Retraining writing for functional purposes: a review of the writing therapy literature

THIEL, Lindsey, SAGE, Karen <http://orcid.org/0000-0002-7365-5177> and CONROY, Paul

Retraining writing for functional purposes: A review of the writing therapy literature

Lindsey Thiel*[1]

Karen Sage[2]

Paul Conroy[1]

[1]NARU, School of Psychological Sciences, University of Manchester

[2]Bristol Speech and Language Therapy Research Unit, Frenchay Hospital,

University of the West of England

For submission to: Aphasiology

Keywords: brain injury, therapy, stroke, spelling, writing, technology

Short title: Writing therapy review

* Corresponding author: Lindsey Thiel.

Neuroscience and Aphasia Research Unit, School of Psychological Sciences,

University of Manchester, Oxford Road, Manchester, M13 9PL

Email: lindsey.thiel@postgrad.manchester.ac.uk

Acknowledgements:

This work is supported by an ESRC Bursary to Lindsey Thiel.

Abstract

Background: Acquired dysgraphia (impaired writing/spelling skills) can significantly restrict people from participating in social, professional and educational life. Using writing in order to access the internet via computers, tablets and mobiles phones has become an important part of everyday life for people of all ages. Improving writing in people with acquired dysgraphia could facilitate communication, reduce isolation and increase access to information.*Aims:* This review evaluates the writing therapy literature in terms of its usefulness in guiding clinicians in training writing in adults with acquired dysgraphia generally, with specific reference to functional writing activities. The databases Web of Knowledge and Psychinfo were searched for studies evaluating writing therapies for participants with acquired dysgraphia following brain injury. Studies were categorised according to type of treatment (e.g. impairment-based or assistive technology training) and outcome measures (e.g. single words or sentences).

Main Contribution: 62 studies were found. Of these, 54 described impairment-based writing therapies targeting single words or sentences using either lexical or phonological therapies. A small body of 14 studies evaluated the use of assistive writing technologies either alone or in conjunction with an impairment-based therapy. Although all studies reported positive effects of some kind, only 28 measured the effects of therapy on functional or spontaneous writing and only 21 explicitly encouraged the transfer of writing skills to functional tasks.

Conclusions: The writing therapy literature has a dominant tradition of using theoretically-motivated treatments to improve single word writing. It provides limited guidance to clinicians treating functional writing, especially in natural contexts. There may be a specific therapeutic role for assistive technologies which have been as yet largely unexplored in the literature. Furthermore, the cognitive requirements of effective use of assistive technology for dysgraphia warrant research in order to understand which people with dysgraphia may benefit from their use.

Introduction

Dysgraphia is a "disorder of written expression" with "writing skills (that) are substantially below those expected given the person's age, measured intelligence, and age-appropriate education" (DSM IV, American Psychiatric Association, 2000). It often co-occurs with impairments to other language modalities (e.g., naming, auditory comprehension, reading etc.) as one symptom of aphasia (Damasio, 1998), which is a multi-modal language disorder resulting from traumatic brain injury, brain tumour, infection, surgical removal of brain tissue, or most commonly, stroke (Hallowell & Chapey, 2008). Writing is particularly sensitive to brain damage due to its inherent complexity, incorporating linguistic, perceptual and spatial processes (Rapp, 2002).

Spelling disorders have been categorised into syndromes which are used to describe participants with specific clusters of symptoms. For example, individuals with surface dysgraphia present with more reliable regular word and non-word spelling relative to impaired spelling of irregular words (Rapcsak, Henry, Teague, Carnahan & Beeson, 2007), regularisation errors, for example, a word such as *yacht* may be spelt as *yot* (Rapcsak, et al., 2007) and frequency effects, where high frequency words are spelt more accurately than low frequency words (Rapp, 2005). Conversely, phonological dysgraphia (Shallice, 1981) describes a spelling impairment in which performance is better for regular and irregular familiar words than for unfamiliar or non-words (Rapcsak et al., 2007). People with phonological dysgraphia also display lexicality effects in which an attempt to spell an unfamiliar word results in the production of an orthographically similar stored word, for example, *pin* for *plin* (Rapcsak, et al., 2009) and imageability effects, where low imageability words such as *fear* are more difficult to spell than high imageability words such as *pencil* (Whitworth, Webster & Howard, 2005).

Deep dysgraphia shares some characteristics with phonological dysgraphia, such as impaired non-word writing and imageability effects, but is also characterised by semantic errors in writing, where a target word is substituted by a word with a similar meaning or from the same semantic category, such as *apple* for *banana* (Whitworth et al., 2005). Graphemic buffer disorder refers to an impairment of the short-term holding mechanism for lexical representations while writing is planned or executed. Associated symptoms include a length effect, whereby longer words are more difficult to spell, and errors such as letter additions, omissions, transpositions and substitutions (Rapp, 2005). Finally, peripheral dysgraphias include impairments to the processes involved in accessing the appropriate allographs (letter shapes) and to the motor programmes responsible for letters being written or typed (Beeson & Rapcsak, 2002). Many people who present with dysgraphic symptoms do not, however, fit neatly into any one category. According to Beeson and Rapcsak (2002) the subcategories of dysgraphia can be useful for communicating clusters of symptoms, but are best supplemented with descriptions of impaired and preserved processes.

Given the dominance of oral communication in everyday interactions (Nickels, 2002), the treatment of spoken language is often prioritised over written language in the clinical management of aphasia. And yet, for some people, spoken communication impairments may be resistant to treatment and writing may become a more realistic therapy goal (Beeson & Rapcsak, 2002). Writing has many uses in everyday situations (shopping lists, telephone messages, diary entries, greetings cards) as well as for employment (Rapp, 2005). In recent years, written communication through the use of email and the social media (e.g. Facebook, Twitter, instant

messaging, blogs, etc.) has become much more common place. According to a survey of participants with acquired brain injury, email is often preferred to the telephone as a mode of communication for brain injury survivors for several reasons: they can write an email at a time convenient to them; they can take as long as they want in reading, writing and editing and there is less chance of communication breakdown, so intimidating or embarrassing situations can be avoided (Todis, Sohlberg, Hood & Fickas, 2005). Moreover, with the increasing acceptability of spelling errors and abbreviated forms of words within the social media and text messages, there is less pressure for written output to be fully 'correct' in terms of spelling and grammar. Therefore, functional writing i.e. writing for real life purposes, may be a realistic therapy goal for many people with acquired dysgraphia and improving writing skills could provide greater opportunity for returning to employment, education and greater involvement in community life.

This review of the dysgraphia therapy literature aims to answer the following questions:

1. To what extent can the dysgraphia therapy literature guide clinicians in training writing?
2. To what extent can the literature guide clinicians in training writing for functional purposes?

Method

The following key search terms were entered into the databases *Web of Knowledge* and *Psychinfo: spelling, writing, aphasia, dysgraphia, therapy, strategy, assistive,*

email, social media, and *technology*. In a secondary search, additional studies were found in the reference lists of articles from the primary search. Studies were included into the review if they reported a therapy study which aimed to improve some aspect of spelling or writing in adult participants with acquired dysgraphia related to any type of brain injury (stroke, traumatic brain injury, encephalitis, tumour, etc.), except dementia or other neurodegenerative diseases. As this review was primarily interested in linguistic deficits in writing, studies were only included when participants had dysgraphia resulting from an acquired language impairment. There were no restrictions regarding year of publication, number of participants or type of therapy. However, studies were required to be published in English.

The single and multiple case studies were evaluated using the Single-Case Experimental Design (SCED) rating scale (Tate, McDonald, Perdices, Togher, Schultz, & Savage, 2008), an 11 point scale developed for the use of rating the methodological quality of single case designs. The between-subject group studies were evaluated using the PEDro-P scale (PsycBITE, 2014), which is an 11 point rating scale for rating the internal validity of randomised and non-randomised controlled trials.

Results

The above search and filter methods resulted in 62 studies for review with a total of 253 participants. The selected studies are listed in Table 1. The table is organised into sections that reflect the different therapy approaches and targets and the sections of the review. The following information has been included: type of design, rating (on SCED or PEDro-P scales) the number of participants, a description of the

participants (type of brain injury, and/or type and severity of aphasia and dysgraphia), a summary of the treatment method, the treatment target, the presence or absence of a statistical analysis, and the outcome of the treatment being investigated. The papers fell into three distinct categories, as follows:

- Impairment-based (i.e., re-learning based) writing therapies: targeting single words
- Impairment-based writing therapies: targeting sentences
- Training in the use of assistive technologies

The main section of the review will give an overview of each of these categories through descriptions of sample studies, which are intended to be representative rather than exhaustive. The review will conclude with a discussion of whether the writing therapy literature is useful in guiding clinicians to, firstly, improve writing in people with acquired dysgraphia and, secondly, prepare people with dysgraphia to use their writing skills for functional activities (e.g. shopping lists, diary entries, letters, emails, text messages).

[Insert Table 1 about here]

Impairment-based writing therapies

Fifty four studies described impairment-based writing therapies which asked participants to ‘relearn’ pre-morbidly established skills. 49 of these aimed to improve

single word writing, while a small group of 5 studies targeted written sentence production. These will be described in the following two sections.

Targeting single words

The single word impairment-based therapy literature consists of 22 single case studies, 24 multiple case studies and 3 group studies. Participants were described as having a range of aphasia and dysgraphia types and severities, and therapy approaches were informed by extensive assessment of the participant's spelling and language and guided by cognitive neuropsychological models. Outcomes were usually measured using either a spelling to dictation or a written picture naming task. Each of these studies have reported positive outcomes, whether this was with respect to the effects on treated or untreated items or on more general tests of language or communication (e.g. Schwartz et al., 1974). The treatment methods fell into two broad categories: lexical therapies (i.e., whole word writing) or phonological therapies (focusing on sound-to-letter correspondences).

Lexical therapies

Forty one of the fifty four impairment-based therapy studies described lexical therapies, either alone or combined with phonological therapies (see Table 1). The lexical therapies rehearsed accurate spelling of a defined set of therapy targets and

involved repeated exposure to the target word, a strategy which is thought to lower the activation threshold of these orthographic representations in the output lexicon (Beeson & Rapcsak, 2002). One lexical therapy, developed by Beeson (1999) was Anagram and Copy Treatment (ACT) (Ball, de Riesthal, Breeding & Mendoza, 2011; Beeson, 1999; Beeson, Hirsch & Rewega, 2002). ACT involves arranging letters of a target word (with and without foil letters), copying it, and then recalling it. Copy and Recall Treatment (CART) in which a word attached to a labelled picture is copied and then recalled was given as home practice by Beeson (1999); however some studies have used this approach within therapy sessions (e.g. Beeson & Egnor, 2006; Raymer, Cudworth & Haley, 2003; Schmalzl & Nickels, 2006). ACT and CART have been trialled successfully in several studies with participants with impaired orthographic representations (e.g. Beeson, 1999; Raymer, Cudworth, & Haley, 2003) or access to them (e.g. Schmalzl & Nickels, 2006) and participants with global dysgraphia (e.g. Orjada & Beeson, 2005).

