Eds.), *Understanding verbal relations* (pp. 69-82). Reno, Nevada: Context Press.

de Souza, D., de Rose, J. C., Faleiros, T. C., Bortoloti, R., Hanna, E. S., & McIlvane, W. J. (2009). Teaching generative reading via recombination of minimal textual units: A legacy of verbal behavior to children in Brazil. *Journal of Psychology and Psychological Therapy, 9, 1,* 19-44.

Dixon, L. S. (1977). The nature of control by spoken words over visual stimulus selection. *Journal of the Experimental Analysis of Behavior, 27,* 433-442.

Dodd, B., & Carr, A. (2003). Young children's letter–sound knowledge. *Language, Speech, and Hearing Services in Schools, 34, 2*, 128-137.

Dolch, E. W. (1941). Sight word lists. In Marinovich, C. (2003). *Dolch sight word activities Volumes 1 and 2*. Michigan: Frank Schaffer Publications.

Duncan, L. G., Seymour, P. H. K., & Hill, S. (1997). How important are rhyme and analogy in beginning reading? *Cognition, 63*, 171-208.

Ecalle, J., Magnan, A., & Calmus, C. (2009). Lasting effects on literacy skills with computer-assisted learning using syllabic units in low-progress readers. *Computers and Education, 52, 3,* 554-561.

Ehri, L. C. (1991). Learning to read and spell words. In L. Rieben & C. A. Perfetti (Eds.), *Learning to read: Basic research and its implications* (pp. 57-73). Hillsdale, NJ: Lawrence Erlbaum.

Ehri, L. C., (1992). Reconceptualising the development of sight word reading and its relationship to recoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp.105-143). Hillsdale, NJ: Lawrence Erlbaum.

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18, 2,* 116-125.

Ehri, L. C. (1998). Grapheme–phoneme knowledge is essential for learning to read words in English. In J. L. Metsala & L. C. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 3-40). London, England: Erlbaum.

Ehri, L. C., (1999). Phases of development in learning to read words. In J. Oakhill & R. Beard (Eds.), *Reading development and teaching of reading: A psychological perspective* (pp. 79-108). Oxford, England: Blackwell.

Ehri, L. C. (2005). Learning to read words: Theory, findings and issues. *Scientific Studies of Reading, 9, 2,* 167-188.

Ehri, L. C., Nunes, S. R., Stahl, S. A., & Willows, D. M. (2001). Systematic phonics instruction helps students learn to read: Evidence from the National Reading Panel's meta-analysis. *Review of Educational Research, 71,* 393-447.

Ehri, L. C., & Robbins, C. (1992). Beginners need some decoding skill to read words by analogy. *Reading Research Quarterly, 27*, 12-26.

Ellis, N. C., & Hooper, A. M. (2001). Why learning to read is easier in Welsh than in English: Orthographic transparency effects evinced with frequency-matched tests. *Applied Psycholinguistics, 22*, 571-599.

Farrell, M., & Elkins, J. (1995). Literacy for all? The case of Down syndrome. *Journal of Reading, 38*, 270-280.

Ferrari, C., de Rose, J. C., & McIlvane, W. J. (1993). Exclusion vs. selection training of auditory–visual conditional relations. *Journal of Experimental Child Psychology, 56*, 49-63.

Fletcher, H., & Buckley, J. (2002). Phonological awareness in children with Down Syndrome, *Down Syndrome Research and Practice, 8, 1*, 11-18.

Fletcher-Flinn, C. M., Shankweiler, D., & Frost, S. J. (2004). Coordination of reading and spelling in early literacy development: An examination of the discrepancy hypothesis. *Reading and Writing, 17, 6*, 617-644.

Foorman, B. R., Francis, D. J., Fletcher, J. M., Schatschneider, J. M., & Christopher, M. P. (1998). The role instruction in learning to read: Preventing reading failure in at-risk children. *Journal of Educational Psychology, 90, 1*, 37-55.

Foy, J. G., & Mann, V. (2006). Changes in letter sound knowledge are associated with development of phonological awareness in pre-school children. *Journal of Research in Reading, 29,* 143-161.

Fredrickson, N., Frith, U., & Reason, R. (1997). *The Phonological Assessment Battery*. Windsor: NFER-Nelson.

Frith, U., Wimmer, H., & Landerl, K. (1998). Differences in phonological recoding in German- and English-speaking children. *Scientific Studies of Reading, 2, 1*, 31-54.