Another type of lexical therapy has used mnemonics to aid relearning of target words. A single case study by Schmalzl and Nickels (2006) used mnemonics to improve writing in a participant with impaired orthographic representations as well as a semantic deficit. It was hypothesised that the semantic information provided by mnemonics would facilitate activation of orthographic representations. In two treatment conditions, the participant was instructed to copy high frequency irregular words and then to recall them after a five second delay. One of these conditions incorporated mnemonics and required the participant to recall an image associated with each target word, which was drawn as part of the word on the cue card.

Therapy resulted in significant improvement in spelling of trained words post-therapy and at follow-up assessment only for the mnemonic condition.

Participants in studies evaluating lexical therapies have included those with global dysgraphia (e.g. Beeson et al., 2013; Orjada & Beeson, 2005), phonological dysgraphia (e.g. Beeson et al., 2010; Raymer et al., 2010), surface dysgraphia (e.g. Behrmann, 1987; Rapp, 2005; Weekes & Coltheart, 1996), deep dysgraphia (e.g. Hatfield, 1983; Raymer et al., 2010) and graphemic buffer disorder (e.g. Panton & Marshall, 2008; Rapp, 2005; Sage & Ellis, 2006). They have all reported successful outcomes and in most cases this was for all participants. However, some studies had participants that did not respond to therapy (Beeson et al., 2003; Hatfield & Weddell, 1976; Sugishita et al., 1993). Suggested factors influencing response to therapy have included severity of impairment to cognitive, linguistic or peripheral writing skills (Beeson et al., 2003; Hatfield & Weddell, 1976) and age (Sugishita et al., 1993). Of the 41 studies, 33 used statistical analyses to test for changes across time and all of these showed significant improvements on at least one of their outcome measures (usually spelling accuracy of treated and/or untreated words). Some studies did not report any data for some or all of their participants (Hatfield, 1983; Kapur & Gordon, 1975); therefore, despite positive descriptions of therapy effects, it was not possible to establish to what degree participants had improved.

One disadvantage of this type of therapy is that improvement is usually item-specific (Beeson & Rapcsak, 2002), and effects have generally not been shown to generalise to untreated items. However, 13 of the 41 lexical therapies reviewed showed positive changes to untreated items in at least one of their participants (Ball et al., 2011;

Behrmann, 1987; Deloche et al, 1993; Hillis & Caramazza, 1987; Mortley et al., 2001; Panton & Marshall, 2008; Pound, 1996; Rapp, 2005; Rapp & Kane, 2000; Raymer et al., 2003; Seron et al., 1980; Sugishita et al., 1993; Thiel & Conroy, 2014). Some of these studies have attributed generalisation to the development and use of a strategy (Deloche et al., 1993; Hillis & Caramazza, 1994; Mortley et al., 2001; Pound, 1996), while Behrmann (1987) hypothesised that therapy (a homophone training programme) improved her participant's lexical and visual processing, which benefited untreated items. Interestingly, in eight of these studies the participants who demonstrated improvements to untrained items had symptoms of graphemic buffer disorder. (Mortley et al., 2001 Panton & Marshall, 2008; Pound, 1996; Rapp, 2005; Rapp & Kane; 2002; Raymer, Cudworth & Haley, 2003; Sage & Ellis, 2006; Thiel & Conroy, 2014). Rapp and Kane (2002) hypothesised that their repeated study and delayed copy treatment strengthened the orthographic representations of treated words and also improved the capacity of the graphemic buffer, which led to improvements in spelling untreated words in a participant with graphemic buffer disorder.

Phonological therapies

Fifteen of the fifty four impairment-based studies evaluated phonological therapies, either alone or integrated with lexical therapy techniques (see Table 1). The majority of these involved strengthening sound-to-letter correspondences. These therapies sometimes included the use of key words (which the participant could already spell) to cue a particular letter (e.g. Carlomagno & Parlato, 1989). For example, a participant might be trained to associate the sound /d/ with 'dog', and will then know

that they should write the letter *d*. Other phonological therapy studies have succeeded in improving spelling by training participants in skills such as phonological awareness, i.e. knowledge of the structure of spoken words (Conway et al., 1998), segmentation, the ability to identify which letters or sounds make up a word (Cardell & Chenery, 1999; de Partz, 1995), or through training auditory processing skills (Hatfield & Weddell, 1976).

Participants included in these studies have usually had phonological dysgraphia (e.g. Beeson et al., 2010) or damage to more than one aspect of the writing process (e.g. Greenwald, 2004; Tsapkini & Hillis, 2013). Some studies which have used combined approaches including both lexical and phonological elements have consisted of participants with mixed impairments (Beeson, 2000; Cardell & Chenery, 1999) or surface dysgraphia (Beeson, 2000; de Partz et al., 1992). Similar to lexical therapies, all of the phonological therapy studies have reported successful outcomes (again, usually spelling accuracy of treated and/or untreated words). Of the 13 studies that conducted statistical analyses all reported significant improvements to at least one of their outcome measures. However, not all participants improved. Kiran (2005) reported that one of her three participants did not improve significantly on writing to dictation, oral spelling or written naming, which she hypothesised may have been related to his impaired auditory processing.

Phonological therapies have usually resulted in generalisation to untreated items as the participant learns a strategy within therapy that can be used when writing untrained words. 13 of the 15 phonological studies have reported improvements to untreated words (Beeson et al., 2000; Beeson et al., 2008; Beeson et al., 2010;

Cardell & Chenery, 1999; Carlomagno & Parlato, 1989; Carlomagno et al., 1994; Conway et al., 1998; de Partz et al., 1992; Greenwald, 2004; Hillis & Caramazza, 1994; Kiran, 2005; Luzzatti et al., 2000; Tsapkini & Hillis, 2013). However, one difficulty with training sound-to-letter correspondences is that spelling in this way can be a slow and more laborious process than spelling a word from lexical memory (Greenwald, 2004). Moreover, only words with regular spellings can benefit; therefore, in languages such as English which have a large number of irregular words, many words cannot be treated with this type of therapy (Beeson et al., 2010).

Beeson, Rising, Kim and Rapcsak (2010) sought to overcome this difficulty by measuring the effects of a combined approach. This consisted of phonological therapy and interactive therapy, given to two participants with dysgraphia and dyslexia to improve their phonological processing ability and links between phonology and orthography. Both participants had a phonological impairment that affected their ability to complete reading and writing tasks as well as non-orthographic phonological tasks and displayed more difficulty spelling non-words than words. The first phase of the treatment (phonological treatment) improved sound-to-letter correspondences for vowels and consonants. Among other phonological tasks, a cueing hierarchy was implemented, in which participants were instructed to think of key words for each sound to cue the corresponding letter. Participants were then trained to spell non-words through a process of segmentation, converting sounds to letters, writing and then reading aloud. Interactive treatment provided a problem-solving approach to spelling regular and irregular words. Participants were instructed to use the strategy they had learnt in phonological treatment to generate phonologically plausible spellings, and then to check their spelling based on their residual orthographic knowledge and then finally using an

electronic spelling aid. Following phonological treatment, both participants significantly improved in phonological processing and displayed improved reading and spelling via the sub-lexical route. Moreover, both participants improved their spelling of non-words, including those that were not trained. Only one participant showed statistically significant improvements in spelling untreated regular and irregular words; however, both were significantly more accurate in their spelling compared to pre-treatment when using the electronic speller.

These lexical and phonological therapy studies show that single word spelling can be to some extent remediated in a range of participants, and that in some cases effects can generalise to words not treated in therapy. This not only has positive implications for the clinical management of writing disorders, but also provides important information on the processes involved in relearning linguistic skills. However, many of the studies discussed so far did not investigate, firstly, whether the therapies resulted in improvements to spontaneous writing, and secondly, whether an additional phase of therapy (i.e. a transfer phase) benefited participants after therapy has finished. There were some exceptions to this.

Measuring generalisation to spontaneous writing

Four out of fifty four studies have provided a therapy targeting single words but have also assessed generalisation to spontaneous writing (Carlomagno & Parlato, 1989;

Hillis & Caramazza, 1994; Pound, 1996; Raymer et al., 2003). In each of these studies, changes were measured by asking participants to complete spontaneous writing or picture description tasks. Analysis has involved, for example, counting numbers of errors and comparing these across pre and post intervention samples (Carlomagno and Parlato, 1989). All of these studies reported clinically noteworthy improvements to spontaneous writing, though only Carlomagno & Parlato (1989) included a statistical analysis to show that improvements were significant.

Encouraging transfer to face-to-face conversations

Seven studies evaluated the effects of a spelling therapy with an additional phase to encourage generalisation to functional use of words learnt in therapy for face-to-face conversations (Beeson, 1999; Beeson, Hirsch & Rewega, 2002; Beeson, Rising & Volk, 2003; Clausen & Beeson, 2003; Jackson-Waite, Robson & Pring, 2003; Robson, Marshall, Chiat, & Pring, 2001; Robson, Pring, Marshall, Morrison, & Chiat, 1998). For example, Clausen and Beeson (2003) provided individual and then small group therapy to four participants with severe Broca's aphasia. Individual therapy sessions followed a CART approach which targeted personally relevant vocabulary. In group therapy, participants were encouraged to use their target words in naturalistic group conversations and then in conversations with an unfamiliar person. For all participants, large effect sizes were found for spelling of treated words in group conversations. Moreover, they all demonstrated an enhanced ability to communicate with new people through telegraphic written communication.

Outcome measurement has typically involved counting the number of appropriately used words within structured or unstructured conversations (Beeson, 1999; Clausen

& Beeson, 2003; Robson et al., 1998; Robson et al., 2001) or in response to questions in a questionnaire (Jackson-waite, 2003; Robson et al., 1998). Two studies reported improvements anecdotally without presenting data (Beeson et al., 2002; Beeson et al., 2003). Four of the seven studies targeting conversational writing used statistics to test for improvements (Clausen & Beeson, 2003; Jackson-waite, 2003; Robson et al., 1998; Robson et al., 2001) and all of these found significant changes to functional writing. However, Robson et al., (2001) only found significant gains in a message assessment (measuring communicative use of writing) for one out of three participants.

Encouraging transfer to spontaneous writing

Six studies encouraged participants to generalise therapy gains (often involving use of a strategy such as oral spelling or phoneme-to-grapheme conversion) to more natural writing contexts such as letters, emails and essays (Beeson, Rewega, Vail, & Rapcsak, 2000; de Partz, Seron, & Van der Linden, 1992; Greenwald, 2004; Hillis & Caramazza, 1987; Mortley, Enderby, & Petheram, 2001; Panton & Marshall, 2008). In a single case study of a participant with severe writing difficulties, Mortley, Enderby and Petheram (2001) provided a model-driven therapy in which a compensatory strategy was developed. The participant had a graphemic buffer impairment, but with residual oral spelling skills. Therapy tasks focussed on single word spelling accuracy which included spelling to dictation and oral spelling practice, familiarisation with a computer and keyboard, and then development of a strategy in which the participant orally spelt words and then wrote the word letter-by-letter. He practised the strategy through typing picture names on a computer that provided

feedback and letter choices for errors. The participant was also trained to find words that he could not spell in a dictionary, then to write these words in full sentences and to use these skills for functional writing, such as diary and letter writing. Functional writing was further facilitated through use of predictive writing software on a computer. Therapy led to improved single word spelling of treated and untreated items as well as significant positive changes to all post-therapy writing tasks at immediate and follow-up assessment. The participant also demonstrated the ability to write letters to his daughter, which he could not do before therapy.

Outcome measurement for these studies has included essay or letter writing (Beeson et al., 2000; Mortley et al., 2001), typing sentences in response to questions (Greenwald, 2004), correcting errors in written narratives (Hillis & Carramazza, 1989) and taking notes in response to recorded phone messages (Panton & Marshall, 2008). Some of these studies presented writing samples with descriptive reports (Beeson et al., 2000; Mortley et al., 2001), while others have counted errors corrected (Hillis & Carramazza, 1989) or the number of elements or lexical items included in notes (Panton & Marshall, 2008). Although all of the studies reported improvements, only one (Panton & Marshall, 2001) subjected their data to statistical analysis and found significant changes to note-taking ability.

Methodological Rating

Of the 49 impairment-based therapies targeting single words, 46 were rated using the SCED (Tate et al., 2008) as they were either single or multiple case studies. The ratings ranged from 1 to 11 (highest possible score), with a mean rating of 8 (SD 1.7). All of the studies specified the clinical history of the participant(s). 44 reported

precise and repeated measures. 44 had an ABA or multiple baseline design (24 had a multiple baseline design). 37 were considered to have conducted sufficient baseline sampling. 26 were considered to have sufficient sampling in their treatment phase. 44 reported raw data points. 6 reported inter-rater reliability. 1 included an independent assessor. 38 conducted a statistical analysis. 25 replicated their results across subjects, therapists or settings and 32 provided evidence for generalisation. Therefore, the major weaknesses within this group of studies seem to be related to reliability i.e. not testing for inter-rater reliability or using an independent assessor. A separate count was conducted to establish how many single and multiple case studies included a control condition to ascertain that gains in therapy were in fact due to therapy. 31 out of 49 studies did include a control condition, which usually took the form of assessing performance on untreated items before and after therapy.

The two between-subjects group studies (Pizzamiglio & Roberts, 1967; Schwartz et al., 1974) were rated using the PEDro-P scale (PsycBITE, 2014). They scored 5 and 4 respectively out of a possible 10 (the first point related to external validity and was not counted in the final score). These low ratings reflected the fact that either one or both of the studies did not match groups on baseline scores (Pizzamiglio & Roberts, 1967), did not report randomly allocating participants (Schwartz et al., 1974), did not provide point measures and measures of variability for their groups (Schwartz et al., 1974), and did not conceal allocation (both) or blind subjects, therapists or assessors (both). It is worth noting though, that some of these items (concealing allocation and blinding subjects or therapists) would not have been a realistic option for these therapy studies.

In conclusion, people with acquired dysgraphia can relearn a list of single words targeted in therapy, and in some cases can improve their writing of words that were not practised in therapy. Furthermore, there has been some limited evidence that these therapies can have practical benefits: participants can be trained to use learnt words or spelling strategies to communicate.

Targeting sentences

The frequent co-occurrence of dysgraphia and aphasia means that many people with dysgraphia not only have difficulties with written word retrieval and spelling but also with writing simple or complex phrases and sentences. Five writing therapy studies aimed to improve written syntax (Jacobs & Thompson, 2000; Mitchum, Haendiges, & Berndt, 1993; Murray & Karcher, 2000; Murray, Timberlake & Eberle, 2007; Salis & Edwards, 2010). The syntactic structures targeted included subject-verb (Salis & Edwards, 2010), subject-verb-object (Mitchum et al., 1993; Murray & Karcher, 2000; Salis & Edwards, 2010), object cleft (Jacobs & Thompson, 2000, p.6), passive sentences (Jacobs & Thompson, 2000) and object- and subject extracted embedded who-question sentences (Murray et al., 2007). The studies had either single (4) or multiple (1) case study designs and participants had either non-fluent aphasia (Jacobs & Thompson, 2000; Mitchum, Haendiges, & Berndt, 1993; Murray, Timberlake, and Eberle, 2007), Wernicke's aphasia (Murray & Karcher, 2000) or both expressive and receptive language impairments (Salis & Edwards, 2010).

Salis and Edwards (2010) improved the written production of transitive and intransitive verbs as well as subject-verb (SV) and subject-verb-object (SVO)

sentences in a participant with moderate to severe aphasia and apraxia of speech. The aim was to improve the participant's ability to convey information; therefore, as the participant found it difficult to produce function words (e.g. *the*) she was discouraged from using them. The progressive (*-ing*) form of the verb was targeted for each sentence. Verbs and sentences were targeted simultaneously within sessions with a 'cue and copy' approach to treatment. In each session the participant was first asked to write the verb depicted in a picture and was provided with orthographic cues on failed attempts. The same procedure was then followed for the nouns (for subjects and objects). She was encouraged to use names of friends and family members as the subject of sentences instead of pronouns. The treatment resulted in significantly improved verb and sentence production, although the participant found transitive verbs more difficult than intransitive verbs. Generalisation occurred to some untreated verbs and sentences; however, no generalisation to everyday writing contexts was observed.

All of the written sentence therapy studies reported improvements to trained sentences, with three reporting gains to trained verbs (Mitchum et al., 1993; Murray & Karcher, 2000; Salis & Edwards, 2010). One study demonstrated generalisation to untrained verbs (Salis & Edwards, 2010) and three showed improvements to untrained sentences (Jacobs & Thompson, 2000; Murray et al., 2007; Salis & Edwards, 2010). Two studies used statistical analyses to demonstrate significant improvements on their measures (Mitchum et al., 1993; Salis & Edwards, 2010).

Generalisation to spontaneous writing

Three of these studies have included measures of spontaneous writing (Mitchum, et al., 1993; Murray & Karcher, 2000; Murray, et al., 2007). Using assessments such as picture description and narrative and procedural discourse tasks (e.g., describing how to carry out an everyday task such as making scrambled eggs), they have found that written sentence therapies have led to changes such as significant improvements to syntax, number of lexical verbs and content (Mitchum et al., 1993), a higher number of function words, longer, more grammatical sentences, more substantive verbs and fewer unsuccessful sentences (Murray & Karcher, 2000) and an increase in number of words, correct information units (CIUs), words per minute, CIUs per minute, percentage of CIUs, ratio of open to closed class words and number of substantive verbs (Murray et al., 2007).

Methodological Rating

All of the written sentence therapy studies were rated using the SCED (Tate et al., 2008). The mean rating was 8.2 (SD 0.8) and they ranged from 7 to 9. Of the five studies in this group all specified clinical history, reported precise and repeated measures and had an ABA or multiple baseline design (four had a multiple baseline design), four were considered to have conducted sufficient baseline sampling, four were considered to have sufficient sampling in their treatment phase, all reported raw data points, four reported inter-rater reliability, one included an independent assessor, two conducted a statistical analysis, one replicated their results across subjects, therapists or settings and five provided evidence for generalisation. All of the written sentence therapies had a control condition (either a control set of words or sentences or a control task).

In summary, written sentence therapy studies have provided some evidence that people with aphasia and acquired dysgraphia can not only relearn the spelling of single words but can learn how to construct sentences with them. Furthermore, this type of therapy has had positive effects on spontaneous writing. However, this evidence has been limited by the relative dearth of studies and numbers of participants.

Training in the use of assistive technologies

So far the writing therapy approaches described have involved training writing accuracy for single words, sound-to-letter correspondence rules or sentences. However, distinct from retraining specific sub-skills within writing, it may also be possible to improve written output by compensating for the deficit through the use of supportive computer technologies. Six studies trained participants to use assistive devices (electronic spelling aid, Lightwriter, predictive writing software) to augment the effects of impairment-based therapies (Beeson, Rewega, Vail, & Rapcsak, 2000; Beeson, Rising, Kim, & Rapcsak, 2008, 2010; Jackson-Waite, Robson, & Pring, 2003; Mortley et al., 2001; Murray & Karcher, 2000). In a study by Beeson et al. (2010) participants used an electronic spelling aid to help with self-correction and confirmation of spellings. Although spelling of untreated regular and irregular words only improved significantly for one participant without the spelling aid, both were significantly more accurate in their spelling when using the aid. Similarly, following their verb and sentence therapy, Murray and Karcher's (2000) participant improved on a written discourse task but demonstrated more marked improvements when using word prompt software.

Eight studies evaluated the effects of training people with acquired dysgraphia to use computer technologies to directly compensate for writing difficulties, as opposed to this element being only a part of relearning of writing skills (Armstrong & Macdonald, 2000; Behrns, Hartelius & Wengelin, 2009; Bruce, Edmundson & Coleman, 2003; Estes & Bloom, 2011; King & Hux, 1995; Manasse, Hux & Rankin-Erickson, 2000; Nicholas, Sinotte & Helm-Estabrooks, 2005; Nicholas, Sinotte & Helm-Estabrooks, 2011). Five of these had single case designs and three were multiple case studies. Five technologies were trialled in these studies: voice recognition software (VRS), speech synthesiser software, predictive writing software, spell checker software and C-Speak Aphasia.

Voice recognition software generates text as the user speaks into a microphone attached to a computer (Bruce et al., 2003; Estes & Bloom, 2011; Manasse et al., 2000). It has been trialled in three studies on participants with mild to moderate fluent aphasia, reasonably good reading skills and more severely impaired written language (Bruce et al., 2003; Estes & Bloom, 2011, Manasse et al., 2000), as the aim is to compensate for poor writing skills with more intact spoken language. As well as measuring improvements to the speech recognition accuracy of the software, these studies measured changes to written production, either through composite picture description tasks (Bruce et al., 2003; Estes & Bloom, 2011) or an essay about a chosen topic (Manasse et al., 2000). With the software all participants demonstrated improvements such as increased vocabulary and syntax (Estes & Bloom, 2011; Manasse et al. (2000), more content (Bruce et al., 2003; Estes & Bloom) and longer and more complex texts (Bruce et al., 2003) compared to writing with no support. Bruce et al. (2003) also found that texts were produced more quickly with the software. However, Manasse et al.'s (2000) participant produced less text

with the VRS than by typing, which the authors hypothesised may be due to the software's misperception of her words and extra time needed to correct the spellings. The data in these studies were either analysed qualitatively (Bruce et al., 2003; Estes & Boom, 2011; Manasse et al., 2000) or by comparing, for example, numbers of words or syntactic elements with and without the software (Manasse et al., 2000).