Frost, R. (2005). Orthographic systems and skilled word recognition processes in reading. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading: A Handbook* (pp. 272-295). Malden, MA: Blackwell Publishing.

Funnell, E. (1996). Response biases in oral reading: An account of the co-occurrence of surface dyslexia and semantic dementia. *Quarterly Journal of Experimental Psychology, 49A, 2*, 417-446.

Georgiou, G. K., Parrila, R., & Papadopoulos, T. C. (2008). Predictors of word decoding and reading fluency across languages varying in orthographic consistency. *Journal of Educational Psychology, 100, 3*, 566-580.

Gersten, R., Fuchs, L., Williams, J., & Baker, S. (2001). Teaching reading comprehension to students with learning disabilities: A review of research. *Review of Educational Research*, *71*, *2*, 279-320.

Glushko, R. J. (1979). The organisation and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 674-691.

Goldstein, H. (1993). Structuring environmental input to facilitate generalized learning by children with mental retardation. In A. P. Kaiser & D. B. Gray (Eds.), *Enhancing children's communication: Research foundations for intervention, Vol. 2* (pp. 317-334). Baltimore: Brookes.

Goldstein, H., & Mousetis, L. (1989). Generalised language learning with severe mental retardation: Effects of peers' expressive modelling. *Journal of Applied Behavior Analysis, 22*, 245-259.

Goswami, U. (1986). Children's use of analogy in learning to read: a developmental study. *Journal of Experimental Child Psychology, 42*, 73-83.

Goswami, U. (1988). Orthographic analogies and reading development. *The Quarterly Journal of Experimental Psychology, 40*, 239-268.

Goswami, U. (1993). Toward an interactive analogy model of reading development: Decoding vowel graphemes in beginning reading. *Journal of Experimental Child Psychology, 56,* 443-475.

Goswami, U. (2002). In the beginning was the rhyme? A reflection on Hulme, Hatcher, Nation, Brown, Adams, and Stuart (2002). *Journal of Experimental Child Psychology, 82*, 47-57.

Goswami, U. (2005). Synthetic phonics and learning to read: A cross-language perspective. *Educational Psychology in Practice, 21*, 273-282.

Goswami, U., & Bryant, P. E. (1990). *Phonological skills and learning to read*. Hillsdale, NJ: Erlbaum.

Goswami, U., Gombert, J. E., & de Barrera, L. F. (1998). Children's orthographic representations and linguistic transparency: nonsense word reading in English, French, and Spanish. *Applied Psycholinguistics, 19, 1,* 19-52.

Goswami, U., Porpodas, C., & Wheelwright, S. (1997). Children's orthographic representations in English and Greek. *European Journal of Psychology of Education, 3,* 273-292.

Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2003). Nonword reading across orthographies: How flexible is the choice of reading units? *Applied Psycholinguistics, 24*, 235-247.

Greaney, K. T. & Tunmer, W. E. (1996). Onset-rime sensitivity and orthographic analogies in normal and poor readers, *Applied Psycholinguistics, 17,* 15-40.

Greaney, K. T., Tunmer, W. E. & Chapman, J. W. (1997). Effects of rime-based orthographic analogy training on the word recognition skills of children with reading disability, *Journal of Educational Psychology, 89,* 645-651.

Hatcher, P. J., Hulme, C., & Snowling, M. J. (2004). Explicit phonological training combined with reading instruction helps young children at risk of reading failure. *Journal of Child Psychology and Psychiatry, 45*, 338-358.

Hendrick, W. B., Katims, D. S., & Carr, N. J. (1999). Implementing a multimethod, multilevel literacy program for students with mental retardation. *Focus on Autism and Other Developmental Disabilities, 14,* 231-239.

Hines, S. J. (2009). The effectiveness of a color-coded onset-rime decoding intervention with first grade students at serious risk for reading disabilities. *Learning Disabilities Research and Practice, 24, 1*, 23-32.

Hodapp, R. M. & Fidler, D. J. (1999). Special education and genetics: Connections for the 21st century, *Journal of Special Education,* 33, 130-137.

Hoogeveen, F. R., Smeets, P. M., & Lancioni, G. E. (1988). Teaching moderately mentally retarded children basic reading skills. *Research in Developmental Disabilities, 10*, 1-18.

Hulme, C. (2002). Phonemes, rimes and the mechanisms of early reading development. *Journal of Experimental Child Psychology, 82,* 58-64.