In contrast to VRS, speech synthesiser software, word prediction (or word prompt) software and spell check software are used to facilitate the writing process (rather than being an alternative to writing). Speech synthesiser software provides speech output for any part of a text that the user chooses to highlight (Armstrong & Macdonald, 2000; King & Hux, 1995). This can be a letter, word, sentence or paragraph. Although this was developed to aid reading, it also functions as an editing tool for writing. Predictive writing software provides a list of possible words as letters are typed into the word processor (Armstrong & Macdonald, 2000; Behrns et al., 2009; Mortley et al., 2001; Murray & Karcher, 2000). This list narrows as more letters of the word are typed. The user can select the required word from the list without having to type the entire word. Spell checker software alerts the user to a word that has been incorrectly spelt or to a sentence or phrase that is ungrammatical and suggests alternatives (Behrns et al., 2009). These technologies have been used in three studies to compensate for writing or editing difficulties in participants with mild, moderate and severe non-fluent aphasia (Armstrong & Macdonald, 2000; Behrns, et al., 2009; King & Hux, 1995).

Outcomes of the studies using these technologies have been measured by asking participants to complete single word spelling tests (Armstrong & Macdonald, 2000) or

to write definitions of words (Armstrong & Macdonald, 2000), picture descriptions (Armstrong & Macdonald, 2000) or essays on a chosen topic (Behrns et al., 2009; King & Hux, 1995), both with and without the aid before and after therapy. The written texts produced in these studies were longer (Armstrong & Macdonald, 2000; Behrns et al., 2009), more accurate (Armstrong & Macdonald, 2000; Behrns et al., 2009; King & Hux, 1995) and/or richer in terms of content (Armstrong & Macdonald, 2000) when using the device. Data were either analysed qualitatively (Bruce et al., 2003) or with counts of, for example, numbers of errors or correctly written words (Armstrong & Macdonald, 2000; Behrns et al., 2009; Bruce et al., 2003). In some cases data have been analysed statistically and improvements have been shown to be significant (Behrns et al., 2009; Bruce et al., 2003). However, one of the participants in Behrns et al.'s (2009) study did not improve significantly on any of their outcomes measures.

Finally, C-Speak Aphasia (CSA) is a picture-based, alternative communication computer programme (Nicholas & Elliot, 1998). The user selects icons from semantic categories and creates messages with them which are then spoken by the computer or converted into written words sent by email (Nicholas et al., 2011). In two studies, Nicholas and colleagues evaluated the effects of this programme on the functional spoken and written communication of participants with severe non-fluent aphasia and a range of auditory comprehension and non-verbal cognitive abilities (Nicholas et al., 2005; Nicholas et al., 2011). Five participants in the first study (Nicholas et al., 2005) and ten in the second study (Nicholas et al., 2011) were trained to use the programme over at least six months. The training consisted of three modules in which participants learnt how to use CSA for: generative language (i.e. producing statements, questions, and commands), communicating on the telephone, and communicating via writing and/or email.

Within the writing module participants learned to combine pre-programmed phrases and novel vocabulary via picture selections. These messages could then be converted into text and sent as emails. Outcomes were measured through repeated probing of five communication tasks. The writing task comprised of writing a birthday card and a grocery list. Nicholas et al. (2005) found that three out of five participants communicated more information using CSA than without. However, none of the participants communicated more information on the writing tasks with CSA. In the Nicholas et al. (2011) study, four participants communicated substantially more information in the CSA condition than in their "off-computer" condition. One participant performed better using CSA for the writing task.

Methodological Rating

The SCED (Tate et al., 2008) was used to evaluate all of the assistive technology studies. The ratings ranged from 3 to 10 with a mean of 6.9 (SD 2.5). Of the eight studies in this group, all specified clinical history, seven reported precise and repeated measures, eight had an ABA or multiple baseline design (three had multiple baseline designs), three were considered to have conducted sufficient baseline sampling, six were considered to have sufficient sampling in their treatment phase, six reported raw data points, four reported inter-rater reliability, one included an independent assessor, four conducted a statistical analysis, three replicated their results across subjects, therapists or settings and five provided evidence for generalisation. None of these studies had a control condition to control for any changes that were not due to treatment. However, most compared performance with and without the technology, which controlled for changes to writing not related to technology use.

In summary of this small group of studies evaluating assistive technologies, the findings have suggested that these devices can be useful for some people with aphasia and dysgraphia as they compensate for impairments in written word retrieval, spelling, monitoring and editing and allow for more complex and meaningful messages to be conveyed.

Discussion

This review has aimed to explore the extent to which the dysgraphia therapy literature can guide clinicians in training writing. 62 studies evaluating writing therapies for people with aphasia have been reviewed. The largest group of therapy studies measured the effects of impairment-based lexical therapies targeting single words. These constituted 41 of the reviewed studies and typically involved repeated writing practice of a list of target words. 15 studies included a phonological therapy, which strengthened phoneme-to-grapheme conversion skills. Just 5 studies measured the effects of written sentence therapies. Finally, 14 studies evaluated assistive technologies, either alone or in conjunction with an impairment-based therapy. Overall, 47 studies had single word spelling accuracy as at least one of their targets, while 21 studies had functional writing as a therapy goal and 28 included functional or spontaneous writing as an outcome measure.

Most of the studies in this review were either single or multiple case studies. The SCED rating scale (Tate et al., 2008) was used to evaluate the methodological quality of these studies. Ratings varied substantially, with scores ranging from 1 and 11. The impairment based studies targeting single words or sentences had higher ratings (mean of 8) than the assistive technology studies (mean of 6.9). The main weaknesses in both included not testing

for reliability or including an independent assessor, not including a statistical analysis and not replicating results across different participants, therapists or settings. There is clearly a strong need for more rigour in the implementation of certain aspects of high quality research into the rehabilitation of acquired dysgraphia.

The majority of studies conducted an in-depth assessment and analysis of the participants' language and spelling skills and have shown that participants with a range of linguistic and spelling abilities can achieve positive gains following therapy. Because of the differences in therapy protocols, outcome measures and methods of analyses, it is difficult to synthesise the existing data to derive an impression of outcomes at large group level. However, some useful patterns have emerged, for example that phonological therapies have been effective in retraining phoneme-to-grapheme conversion skills in participants with phonological dysgraphia and that, for participants with all types of dysgraphia, lexical methods such as copy and recall therapy or visual-imagery strategies may be effective. Participants with graphemic buffer disorder have been more able than others to generalise lexical therapy gains to untreated words (Rapp, 2005; Rapp & Kane, 2002; Raymer et al., 2003). Participants with severe and often global aphasia and dysgraphia have been included in therapy studies and have made improvements (e.g. Ball et al., 2011; Beeson et al., 2013; Mortley et al., 2001).

Many of the writing therapy studies have also assessed non-linguistic cognitive skills (Ball et al., 2011; Beeson, 1999; Beeson & Egnor, 2006; Beeson et al., 2013; Beeson et al., 2002; Beeson et al., 2000; Beeson et al., 2010; Beeson et al., 2008; Behrmann, 1987; Brown & Chobor, 1989; Clausen & Beeson, 2003; Conway et al., 1998; de Partz et al., 1992; de Partz, 1995; Greenwald, 2004; Hillis & Caramazza, 1987; Jacobs & Thompson, 2000; Kapur & Gordon, 1975; Manasse et al., 2000; Murray, et al., 2007; Nicholas et al., 2005; Nicholas et

al., 2011; Pound, 1996; Rapp, 2005; Rapp & Kane, 2002; Sage & Ellis, 2006; Salis & Edwards, 2010; Schmalzl & Nickels, 2006; Tsapkini & Hillis, 2013; Weekes & Coltheart, 1996). Beeson et al. (2013) found that their participant performed well on CART and T-CART therapies despite poor performance on the Raven's Coloured Progressive Matrices (Raven, Court & Raven, 1990), a nonverbal test of visual problem solving. In contrast, Beeson et al. (2003) partly attributed their participant's inability to meet criterion levels on treated sets of words following CART therapy to poor performance on visual problem solving abilities and visual span. De Partz et al. (1992) and Schmalzl and Nickels (2006) found that visual imagery strategies led to effective word learning in participants with memory disorders, especially when the participant had a stronger visual than verbal memory.

These case studies highlight that spelling, linguistic and cognitive abilities may well be factors influencing a participant's response to therapy. A substantial gap in the current literature is of larger therapy studies that investigate which patient characteristics are predictive of therapy success and why some individuals do not respond to particular therapies. Information pertaining to measures which may predict likely success in certain therapy domains can be used by clinicians to guide clinical decision-making. In the anomia literature, studies have shown that participant performance in therapy can be predicted from cognitive and/ or linguistic profiles (e.g. Lambon Ralph, Snell, Fillingham, Conroy & Sage, 2010). Most of the writing therapy studies have been single case or small multiple case studies where it has not been possible to conduct correlational analyses to find relationships between participant characteristics and therapy outcomes. Two exceptions were Nicholas et al. (2005; 2011), who found a significant correlation between scores on the Cognitive Linguistic Quick Test (CLQT: Helm-Estabrooks, 2001), a test of nonverbal executive

functioning, and CSA scores, indicating that executive functioning ability is a factor in an individual's ability to use the programme to communicate.

The information available to clinicians on training participants for functional writing is severely lacking. The primary aim of many relearning therapy studies, which have dominated this field, has been to inform models of single word language processing, so transfer to functional, everyday writing has not been a priority. A further reason for this dearth of evidence on functional outcomes could be that there is no standardised and ecologically valid tool for measuring functional writing. On a positive note, however, as well as there being substantial evidence that lexical and phonological therapies can improve writing of treated words and sentences (which could be useful if carefully chosen to be personally relevant), there is some evidence that lexical and phonological writing therapies can lead to improved spelling of untreated words (e.g. Mortley et al., 2001; Panton & Marshall, 2008; Raymer et al., 2003; Luzzatti et al., 2000; Tsapkini & Hillis, 2013). This could mean that treatment participants may notice improvements to everyday writing tasks, at least those that only require single word writing, such as shopping lists. Thirdly, there is a small amount of evidence that impairment-based therapies can lead to improvements to spontaneous writing without a transfer phase (Carlomagno & Parlato, 1989). Finally, both assistive technologies and impairment-based therapies that encourage transfer to functional writing can result in improvements to activities such as essay or letter writing (Beeson et al., 2000; Behrns et al., 2009; King & Hux, 1995; Manasse et al., 2003; Mortley et al., 2001), picture descriptions or narratives (Armstrong & Macdonald, 2000; Bruce et al., 2003; Estes & Bloom, 2011; Mitchum, et al., 1993; Murray & Karcher, 2000; Murray, et al., 2007), note taking (Panton & Marshall, 2008) and writing words to support face to face to face

conversations (Clausen & Beeson, 2003; Jackson-waite, 2003; Robson et al., 1998; Robson et al., 2001).