Hulme, C., Hatcher, P. J., Nation, K., Brown, A., Adams, J., & Stuart, G. (2002). Phoneme awareness is a better predictor of early reading skill than onset-rime awareness. *Journal of Experimental Child Psychology, 82*, 2-28.

Hulme, C., Snowling, M., Caravolas, M., & Carroll, J. (2005). Phonological skills are (probably) one cause of success in learning to read: A comment on Castles and Coltheart. *Scientific Studies of Reading, 9*, 351-365.

Jared, D., McRae, K., & Seidenberg, M. S. (1990). The basis of consistency effects in word naming. *Journal of Memory and Language, 29*, 687-715.

Jared, D., & Seidenberg, M. S. (1990). Naming multisyllabic words. *Journal of Experimental Psychology: Human Perception and Performance, 16, 1*, 92-105.

Jenkins, J. R., Fuchs, L. S., van den Broek, P., Espin, C., & Deno, S. (2003). Sources of individual differences in reading comprehension and reading fluency. *Journal of Educational Psychology, 95,* 719–729.

Jorm, A. F., & Share, D. L. (1983). Phonological recoding and reading acquisition. *Applied Psycholinguistics, 4,* 103-147.

Joseph, L. M., & McCachran, M. (2003). Comparison of a word study phonics technique between students with moderate to mild mental retardation and struggling readers without disabilities. *Education and Training in Developmental Disabilities, 38*, 192-199.

Katims, D. S. (2000). Literacy instruction for people with mental retardation: Historical highlights and contemporary analysis. *Education and Training in Mental Retardation and Developmental Disabilities, 35*, 3-15.

Katims, D. S. (2001). Literacy assessment of students with mental retardation: An exploratory investigation. *Education and Training in Mental Retardation and Developmental Disabilities, 36, 4,* 363-372.

Katz, L., & Frost, R. (1992). Reading in different orthographies: the Orthographic Depth Hypothesis. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp.67-84). Advances in Psychology. Amsterdam: Elsevier.

Keaveney, J. (2005). *Symmetry, recombinative generalisation, equivalence and language: A behavioural model of reading*. Unpublished doctoral dissertation, National University of Ireland, Maynooth.

Kennedy, E. J., & Flynn, M. C. (2003). Training phonological awareness skills in children with Down syndrome. *Research in Developmental Disabilities, 24, 1,* 44-57.

Kessler, B., & Treiman, R. (2001). Relationships between sounds and letters in English monosyllables. *Journal of Memory and Language, 44,* 592-617.

Kintsch, W., & Kintsch, E. (2005). Comprehension. In S. G. Paris & S. A. Stahl (Eds.), *Children's reading comprehension and assessment* (pp. 71–104). Mahwah, NJ: Erlbaum.

Kirby, J. R., Desrochers, A., Roth, L., & Lai, S. S. V. (2008). Longitudinal predictors of word reading development. *Canadian Psychology, 49, 2*, 103-110.

Koppenhaver, D. A., & Erickson, K. A. (2003). Natural emergent literacy supports for preschoolers with autism and severe communication impairments. *Topics in Language Disorders, 23,* 283-292.

Koppenhaver, D. A., Evans, D. A., & Yoder, D. E. (1991). Childhood reading and writing experiences of literate children with severe speech and motor impairments. *Augmentative and Alternative Communication, 7*, 20-33.

Lane, S. D., & Critchfield, T. S. (1998). Classification of vowels and consonants by individuals with moderate mental retardation: Development of arbitrary relations via match-to-sample training with compound stimuli. *Journal of Applied Behavior Analysis, 31,* 21-41.

Laws, G. (2002). Working memory in children and adolescents with Down syndrome: Evidence from a colour memory experiment. *Journal of Child Psychology and Psychiatry, 43, 4*, 353-364.

Lee, H. W., Rayner, K., & Pollatsek, A. (2001). The relative contribution of consonants and vowels to word identification during silent reading. *Journal of Memory and Language, 44,* 189-205.

Lemons, C. J., & Fuchs, D. (2010). Phonological awareness of children with Down Syndrome: Its role in learning to read and the effectiveness of related interventions. *Research in Developmental Disabilities, 31*, 316-330.

Levy, B. A., & Lysynchuk, L. (1997). Beginning word segmentation: Benefits of training by segmentation and whole word methods. *Scientific Studies of Reading, 1,* 359–387.

Lovett, M. W., Laceranza, L., Borden, S. L., Frijers, J. C., Steinbach, K. A.,& DePalma, M. (2000). Components of effective remediation for developmental reading disabilities: Combining phonological and strategy based instruction to improve outcomes. *Journal of Educational Psychology, 92,* 1-30.

Luce, P. A. & Pisoni, D. B. (1998). Recognising spoken words: The neighbourhood activation model. *Ear and Hearing, 19*, 1-36.

Lukatela, K., Carello, C., Shankweiler, D., & Liberman, I. Y. (1995). Phonological awarness in illiterates: Observations from Serbo-Croatian. *Applied Psycholinguistics, 16*, 463-487.

Mackay, H. A., & Sidman, M. (1984). Teaching new behaviour via equivalence relations. In P. H. Brooks, R. Sperber, & C. MacCauley (Eds.), *Learning and cognition in the mentally retarded* (pp. 493-513). Hillsdale, NJ: Erlbaum.

Mahon, C., Lyddy, F., & Barnes-Holmes, D. (2010). Recombinative generalization of subword units using matching to sample. *Journal of Applied Behavior Analysis, 43, 2*, 303-307.

Manis, F. R. (1985). Acquisition of word identification skills in normal and disabled readers. *Journal of Educational Psychology, 77*, 78-90.

Martens, B. K., Daly, E. J. III., Begeny, J. C., & Van der Heyden, A. (in press). In W. Fisher, C. Piazza, & H. Roane (Eds.), *Handbook of Applied Behavior Analysis*. New York: Guilford Press.

Masterson, J., Laxon, V., & Stuart, M. (1992). Beginning reading with phonology. *British Journal of Psychology, 83*, 1-12.

Masterson, J., Stuart, M., Dixon, M., & Lovejoy, S. (2003). The Children's Printed Word Database. Retrieved from www.essex.ac.uk/psychology/cpwd

McBride-Chang, C. (1995). What is phonological awareness? *Journal of Educational Psychology, 87*, 179-192.

McCandliss, B., Beck, I. L., Snadak, R., & Perfetti, C. (2003). Focusing attention on decoding for children with poor reading skills: Design and preliminary tests of the word building intervention. *Scientific Studies of Reading, 7*, 75-104.

McCann, R. S., Besner, D., & Davelaar, E. (1988). Word recognition and identification: Do word-frequency effects reflect lexical access? *Journal of Experimental Psychology: Human Perception and Performance, 13,* 693-706.

Melchiori, L. E., de Souza, D. G., & de Rose, J. C. (2000). Reading, equivalence, and recombination of units: A replication with students with different learning histories. *Journal of Applied Behavior Analysis, 33*, 97-100.

Morais, J., Carey, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition, 7*, 323-331.

Mueller, M. M., Olmi, D. J., & Saunders, K. J. (2000). Recombinative generalization of within-syllable units in prereading children. *Journal of Applied Behavior Analysis, 33,* 515-531.

Muter, V., Hulme, C., Snowling, M., & Taylor, S. (1997). Segmentation, not rhyming, predicts early progress in learning to read. *Journal of Experimental Child Psychology, 65*, 370-398.

Muter, V., Snowling, M., & Taylor, S. (1994). Orthographic analogies and phonological awareness: Their role and significance in early reading development. *Journal of Child Psychiatry, 35, 2,* 293-310.

Nation, K. (2008). Learning to read words. *The Quarterly Journal of Experimental Psychology, 61, 8*, 1121-1133.

Nation, K., Allen, R., & Hulme, C. (2001). The limitations of orthographic analogy in early reading development: Performance on the clue word task depends on phonological priming and elementary decoding skill not the use of orthographic analogy. *Journal of Experimental Child Psychology, 80*, 75-94.

Nation, K., Angell, P., & Castles, A. (2007). Orthographic learning via self-teaching in children learning to read English: Effects of exposure, duration, and context. *Journal of Experimental Child Psychology, 96,* 71-84.

Nation, K., & Hulme, C. (1997). Phonemic segmentation, not onset-rime segmentation, predicts early reading and spelling skills. *Reading Research Quarterly, 22*, 154-167.

Nielsen, E., & Bourassa, D. (2008). Word learning performance in beginning readers. *Canadian Journal of Experimental Psychology, 62, 2*, 110-116.