It is interesting to note that despite the recent and rapid growth of social media, only six of the reviewed studies included internet use or text messaging into their therapy protocols (Beeson et al., 2002; Beeson et al., 2013; Greenwald, 2004; Estes & Bloom, 2011; Nicholas et al., 2005; Nicholas et al., 2011) and only Beeson et al. (2013) and Estes and Bloom (2011) measured changes to writing in these modalities. This could reflect that fact that many of the studies reviewed were conducted between the 1960s and the 1990s, before web and mobile phone based communication became widespread. There is clearly a need for more robust and scientific research measuring the effects of a range of therapies on functional writing and investigating which patients might benefit from certain therapies. Future studies could also explore ways of supporting people with aphasia to use the internet independently so that writing activities such as emailing and using Facebook can be more realistically achieved.

This review has highlighted that there is a considerable gap in the literature regarding the rehabilitative potential of assistive writing technologies such as predictive writing software and spell-check which are widely available and often standard software features without additional costs. These are often email compatible and could support people with aphasia in emailing, blogging, using Facebook and instant messaging (Dietz, Ball, Angel & Griffith, 2011). Other strands of neuro-rehabilitation have already found an established role for technological devices which offer active compensation for cognitive deficits, in particular, electronic memory aids (Fish, Manly, Emslie, Evans & Wilson, 2007; Wilson, Evans, Emslie, & Malinek, 1997; Wilson, Emslie, Quirk, Evans & Watson, 2005). As Nicholas et al. (2005;

2011) found, cognitive skills may be particularly important for use of assistive technologies. Software such as spell-check, for example, requires active control of attention and executive skills through which to monitor errors, consider alternatives and implement correct editing. Other factors that may play a role in success of learning to use assistive technologies include reading, spelling, auditory comprehension or expressive language abilities (Dietz, Ball & Griffith, 2011) as well as motor skills (Manasse et al., 2000), pre-morbid experience with computers and support from others. These need to be explored in future studies.

In conclusion, dysgraphia therapy studies have been predominantly focused on single word spelling accuracy and have been well motivated by models of intact and impaired language processing. There has been some consideration of the importance of cognitive as well as linguistic factors in determining treatment outcomes. The current evidence may be helpful in guiding clinicians to improve writing at the single word level; however, it is currently limited in the extent to which it might provide information on training adults with acquired dysgraphia to use writing for real-life situations. The specific cognitive requirements of active use of writing software, and the deficits which would restrict effective use of these (e.g. in executive and attentional skills) warrants further research. This could allow for very supportive, widely and readily available software to be used as an adjunct to relearning, impairment-focused therapies.

7983

References

Aliminosa, D., McCloskey, M., Goodman-schulman, R., & Sokol, S. M. (1993). Remediation of acquired dysgraphia as a technique for testing interpretations of deficits. *Aphasiology*, *7*(1), 55-69.

American Psychiatric Association (2000). *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV-TR*. Edition 4. American Psychiatric Pub.

Armstrong, L., & MacDonald, A. (2000). Aiding chronic written language expression difficulties: A case study. *Aphasiology, 14*(1), 93-108.

Ball, A. L., de Riesthal, M., Breeding, V. E., & Mendoza, D. E. (2011). Modified ACT and CART in severe aphasia. *Aphasiology, 25*(6-7), 836-848.

Beeson, P. M. (1999). Treating acquired writing impairment: strengthening graphemic representations. *Aphasiology, 13*(9-11), 767-785.

Beeson, P. M., & Egnor, H. (2006). Combining treatment for written and spoken naming. *Journal of the International Neuropsychological Society, 12*(6), 816-827.

Beeson, P., Higginson, K. & Rising, K. (2013). Writing treatment for aphasia: A texting approach. *Journal of Speech, Language, and Hearing Research, 56*, 945–955

Beeson, P. M., Hirsch, F. M., & Rewega, M. A. (2002). Successful single-word writing treatment: Experimental analyses of four cases. *Aphasiology, 16*(4-6), 473-491.

Beeson, P. M., & Rapcsak, S. Z. (2002). Clinical diagnosis and treatment of spelling disorders. In A. E. Hillis (Ed.), *Handbook on adult language disorders: Integrating cognitive neuropsychology, neurology, and rehabilitation* (pp. 101-120). Philadelphia: Psychology Press.

Beeson, P. M., Rewega, M. A., Vail, S., & Rapcsak, S. Z. (2000). Problem-solving approach to agraphia treatment: Interactive use of lexical and sublexical spelling routes. *Aphasiology, 14*(5-6), 551-565.

Beeson, P. M., Rising, K., Kim, E. S., & Rapcsak, S. Z. (2008). A novel method for examining response to spelling treatment. *Aphasiology, 22*(7-8), 707-717.

Beeson, P. M., Rising, K., Kim, E. S., & Rapcsak, S. Z. (2010). A treatment sequence for phonological alexia/agraphia. *Journal of Speech Language and Hearing Research, 53*(2), 450-468.

Beeson, P. M., Rising, K., & Volk, J. (2003). Writing treatment for severe aphasia: Who benefits? *Journal of Speech Language and Hearing Research, 46*(5), 1038-1060.

Behrmann, M. (1987). The rites of righting writing: Homophone remediation in acquired dysgraphia. *Cognitive Neuropsychology, 4*(3), 365-384.

Behrns, I., Hartelius, L., & Wengelin, A. (2009). Aphasia and computerised writing aid supported treatment. *Aphasiology, 23*(10), 1276-1294.

Brown, J. W., & Chobor, K. L. (1989). Therapy with a prosthesis for writing in aphasia. *Aphasiology, 3*(8), 709-715.

Bruce, C., Edmundson, A., & Coleman, M. (2003). Writing with voice: an investigation of the use of a voice recognition system as a writing aid for a man with aphasia. *International Journal of Language & Communication Disorders, 38*(2), 131-148.

Cardell, E., & Chenery, H. (1999). A cognitive neuropsychological approach to the assessment and remediation of acquired dysgraphia. *Language Testing, 16*(3), 353-388.

Carlomagno, S., Iavarone, A., & Colombo, A. (1994). Cognitive approaches to writing rehabilitation. In M. J. Riddoch & G. W. Humphreys (Eds.), *Cognitive Neuropsychology and Cognitive Rehabilitation*. Hillsdale NJ: Lawrence Erlbaum Associates.

Carlomagno, S., & Parlato, V. (1989). Writing rehabilitation in brain damaged adult patients: A cognitive approach. In X. Seron & S. Deloche (Eds.), *Cognitive Approaches in Neuropsychological Rehabilitation* (pp. 179-209). Hillsdale NJ: Lawrence Erlbaum.

Clausen, N. S., & Beeson, P. M. (2003). Conversational use of writing in severe aphasia: A group treatment approach. *Aphasiology, 17*(6-7), 625-644.

Conway, T. W., Heilman, P., Rothi, L. J. G., Alexander, A. W., Adair, J., Crosson, B. A. & Heilman, K. M. (1998). Treatment of a case of phonological alexia with agraphia using the Auditory Discrimination in Depth (ADD) Program. *Journal of the International Neuropsychological Society, 4*(6), 608-620.

Damasio, A. (1998). Signs of Aphasia. In M. J. Sarno (Ed.) *Acquired Aphasia* (3rd ed.) (pp.25-42). San Diego: Academic Press.

de Partz, M. P. (1995). Deficit of the graphemic buffer: Effects of a written lexical segmentation strategy. *Neuropsychological Rehabilitation, 5*(1-2), 129-147.

de Partz, M. P., Seron, X., & Vanderlinden, M. (1992). Reeducation of a surface dysgraphia with a visual-imagery strategy. *Cognitive Neuropsychology, 9*(5), 369-401.

Deloche, G., Dordain, M., & Kremin, H. (1993). Rehabilitation of confrontation naming in aphasia: Relations between oral and written modalities. *Aphasiology, 7*(2), 201-216.

Dietz, A., Ball, A. & Griffith, J. (2011). Reading and writing with aphasia in the 21st century: Technological applications of supported reading comprehension and written expression. *Topics in Stroke Rehabilitation, 18*(6), 758-769.

Estes, C., & Bloom, R. L. (2011). Using voice recognition software to treat dysgraphia in a patient with conduction aphasia. *Aphasiology, 25*(3), 366-385.

Fish., J., Manly, T,, Emslie, H., Evans, J. & Wilson, B. (2007). Compensatory strategies for acquired disorders of memory and planning: Differential effects of a paging system for patients with brain injury of traumatic versus cerebrovascular aetiology. *Journal of Neurology, Neurosurgery and Psychiatry, 79*(8), 930-935.

Greenwald, M. (2004). "Blocking" lexical competitors in severe global agraphia: A treatment of reading and spelling. *Neurocase, 10*(2), 156-174.

Hallowell, B. & Chapey, R. (2008). Introduction to Language Intervention Strategies in Adult Aphasia. In R. Chapey (Ed.) *Language Intervention Strategies in Aphasia and Related Neurogenic Communication Disorders* (5th ed.) (pp. 3-19). Philadelphia: Lippincott Williams & Wilkins.

Hatfield, F., & Weddell, R. (1976). Retraining in writing in severe aphasia. Y. Lebrun & R. Hoops (Ed.). *Neurolinguistics, Vol. 4. Recovery in Aphasics.* Proceedings of an International Conference. Brussels, Belgium, April 21-23, 1975. 270p. Illus. Swets and Zeitlinger B. V.: Amsterdam, Netherlands. (Dist. in U.S.a. by Humanities Press, Atlantic Highlands, N.J.). Isbn 90-265-0228-1, 65-78.

Hatfield, M. (1983). Aspects of acquired dysgraphia and implication for re-education. In C. Code & D. Miller (Eds.), *Aphasia Therapy*. London: Edward Arnold Publisher.

Helm-Estabrooks, N. (2001). *Cognitive Linguistic Quick Test (CLQT): Examiners Manual.,* San Antonio, Texas: Psychological Corporation.

Hillis, A., & Caramazza, A. (1987). Model-driven remediation of dysgraphia. In R. H. Brookshire (Ed.), *Clinical Aphasiology* (pp. 84-105). Minneapolis, Minnesota: BRK Publishers.