Nittrouer, S., & Boothroyd, A. (1990). Context effects in phoneme and word recognition by young children and older adults. *Journal of the Acoustical Society of America, 87, 6,* 2705-2715.

Noell, G. H., Connell, J. E., & Duhon, G. J. (2006). Spontaneous response generalization during whole word instruction: Reading to spell and spelling to read. *Journal of Behavioral Education, 15, 3,* 121-150.

Oakhill, J., & Cain, K. (2000). Children's difficulties in text comprehension: Assessing causal issues. *Journal of Deaf Studies and Deaf Education*, *5*(1), 51–59.

O'Connor, R. E., Swanson, L., & Geraghty, C. (2010). Improvement in reading rate under independent and difficult text levels: Influences on word and comprehension skills. *Journal of Educational Psychology, 102, 1*, 1-19.

O'Shaughnessy, T. E., & Swanson, H. L. (2000). A comparison of two reading interventions for children with learning disabilities. *Journal of Learning Disabilities, 33,* 257-278.

Perfetti, C. A. (1991). Representations and awareness in the acquisition of reading competence. In L. Rieben, & C. A. Perfetti (Eds.), *Learning to read: Basic research and its implications* (pp 33-44). Hillsdale, New Jersey: Lawrence Erlbaum.

Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: The CDP model of reading aloud. *Psychological Review, 114,* 273–315.

Pexman, P. M., Trew, J. L., & Hoylk, G. G. (2005). How a pint can hurt you now but help you later: The time course of priming for word body neighbors. *Journal of Memory and Language, 53, 3*, 315-341.

Pickering, S. J., & Gathercole, S. E. (2004). Distinctive working memory profiles in children with varying special educational needs. *Educational Psychology, 24*, 393-408.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103, 1*, 56-115.

Rack, J. P., Snowling, M. J., & Olson, R. K. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly, 27,* 29-53.

Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest, 2, 2*, 31-74.

Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2002). How should reading be taught? *Scientific American, 286*, 85-91.

Reitsma, P. (1983). Printed word learning in beginning readers. *Journal of Experimental Child Psychology, 36*, 321-339.

Reynolds, M., & Besner, D. (2004). Neighbourhood density, word frequency and spelling–sound regularity effects in naming: Similarities and differences between skilled readers and the dual route cascaded computational model. *Canadian Journal of Experimental Psychology, 58,* 13-31.

Richards, G. P., Samuels, S. J., Turnure, J. E., & Ysseldyke, J. E. (1990). Sustained and selected attention in children with learning disabilities. *Journal of Learning Disabilities, 23, 2*, 129-136.

Roberts, T. A. (2003). Effects of alphabet-letter instruction on young children's word recognition. *Journal of Educational Psychology, 95*, 41-51.

Roberts, L., & McDougall, S. (2003). What do children do in the rime analogy task? An examination of the skills and strategies used by early readers. *Journal of Experimental Child Psychology, 84*, 310-337.

Roe, K., Jahn-Samilo, J., Juarez, L., Mikel, N., Royer, I., & Bates, E. (2000). Contextual effects on word production: A lifespan study. *Memory and Cognition, 28, 5*, 756-765.

Russell, J., Jarrold, C., & Henry, L. (1996). Working memory in children with autism and moderate learning difficulties. *Journal of Child Psychology and Psychiatry, 37*, 673-686.

Samuels, S. J. (1994). Word recognition. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (pp. 359-380). Newark, DE: International Reading Association.

Samuels, S. J., & Flor, R. (1997). The importance of automaticity for developing expertise in reading. *Reading and Writing Quarterly, 13,* 107–122.

Saunders, K. J. (2007). Word attack skills in individuals with mental retardation. *Mental Retardation and Developmental Disabilities Research Reviews, 13*, 78-84.

Saunders, K. J., Johnston, M. D., & Brady, N. C. (2000). Identity matching of consonant-vowel-consonant words by prereaders. *Journal of Applied Behavior Analysis, 33, 3,* 309-312.

Saunders, K. J., O'Donnell, J., Vaidya, M., & Williams, D. C. (2003). Recombinative generalization of within-syllable units in nonreading adults with mental retardation. *Journal of Applied Behavior Analysis, 36*, 95-99.

Savage, R. S. (1997). Do children need concurrent prompts in order to use lexical analogies in reading? *Journal of Child Psychology and Psychiatry, 38*, 235-246.

Savage, R.S., Blair, R., & Rvachew, S. (2006). Rimes are not necessarily favoured by prereaders: Evidence from meta- and epilinguistic phonological tasks. *Journal of Experimental Child Psychology, 94*, 183-205.

Savage, R., Carless, S., and Stuart, M. (2003). The effects of rime-and phoneme-based teaching delivered by learning support assistants. *Journal of Research in Reading, 26,* 211-233.

Savage, R. S., & Stuart, M. (1998). Sublexical inferences in beginning reading: Medial vowel digraphs as functional units of transfer. *Journal of Experimental Child Psychology, 69*, 85-108.

Schiff, R. (2003). The effects of morphology and word length on the reading of Hebrew nominals. *Reading and Writing: An Interdisciplinary Journal, 16*, 263-287.

Schonell, F. & Goodacre, E. (1971). *The Psychology and Teaching of Reading (5th ed.).* London: Oliver & Boyd.

Sears, C. R., Campbell, C. R., & Lupker, S. J. (2006). Is there a neighbourhood frequency effect in English? Evidence from reading and lexical decision. *Journal of Experimental Psychology: Human perception and performance, 32, 4*, 1040-1062.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition. *Psychological Review, 96*, 523-568.

Seidenberg, M. S., Peterson, A., MacDonald, M.C., & Plaut, D.C. (1996). Pseudohomophone effects and models of word recognition. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 22, 1*, 48-62.

Seymour, P. H. K. (2005). Early reading development in European Orthographies in reading. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading: A Handbook* (pp. 296-315). Malden, MA: Blackwell Publishing.

Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*, 143-174.

Seymour, P. H. K., & Duncan, L. G. (2001). Learning to read in English. *Psychology: The Journal of the Hellenic Psychological Society, 8,* 281-299.

Seymour, P. H. K., Duncan, L. G., & Bolik, F. M. (1999). Rhymes and phonemes in the common unit task: Replications and implications for beginning reading. *Journal of Research in Reading, 22, 2*, 113-130.

Seymour, P. H. K., & Elder, L. (1986). Beginning reading without phonology. *Cognitive Neuropsychology, 3,* 1-36.

Shankweiler, D. (1989). How problems of comprehension are related to difficulties in word reading. In D. Shankweiler & I. Y. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 35-68). Ann Arbor: University of Michigan Press.

Shankweiler, D., & Fowler, A. E. (2004). Questions people ask about the role of phonological processes in learning to read. *Reading and Writing, 17, 5*, 483-515.

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55*, 151-218.

Share, D. L. (1999). Phonological recoding and orthographic learning: A direct test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 72,* 95-129.

Share, D. L. (2008). On the Anglocentrics of current reading research and practice: The perils of overreliance on an "outlier" orthography. *Psychological Bulletin, 134, 4*, 584-615.

Share, D.L., & Stanovich, K.E. (1995). Cognitive processes in early reading development: A model of acquisition and individual differences. *Issues in Education: Contributions from Educational Psychology, 1,* 1-57.

Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research, 14*, 5-13.

Sidman, M. (1994). *Equivalence relations: A research story*. Boston: Authors Cooperative.

Sidman, M., & Cresson, O., Jr. (1973). Reading and crossmodal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Retardation, 77,* 515-523.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching-to-sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis Behavior, 37*, 5-22.

Sidman, M., Willson-Morris, M., & Kirk, B. (1986). Matching-to-sample procedures and the development of equivalence relations: The role of naming. *Analysis and Intervention in Developmental Disabilities, 6, 1-2*, 1-19.

Singh, N. N., & Singh, J. (1988). Increasing oral reading proficiency through overcorrection and phonic analysis. *American Journal on Mental Retardation,* 93, 312-319.

Snow, C. E., Burns, M. S., & Griffin, P. (Eds.), (1998). *Preventing reading difficulties in young children.* Washington: National Academy Press.

Snow, C. E. & Juel, C. (2005). Teaching children to read: What do we know about how to do it? In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading: A Handbook* (pp. 501-520). Malden, MA: Blackwell Publishing.

Snow, C. E., Scarborough, H. S., & Burns, M. S. (1999). What speech-language pathologists need to know about early reading. *Topics in Learning Disorders, 20*, 48-58.

Spencer, L. H., & Hanley, J. R. (2003). Effects of orthographic transparency on reading and phoneme awareness in children learning to read in Wales. *British Journal of Psychology, 94*, 1-28.