Hillis, A.E. & Caramazza, A. (1994). Theories of lexical processing and rehabilitation of lexical deficits. In J. Riddoch & G. Humphreys (Eds.), *Cognitive Neuropsychology and Cognitive Rehabilitation*. London, UK: Lawrence Erlbaum Associates.

Jacobs, B. J., & Thompson, C. K. (2000). Cross-modal generalization effects of training noncanonical sentence comprehension and production in agrammatic aphasia. *Journal of Speech, Language, and Hearing Research, 43*, 5–20.

Jackson-Waite, K., Robson, J., & Pring, T. (2003). Written communication using a Lightwriter in undifferentiated jargon aphasia: A single case study. *Aphasiology, 17*(8), 767-780.

Kapur, N., & Gordon, D. S. (1975). Retraining of dysgraphia: A case study. *Journal of Neurology, Neurosurgery and Psychiatry, 38*(5), 465-468.

King, J., & Hux, K. (1995). Intervention using talking word processing software: An aphasia case study. *Augmentative and Alternative Communication, 11*, 187-192.

Kiran, S. (2005). Training phoneme to grapheme conversion for patients with written and oral production deficits: A model-based approach. *Aphasiology, 19*(1), 53-76.

Lambon Ralph, M.A., Snell, C., Fillingham, J., Conroy, P. & Sage, K. (2010). Predicting the outcome of anomia therapy for people with aphasia post CVA: Both language and cognitive status are key predictors. *Neuropsychological Rehabilitation, 20,* 289-305.

Luzzatti, C., Colombo, C., Frustaci, M., & Vitolo, F. (2000). Rehabilitation of spelling along the sub-word-level routine. *Neuropsychological Rehabilitation, 10*(3), 249-278.

Manasse, N. J., Hux, K., & Rankin-Erickson, J. L. (2000). Speech recognition training for enhancing written language generation by a traumatic brain injury survivor. *Brain Injury, 14*(11), 1015-1034.

Mitchum, C. C., Haendiges, A. N., & Berndt, R. S. (1993). Model-guided treatment to improve written sentence production: A case study. *Aphasiology, 7*(1), 71-109.

Mortley, J., Enderby, P., & Petheram, B. (2001). Using a computer to improve functional writing in a patient with severe dysgraphia. *Aphasiology, 15*(5), 443-461.

Murray, L. L., & Karcher, L. (2000). A treatment for written verb retrieval and sentence construction skills. *Aphasiology, 14*(5-6), 585-602.

Nicholas, M., & Elliott, S. (1998). *C-Speak Aphasia: A Communication System for Adults with Aphasia*. Solana Beach, CA: Mayer-Johnson Co.

Murray, L. L., Timberlake, A., & Eberle, R. (2007). Treatment of underlying forms in a discourse context. *Aphasiology, 21*, 139–163.

Nicholas, M., & Elliott, S. (1998). C-Speak Aphasia: A Communication System for Adults with Aphasia. Solana Beach, CA: Mayer-Johnson Co.

Nicholas, M., Sinotte, M. P., & Helm Estabrooks, N. (2005). Using a computer to communicate:Effect of executive function impairments in people with severe aphasia. Aphasiology,19(10–11), 1052–1065.

Nicholas, M., Sinotte, M.P., Helm-Estabrooks, N. (2011). C-Speak Aphasia alternative communication program for people with severe aphasia: Importance of executive functioning and semantic knowledge. *Neuropsychological Rehabilitation, 21*(3), 322-366.

Nickels, L. (2002). Theoretical and methodological issues in the cognitive

neuropsychology of spoken word production. *Aphasiology, 16*(1/2), 3-19.

Orjada, S. A., & Beeson, P. M. (2005). Concurrent treatment for reading and spelling in aphasia. *Aphasiology, 19*(3-5), 341-351.

Panton, A., & Marshall, J. (2008). Improving spelling and everyday writing after a CVA: A single-case therapy study. *Aphasiology, 22*(2), 164-183.

Pizzamiglio, L., & Roberts, M. (1967). Writing in aphasia: A learning study. *Cortex, 3*, 250-257.

Pound, C. (1996). Writing remediation using preserved oral spelling: A case for separate output buffers. *Aphasiology, 10*(3), 283-296.

PsycBITE (2014). *The PsycBITE Rating Scales*. [Online]. [Accessed 12.6.2014]. Available from http://www.psycbite.com/page.php?id=10

Rapcsak, S.Z., Beeson, P.M., Henry, M.L., Leyden, A., Kim, E., Rising, K., Andersen, S. & Cho, H. (2009). Phonological dyslexia and dysgraphia: cognitive mechanisms and neural substrates. *Cortex, 45,* 575-591.

Rapcsak, S.Z., Henry, M.L., Teague, S.L., Carnahan, S.D. & Beeson, P.M. (2007). Do dual-route models accurately predict reading and spelling performance in individuals with acquired alexia and agraphia? *Neuropsychologia, 45*, 2519–2524.

Rapp, B. (2002).Uncovering the Cognitive Architecture of Spelling. In A. Hillis (Ed.), *The Handbook of Adult Language Disorders: Integrating Cognitive Neuropsychology, Neurology, and Rehabilitation* (pp. 47-69). Philadelphia: Psychology Press.

Rapp, B. (2005). The relationship between treatment outcomes and the underlying cognitive deficit: Evidence from the remediation of acquired dysgraphia. *Aphasiology, 19*(10-11), 994-1008.

Rapp, B., & Kane, A. (2002). Remediation of deficits affecting different components of the spelling process. *Aphasiology, 16*(4-6), 439-454.

Raven, J.C., Court, J.H. & Raven, J.C. (1990). Manual for Raven's Progressive Matrices and Vocabulary Scales - Section 2: Coloured Progressive Matrices. Oxford: Oxford Psychologists Press.

Raymer, A., Strobel, J., Prokup, T., Thomason, B., & Reff, K.L. (2010). Errorless versus errorful training of spelling in individuals with acquired dysgraphia. *Neuropsychological Rehabilitation, 20*(1), 1-15.

Raymer, A. M., Cudworth, C., & Haley, M. A. (2003). Spelling treatment for an individual with dysgraphia: Analysis of generalisation to untrained words. *Aphasiology, 17*(6-7), 607-624.

Robson, J., Marshall, J., Chiat, S., & Pring, T. (2001). Enhancing communication in jargon aphasia: A small group study of writing therapy. *International Journal of Language & Communication Disorders, 36*(4), 471-488.

Robson, J., Pring, T., Marshall, J., Morrison, S., & Chiat, S. (1998). Written communication in undifferentiated jargon aphasia: A therapy study. *International Journal of Language & Communication Disorders, 33*(3), 305-328.

Sage, K., & Ellis, A. W. (2006). Using orthographic neighbours to treat a case of graphemic buffer disorder. *Aphasiology, 20*(9-11), 851-870.

Salis, C., & Edwards, S. (2010). Treatment of written verb and written sentence production in an individual with aphasia: A clinical study. *Aphasiology, 24*(9), 1051-1063.

Schechter, I., Bar-Israel, J., Ben-Nun, Y., & Bergman, M. (1985). The phonemic analysis as a treatment method in dysgraphic aphasic patients. *Scandinavian journal of rehabilitation medicine. Supplement, 12*, 80-83.

Schmalzl, L., & Nickels, L. (2006). Treatment of irregular word spelling in acquired dysgraphia: Selective benefit from visual mnemonics. *Neuropsychological Rehabilitation, 16*(1), 1-37.

Schwartz, L., Nemeroff, S., & Reiss, M. (1974). An investigation of writing therapy for the adult aphasic: The word level. *Cortex, 10*(3), 278-283.

Seron, X., Deloche, G., Moulard, G., & Rousselle, M. (1980). Computer-based therapy for the treatment of aphasic subjects with writing disorders. *Journal of Speech and Hearing Disorders, 45*(1), 45-58.

Shallice, T. (1981). Phonological agraphia and the lexical route in writing. *Brain, 104*, 413-429.

Sugishita, M., Seki, K., Kabe, S., & Yunoki, K. (1993). A material-control single-case study of the efficacy of treatment for written and oral naming difficulties. *Neuropsychologia, 31*(6), 559-569.

Tate, R. L., McDonald, S., Perdices, M., Togher, L., Schultz, R., & Savage, S. (2008). Rating the methodological quality of single-subject designs and n-of-1 trials: Introducing the Single-Case Experimental Design (SCED) Scale. Neuropsychological Rehabilitation, 18(4), 385–401.

Thiel, L. & Conroy, P. (2014). A comparison of errorless and errorful therapies for dysgraphia after stroke. *Neuropsychological Rehabilitation, 24* (2), 172-201.

Todis, M., Sohlberg, M., Hood, D. & Fickas, S. (2005). Making electronic mail accessible: Perspectives of people with acquired cognitive impairments, caregivers and professionals. *Brain Injury, 19*(6), 389-401.

Tsapkini, K., Hillis, A. (2013). Spelling intervention in post-stroke aphasia and primary progressive aphasia. *Behavioural Neurology, 26*, 55-66.

Weekes, B., & Coltheart, M. (1996). Surface dyslexia and surface dysgraphia: Treatment studies and their theoretical implications. *Cognitive Neuropsychology, 13*(2), 277-315.

Wilson, B., Emslie, H., Quirk, K., Evans, J., Watson, P. (2005). A randomized control trial to evaluate a paging system for people with traumatic brain injury. *Brain Injury , 19,* 891-894.

Wilson, B., Evans, J., Emslie, H. & Malinek, V. (1997). Evaluation of NeuroPage: A new memory aid. *Journal of Neurology, Neurosurgery and Psychiatry, 63,* 113-115.

Whitworth, A, Webster, J, & Howard, D (2005). *A Cognitive Neuropsychological Approach to Assessment and Intervention in Aphasia: A Clinician's Guide***.** Hove: Psychology Press.