Stanovich, K. E. (1989). Individual differences in the cognitive processes of reading: I. Word decoding. *Journal of Learning Disabilities, 15, 8,* 485-493.

Stanovich, K. E. (2000). *Progress in understanding reading: Scientific foundations and new frontiers*. New York: Guilford Press.

Stanovich, K., Cunningham, A., & Cramer, B. (1984). Assessing phonological awareness in kindergarten children: Issues of task comparability. *Journal of Experimental Child Psychology, 38*, 175-190.

Sterr, A. M. (2004). Attention performance in young adults with learning disabilities. *Learning and Individual Differences, 14, 2*, 125-133.

Suchowierska, M. (2006). Recombinative generalization: Some theoretical and practical remarks. *International Journal of Psychology, 41, 6,* 514-522.

Swanson, H. L., & Hoskyn, M. (1998). Experimental intervention research on students with learning disabilities: A metaanalysis of treatment outcomes. *Review of Educational Research, 68*, 277-321.

Thompson, G. B., Cottrell, D. S., & Fletcher-Flinn, C. M. (1996). Sublexical orthographic-phonological relations early in the acquisition of reading: The knowledge sources account. *Journal of Experimental Child Psychology, 62*, 190-222.

Thompson, G. B., Fletcher-Flinn, C. M., & Cottrell, D. S. (1999). Learning correspondences between letters and phonemes without explicit instruction. *Applied Psycholinguistics, 20*, 21-50.

Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Rose, E., Lindamood, P., Conway, T., & Garvan, C. (1999). Preventing reading failure in young children with phonological processing disabilities: Group and individual responses to instruction. *Journal of Educational Psychology, 91,* 579-593.

Treiman, R., Goswami, U., & Bruck, M. (1990). Not all nonwords are alike: Implications for reading development and theory. *Memory and Cognition, 18, 6*, 559-567.

Treiman, R., Mullennix, J., Bijeljac-Babic, R., & Richmond-Welty, D. E. (1995). The special role of rimes in the description, use, and acquisition of English orthography. *Journal of Experimental Psychology: General, 124*, 107-136.

Van der Molen, M. J., Van Luit, J. E. H., Jongmans, M. J. & Van der Molen, M.W. (2007). Verbal working memory in children with mild intellectual disabilities. *Journal of Intellectual Disability Research, 51, 2,* 162-169.

Van der Schuit, M., Peeters, M., Segers, E., van Balkom, H., & Verhoeven, L. (2009). Home literacy environment of pre-school children with intellectual disabilities. *Journal of Intellectual Disability Research, 53, 12,* 1024-1037.

Van Orden, G. C., Johnston, J. C., & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 371-386.

Van Orden, G. C., & Kloos, H. (2005).The question of phonology and reading. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading: A Handbook* (pp. 61-78). Malden, MA: Blackwell Publishing.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45, 1*, 2-40.

Verhoeven, L., & Vermeer, A. (2006). Literacy achievement of children with intellectual disabilities and differing linguistic backgrounds. *Journal of Intellectual Disability Research, 50, 10,* 725-738.

Walton, P. D., & Walton, M. L. (2002). Beginning reading by teaching in rime analogy: Effects on phonological skills, letter-sound knowledge, working memory, and word reading strategies. *Scientific Studies of Reading, 6,* 79-116.

Wood, C., & Farrington-Flint, L. (2002). Orthographic analogy use and phonological priming effects in non word reading. *Cognitive Development, 16*, 951-963.

Yap, M. J., & Balota, D. A., (2009). Visual word recognition of multisyllabic words. *Journal of Memory and Language, 60*, 502-529.

Yates, M. (2005). Phonological neighbours speed visual word processing: Evidence from multiple tasks. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31, 6*, 1385-1397.

Yates, M., Locker, L., & Simpson, G. B. (2003). Semantic and phonological influences on the processing of words and pseudohomophones. *Memory & Cognition, 31,* 856-866.

Ziegler, J. C. & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131, 1*, 3-29.

Ziegler, J. C., & Goswami, U. (2006). Becoming literate in different languages: Similar problems, different solutions. *Developmental Science, 9, 5*, 429-453.