Table 1. Summary of writing therapy studies

(Listed in alphabetical order according to first author)

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
Impairment-based therapy studies targeting single words: Lexical therapies	Aliminosa, McCloskey, Goodmanschulman, & Sokol (1993)	Single case	7	1	Left CVA; aphasia; acquired dysgraphia	Delayed copying and spelling to dictation	Single word spelling	✓	Improvement to trained words (statistics not reported for this measure). No significant improvement to untrained set
	Ball, de Riesthal, Breeding, & Mendoza (2011)	Multiple case	9	3	Left CVA.1: severe global aphasia; 2: global aphasia 3: severe conduction aphasia	ACT and CART with spoken repetition	Spoken and written naming of single words	x	Improved written naming of trained words but not spoken naming of trained words. Improved written naming of untrained items in 1 participant.
	Beeson (1999)	Single case	7	1	Left CVA; Wernicke's aphasia; severe dysgraphia due to degraded orthographic representations, a phonological processing deficit and possible graphemic	ACT and CART	Written naming and functional use of words in conversation	✓	Improved written naming of trained words (not analysed statistically); no significant improvement to delayed copy of untreated words; increased use of

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
				buffer disorder				writing to support conversational interactions
Beeson & Egnor (2006)	Multiple case	8	2	Severe dysgraphia1: Left CVA; conduction aphasia; global dysgraphia 2. Left frontal and brainstem aneurysms and a subarachnoid haemorrhage; anomic aphasia; global dysgraphia	CART with spoken repetition vs. only spoken repetition	Spoken and written naming of single words	✓	Large effect sizes for written and spoken naming of trained words following CART with repetition; gains in spoken naming only following repetition therapy
Beeson, Higginson & Rising (2013)	Single case	8	1	Left CVA; Broca's aphasia; global dysgraphia	CART and T-CART: a texting version of CART	Spelling and oral naming of single words	✓	Small effect sizes for spelling and spoken naming following CART; small to medium effect size for spelling and a small effect size for spoken naming following T-CART (trained items). Spelling performance declined significantly at follow-up.
Beeson, Hirsch, & Rewega	Multiple case	7	4	Severe dysgraphia 1: Left CVA; global aphasia 2: Left CVA;	ACT and CART including some functional writing	Single word spelling and functional writing	x	Improved spelling of trained words; increased use of

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
(2002)				global aphasia 3: Left CVA; non-fluent aphasia 4: haemorrhagic stroke; Broca's aphasia.	training			writing for communication (e.g. email or face-to-face conversations) observed for all participants
Beeson, Rising, & Volk (2003)	Multiple case	8	8	Left CVA and severe aphasia and dysgraphia; 7: Broca's aphasia 1: Wernicke's aphasia	CART and written conversation training	Written naming and conversational use of target words	✓	Large effect sizes in written naming of trained items for 6 participants; small effect size for one participant and no effect for one participant; observations of use of target words in conversations
Behrmann (1987)	Single case	8	1	Left CVA; conduction aphasia; surface dysgraphia	Homophone retraining programme: pairing with pictorial representation	Spelling of homophone pairs	✓	Significant improvement in spelling trained homophones and untrained irregular words
Brown & Chobor (1989)	Multiple case	7	10	Left CVA; 1: fluent aphasia; 9: non-fluent aphasia	Facilitating writing with the right arm using a limb prosthesis	Writing and other language tasks	x	Improved spelling accuracy and scores on a range of language and non-language tests; better performance

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
								with right hand than left
Clausen & Beeson (2003)	Multiple case	9	4	Left CVA; severe Broca's aphasia	CART and group treatment	Single word spelling and functional use of words in conversation	✓	Significant improvement to spelling of trained words following individual and group treatment; large effect sizes for all participants on spelling of treated words used in the group setting
Deloche, Dordain, & Kremin (1993)	Multiple case	8	2	Meningeal haemorrhage 1: surface dysgraphia 2: conduction aphasia	Written naming treatment with computer-delivered cues	Spoken and written naming	✓	Significant improvement in written naming of trained and untrained words and in spoken naming; effects maintained one year post-therapy
de Partz (1995)	Single case	6	1	Left CVA; deep dysphasia; graphemic buffer disorder	Delayed copy and lexical segmentation strategy	Single word spelling	✓	Significant improvement of trained words; significantly better performance on decomposable words
Hatfield (1983)	Multiple case	2	4	3: deep dysgraphia (2 with left CVA; 1 with TBI) 1: surface dysgraphia	Deep dysgraphia: Training function word spelling using key words,	Deep dysgraphia: function word spelling; Surface dysgraphia:	x	Improved spelling accuracy of trained words; improved

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
					(subarachnoid haemorrhage and fluent aphasia)	homophones and quasi-homophones. Surface dysgraphia: explanations; key-words	doubling of consonants; single word spelling		consonant doubling
	Hillis & Caramazza (1987)	Single case	8	1	Left CVA; graphemic buffer disorder	Treating specific spelling of words vs. training a self-correction strategy	Single word spelling accuracy and detection of errors in narrative	x	Improved trained words following both methods; strategy also improved spelling of untrained words and self-correction in written narratives
	Jackson-Waite et al. (2003)	Single case	7	1	Left CVA; jargon aphasia; severe dysgraphia	Anagrams, delayed copy and written naming; facilitation of writing using a Lightwriter	Written naming and functional use of words in conversation	✓	Significantly improved naming of trained words and responded to questions using a Lightwriter
	Kapur & Gordon (1975)	Single case	1	1	Gunshot wound in left posterior parietal area; dysgraphia	Letter writing practice	Accuracy of letter shape	x	Improved letter shapes
	Mortley, Enderby, & Petheram (2001)	Single case	8	1	Left CVA; severe graphemic buffer disorder	Strategy using residual oral spelling skills; word prompt software	Spelling of single words and sentences; functional writing	✓	Significant improvement of untrained single words and generalisation to functional writing (e.g.

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
								letter writing)
Orjada & Beeson (2005)	Single case	9	1	Left CVA; Broca's aphasia; phonological dyslexia; global dysgraphia	CART and ORT	Accuracy and rate of text reading and accuracy of single word spelling	✓	Large treatment effects for spelling of trained words as well as for reading accuracy; small effect size for reading rate
Panton & Marshall (2008)	Single case	7	1	Left CVA; buffer-level impairment	Spelling to dictation, copy and recall and note-taking practice	Writing to dictation of single words and note-writing ability	✓	Significantly improved writing to dictation of trained and untrained words and note taking ability
Pizzamiglio & Roberts (1967)	Group (between subjects)	5	20	Aphasia, predominantly expressive type; 18: thrombotic CVA; 1: haemorrhage; 1: cerebral trauma	Sentence completion and picture naming on a computer with feedback for correct responses. Comparison of treatment every 24 or 48 hours	Written naming and sentence accuracy	✓	Significantly more accurate responses on trained items following the 24 hour condition; all maintained improvements one week after therapy
Pound (1996)	Single case	5	1	Left CVA; mildly anomic; severe dysgraphia (lexicality and length effects and buffer-type errors)	Strategy using residual oral spelling skills	Spelling of single words and sentences	✓	Significantly improved spelling of untrained single words; improved picture description and spontaneous writing

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
Rapp (2005)	Multiple case	9	3	Left CVA 1: orthographic lexicon impairment 2 & 3: graphemic buffer disorder	Spell-study-spell treatment	Single word spelling	✓	Significantly improved trained words, maintained at follow-up; 2 participants with graphemic buffer disorder significantly improved on untrained words
Rapp & Kane (2000)	Multiple case	9	2	Left CVA; moderate dysgraphia; 1. orthographic output lexicon damage 2. graphemic buffer disorder	Delayed copy treatment	Number of letters correct in single words	✓	Significantly improved spelling of trained words; participant with graphemic buffer disorder improved significantly on untrained words
Raymer, Cudworth, & Haley (2003)	Single case	8	1	Left CVA; severe aphasia; damage to orthographic output lexicon and graphemic buffer	CART with decreasing cues	Single word spelling	✓	Significantly improved spelling of trained words and generalisation to untrained words
Raymer, Strobel, Prokup, Thomason, & Reff (2010)	Multiple case	9	4	CVA; 1: mild anomic aphasia; phonological dysgraphia 2: recovered anomic aphasia; severe dysgraphia at levels of buffer, sublexical and orthographic	Errorless and errorful training	Single word spelling	✓	Large effect sizes for trained words following each therapy (three large effect sizes and one medium for both). Advantage of errorful therapy in 3 participants.

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
					processing 3: moderately severe non-fluent aphasia; phonological dysgraphia 4: moderately severe non-fluent aphasia; deep dysgraphia				
	Robson, Marshall, Chiat, & Pring (2001)	Multiple case	7	6	Jargon aphasia 5: CVA 1: CVA and head injury	Written naming therapy (N.6) and message therapy (N.3)	Written picture naming and message production	✓	Improved written naming of trained items (significant for 4 participants) and improved message production (significant for 1 participant); functional use of words in communicative settings
	Robson, Pring, Marshall, Morrison, & Chiat (1998)	Single case	7	1	Left CVA; jargon aphasia	Picture therapy, generalisation therapy and message therapy	Written picture naming and ability to respond to questions and produce messages using targeted words	✓	Significant gains in written picture naming of trained words, in questionnaire responses and in producing messages
	Sage & Ellis (2006)	Single case	6	1	Left CVA; severe graphemic buffer disorder	Direct spelling therapy vs. therapy to orthographic	Single word spelling	✓	Significant improvement to directly trained words,

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
					neighbours of targets (indirect therapy)			maintained at follow-up; significant improvement to indirectly trained words at follow-up
Schmalzl & Nickels (2006)	Single case	7	1	Left temporal damage resulting from herpes simples encephalitis; damage to the semantic system and a deficit in accessing the orthographic output lexicon	CART alone vs. CART with visual mnemonics	Spelling of irregular words	✓	Significant improvement in spelling of trained words following the CART with mnemonic condition only
Schwartz, Nemeroff, & Reiss (1974)	Group (between subjects)	4	14	Left CVA	8 participants: writing and spelling tasks (experimental group); 6 participants: multi-modal therapy (control group)	Scores on Porch Index of Communicative Ability Screen	✓	Experimental group made significantly greater gains than control group
Seron, Deloche, Moulard, & Rousselle (1980)	Multiple case	7	5	3 CVA 1: tumour 1: trauma	Typing words to dictation with feedback from computer for correct responses	Single word spelling	✓	Significantly improved spelling of untrained words

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
	Sugishita, Seki, Kabe, & Yunoki (1993)	Multiple case	6	22	Cerebrovascular lesion in the left hemisphere; aphasia; written and oral naming deficits; 14: Broca's aphasia 4: global aphasia 2: Wernicke's aphasia 7: dyslexia with dysgraphia.	Copy and spoken repetition in two treatments for two different word sets	Written and spoken naming	✓	Significant improvement of written naming of trained words in 9/21 participants in Treatment 1 and 3/14 participants in Treatment 2; significant improvement of oral naming of trained words in 2/6 participants in Treatment 1 and 1/6 participants in Treatment 2.
	Thiel & Conroy (2014)	Multiple case	9	4	1: Severe non-fluent aphasia; graphemic buffer disorder; 2: severe non-fluent aphasia; deep dysgraphia and graphemic buffer disorder; 3: Mild aphasia; phonological dyagraphia and graphemic buffer disorder; 4: fluent aphasia; deep dysgraphia and	Errorful and errorless training	Single word spelling accuracy	✓	Significantly improved spelling accuracy of treated and untreated words following both approaches for all participants. Only one participant showed an advantage of errorless over errorful learning, otherwise no differences between therapies.