Appendix One: Adult Consent Form

CONSENT FORM

In agreeing to participate in this research I _______________________________ understand the following:

This research is being conducted by Catherine Mahon, a postgraduate student in the Department of Psychology at the National University of Ireland, Maynooth.
The research is designed to explore a number of skills which are related to reading.
Specifically, as a participant in this experiment you will be requested to complete a computer based task. During this task a number of different sounds and visual symbols will be presented. Throughout the task, each participant will learn to match particular symbols or sounds with various other sounds or symbols, resulting in the formation/ learning of a number of sound and symbol pairs. Feedback will be provided by the computer to enable participants to learn the correct pairings (i.e., which sound or symbol correctly matches another symbol or sound).

There are no known expected discomforts or risks associated with participation in this study.

I am aware as a participant, that if I have any concerns about taking part in this study, I understand that I may refuse to participate and withdraw from the research at any stage of the experiment.

Once participation has ended, any questions or concerns I have will be fully addressed by the researcher.

All data from this study will be treated confidentially. Participants will not be required to provide their names at any stage of the research. The data from all participants will remain anonymous. Following completion of the study, all data will be carefully stored in a locked storage facility.
The data from all participants will be compiled, analysed and submitted as part of a doctoral thesis to the Psychology Department. No participant's data will be identified by name at any stage of the data analysis or in the final report. Participants are welcome to access and read the final written report following the completion of the research if they so desire.

In the future, there may be a possibility that an opportunity will arise for the results from this study to be used as part of an academic presentation. In the case of such presentation, I understand that all data will be treated in the strictest confidence, participants will not be referred to by name and thus, the data obtained cannot be linked to any participant.

When you have read and understood the above information, please read through the following statements.
- ☐ I have been informed as to the general nature of the study and agree voluntarily to participate.
- ☐ I have addressed any questions that I may have concerning participation in this research to the above named researcher.
- ☐ I have no known hearing or visual impairments (i.e., hearing/vision is normal or corrected to normal).
- ☐ In signing this consent form, I understand that I am providing my permission for any data obtained from this study to be included in any subsequent written reports that might arise. As outlined previously, all data collected will be treated in the strictest confidence and will not be identifiable as belonging to any one participant.
- ☐ I may withdraw from this study at any time, and may withdraw my data at the conclusion of my participation if I still have any concerns.

In the case of any queries, participants may contact the above named student and/or Dr Fiona Lyddy, Department of Psychology, National University of Ireland, Maynooth on the following telephone number: 01 708 4765.

Signed: ________________________________ Participant ______________________ Date

Signed: ________________________________ Researcher ______________________ Date

Appendix Two: Parental Consent Letter

Dear Parents/Guardians,

As part of my doctoral research at the National University of Ireland, Maynooth, I am conducting research to explore skills related to reading in children with learning difficulties.

Primarily, the research consists of a small number of tasks. Each task relates to an area of reading. During this research, I will also be looking at how reading skills, such as the ability to read unfamiliar words, can be introduced for children with learning difficulties. The research would entail a number of short visits to the school and the visits would commence in September 2007.

The research is not designed to be a reading intervention. Rather, the research will be focused on looking at skills which have been identified as important in regards to reading for children.

All of the research tasks have been specifically designed for use with children and have been created to be as fun and educational as possible. Hopefully, this will ensure an enjoyable experience for all of the children involved in the research. Many of the tasks are similar to the types of activities that the children are already familiar with as part of their classroom activities.

A research scholarship from the National University of Ireland, Maynooth has been granted to carry out this research. Furthermore, the research has been approved by the Ethics Committee at the National University of Ireland, Maynooth.

Consent for pupils from (school) to take part in this research has already been kindly obtained from Ms Wynne.

Any data obtained from the research will be treated in the strictest confidence. All participants will remain anonymous throughout the research. Thus, the school or any of the children involved will not be referred to by name at any stage in the research. All identities will be protected to ensure anonymity. Any results or data that are obtained from the research will be compiled as part of a doctoral thesis dissertation for the Psychology department at the National University of Ireland, Maynooth.

I would be very grateful for your consideration about the possibility of your child potentially taking part in this research. Such research plays an extremely important role in terms of developing knowledge regarding how to facilitate and promote reading in children with learning difficulties.

If you are willing to provide your consent for your child to participate in this research, please could you complete the permission slip located below.

Thank you very much for your consideration in this matter.

Yours thankfully,
Catherine Mahon

Permission Slip

Name of child ____

I provide my consent for my child to take part in this research related to reading skills.

Signed ____ Date _________________________