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
					graphemic buffer disorder				
	Weekes & Coltheart (1996)	Single case	6	1	TBI; surface dyslexia and dysgraphia	Homophone training using mnemonics	Homophone spelling and reading	✓	Significantly improved spelling and reading of trained homophone pairs
Impairment-based therapy studies targeting single words: Phonological therapies	Beeson, et al. (2000)	Multiple case	8	2	1: Left CVA; mild anomic aphasia; damage to graphemic output lexicon and sublexical spelling route. 2: TBI; mild anomic aphasia; surface dysgraphia	Phonological treatment and use of electronic spelling aid	Single word spelling and text writing	✓	Significantly improved spelling of untrained words; significant reduction of errors in text writing
	Carlomagno & Parlato (1989)	Single case	8	1	Left CVA; mild to moderate aphasia and severe dysgraphia with damaged lexical and P-G routes	Phoneme-to-grapheme segmental conversion and lexical relay strategy	Single word spelling	✓	Significant improvement to spontaneous writing and to spelling of untrained words and non-words, which was maintained 2 months

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
								after training
Conway, et al. (1998)	Single case	7	1	Left CVA; conduction aphasia; mild phonological alexia and mixed dysgraphia	Auditory Discrimination in Depth Programme	Phonological awareness, single word reading, sentence and textual reading and spelling to dictation	x	Large gains in phonological awareness, reading and spelling non-words and reading and spelling untrained words
Greenwald (2004)	Single case	9	1	Left CVA; transcortical motor aphasia; severe global agraphia	Phonological treatment and functional computer tasks including emailing	Single word and sentence spelling	✓	Improved P-G and G-P conversion and spelling of trained and untrained regular and irregular words (not analysed statistically); significant improvement to trained but not untrained sentences and significant improvement on untrained spelling assessment
Hillis & Caramazza (1994)	Multiple case	8	2	Left CVA	Phonological treatment	Single word spelling	x	One participant improved spelling of all words (trained and untrained) and accuracy in narrative. The other only improved on trained

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
								verbs
Kiran (2005)	Multiple case	11	3	Left CVA; impaired lexical and sub-lexical spelling routes; 1: transcortical motor aphasia 2: Broca's aphasia 3: anomic aphasia; deep dyslexia/ dysgraphia	Phoneme to grapheme conversion treatment	Oral naming, oral spelling, written naming and writing to dictation	✓	Significantly improved writing to dictation of trained and untrained words and written naming and oral spelling of trained words for 2 participants. No significant improvements for 1 participant.
Luzzatti, Colombo, Frustaci, & Vitolo (2000)	Multiple case	9	2	Severe Broca's aphasia and severe dysgraphia 1: Left cerebral abscess 2: cerebral haemorrhage	Training identification of phonemes in words and P-G correspondences	Single word spelling	✓	Significantly improved spelling and improved written naming of untrained items
Schechter, Bar-Israel, Ben-Nun, & Bergman (1985)	Group (within subjects)	Not rated**	51	31 CVA and 20 chronic cerebral insufficiency; 5: global aphasia; 15: Broca's aphasia; 12: Wernicke's aphasia; 14: anomic aphasia; 5: conduction aphasia	Phonemic analysis-synthesis treatment: training identification of phonemes in words and drilling P-G correspondences	Performance on subtests from the Israeli Loewenstein Aphasia Test: Phonemic analysis and writing a sentence from dictation	✓	All improved significantly
Tsapkini &	Multiple	9	2 (compared PPA to	1: Left CVA; graphemic buffer	Learning of phoneme-to-	Phoneme-grapheme associations;	✓	Both made significant improvements in

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
	Hillis (2013)	case		stroke aphasia)	disorder and impaired p-g conversion; 2: logopenic PPA impaired in accessing orthographic lexical representations for output, and in p-g conversion	grapheme correspondences with help from key words	phoneme-word associations		trained P-G associations and phoneme-word associations; the participant with stroke aphasia also showed significant improvement to untrained words and good maintenance of all measures at 6 month follow-up.
Impairment-based therapy studies targeting single words: Therapies with lexical and phonological elements	Beeson, et al. (2008)	Multiple case	8	8	Left CVA; 3 x anomic, 3 x conduction; 2 x minimal aphasia. Range of dysgraphia types (phonological, surface and global)	Phonological treatment and interactive treatment (self-generation of phonologically plausible spellings and use of electronic spelling aid)	Spelling of regular and irregular words and non-words	✓	Significantly improved spelling of untrained regular and irregular words, but not non-words.
	Beeson, Rising, Kim, & Rapcsak (2010)	Multiple case	9	2	Left CVA and phonological processing impairment	Phonological treatment and interactive treatment (with electronic	Phonological processing ability and reading and spelling of words	✓	Significantly improved phonological processing and improved spelling and

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
					1. moderate conduction aphasia 2: mild aphasia	spelling aid)	and non-words		reading via the sub-lexical route; significantly improved spelling of untrained regular and irregular words for both participants when using the electronic speller (and for one participant without)
	Cardell & Chenery (1999)	Single case	8	1	Subarachnoid haemorrhage; expressive aphasia; damage to lexical and sub-lexical routes and the graphemic assembly buffer	Segmentation hierarchy for non-words; semantic therapy for low imageability words	Spelling of low imageability words and non-words	✓	Improved writing of trained and semantically related low imageability words and trained and untrained non-words (not analysed statistically); generalisation to related language tasks; significant improvement to a spelling to dictation task.
	Carlomagno, Iavarone, & Colombo (1994)	Multiple case	8	6	Mild to moderate aphasia 4: CVA; 2: surgically treated artero-venous	Phonological treatment and visual-semantic strategy	Single word spelling	✓	Significantly improved spelling (untrained words) following phonological treatment for 3 participants,

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
				malformation				visual semantic treatment for 1 participant and both for 2 participants.
de Partz, Seron, & Vanderlinden (1992)	Single case	7	1	Encephalitis; transcortical sensory aphasia; surface dysgraphia	Phonological treatment and visual imagery strategy	Spelling of regular, irregular and ambiguous words; spontaneous writing	✓	Significantly improved spelling of trained regular words following phonological treatment; significantly improved trained irregular and ambiguous words using visual imagery strategy
Hatfield & Weddell (1976)	Multiple case	6	5	CVA; moderately severe or very severe aphasia	Visual-kinaesthetic memorising (2), auditory analysis (2) and global stimulation (1)	Single word spelling	✓	Significant improvement to trained words in 3 participants (following visual-kinaesthetic memorising or global stimulation). Improved spelling performance in 4 participants. No improvements for 1 participant.

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
Impairment-based therapy studies targeting sentences	Jacobs & Thompson (2000)	Multiple case	9	4	Left CVA; Broca's aphasia; agrammatic	Linguistic Specific Treatment (N.2) and Comprehension training (N.2)	Comprehension and production of complex spoken and written sentences	x	Both treatment methods were effective for training comprehension and production of target sentences. Generalisation to spoken and written sentence production following comprehension training; only generalisation to written sentence production following sentence production training.
	Mitchum, Haendiges, & Berndt (1993)	Single case	7	1	Left CVA; severe non-fluent aphasia	Facilitation of written verb retrieval and facilitation of grammatical frame construction	Written action naming and written sentence production	✓	Significantly improved naming of trained verbs, written sentence production and spoken sentence production and generalisation to spontaneous writing
	Murray & Karcher (2000)	Single case	9	1	Left CVA; moderate Wernicke's aphasia	Cueing hierarchy, word-prompt software and home practice	Verb naming and sentence construction	x	Improved accuracy of trained verbs and SVO sentences; generalisation to

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
								written discourse
Murray, Timberlake & Eberle (2007)	Single case	8	1	Left CVA; agrammatic aphasia	Modified treatment of underlying forms	Written sentence structures	x	Improved accuracy of trained and untrained exemplars of sentences. Generalised improvements to untrained related structures and to spoken production of the same structures. Some improvements to discourse measures.
Salis & Edwards (2010)	Single case	8	1	Left CVA; moderate to severe aphasia .	Written picture naming and description; cue and copy	Written verb naming and sentence accuracy in picture description	✓	Significant improvement of trained transitive and intransitive verbs and SV and SVO sentences and significant improvement to untrained verbs and sentences

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
Assistive technology training	Armstrong & MacDonald (2000)	Single case	4	1	Subarachnoid haemorrhage; LH CVA; Broca's aphasia	Predictive writing and speech synthesiser software; splint to use dominant hand	Single word spelling, written sentences and spontaneous writing	x	Improved spelling and improved quantity and quality of writing
	Behrns, Hartelius, & Wengelin (2009)	Multiple case	10	3	Left CVA and moderate to severe writing difficulties; 1: mild to moderate Broca's aphasia 2: mild Broca's aphasia 3: moderate non-fluent mixed aphasia	Predictive writing or spell check software	Written text accuracy and length	✓	All made improvements to writing; however only 2 made significant improvements
	Bruce, Edmundson, & Coleman (2003)	Single case	3	1	Left CVA; fluent, mild-to-moderate aphasia	Voice recognition software	Written text accuracy and length	x	Quantitative and qualitative improvements to written work; started communicating via email
	Estes & Bloom (2011)	Single case	6	1	Left CVA; conduction aphasia	Voice recognition software	Functional written communication including emailing	x	Improved quality of writing
	King & Hux (1995)	Single case	9	1	Haemorrhagic CVA; mild non-fluent aphasia	Speech synthesiser software	Ability to monitor and correct errors in written texts	✓	Reduction in error rate with and without software (not analysed statistically);

	Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
									improvement in quality of writing and independence in writing. Significant positive change in raters' judgements of writing samples.
	Manasse, Hux, & Rankin-Erickson (2000)	Single case	6	1	Severe TBI; mild cognitive-communication deficits	Voice recognition software	Accuracy in using software and correcting errors; accuracy and length of written texts	x	Learnt to use software and to correct errors quickly; quantitative and qualitative improvements to writing
	Nicholas, Sinotte & Helm-Estabrooks (2005)	Multiple case	8	5	Left CVA; severe non-fluent aphasia	C-Speak Aphasia programme	Amount of meaningful, relevant information each participant expressed on five functional communication tasks (verbal and written)	✓	Three participants communicated more information with CSA than without; CSA did not assist any of the participants with writing tasks.
	Nicholas, Sinotte & Helm-Estabrooks	Multiple case	9	10	Left CVA; severe non-fluent aphasia	C-Speak Aphasia programme	Amount of meaningful, relevant information each participant	✓	Four participants communicated more information with CSA than without; only one participant benefited

Study	*Design*	*Rating**	*Participants*	*Description of participants*	*Treatment method*	*Target*	*Statistical analysis*	*Treatment outcome*
(2011)						expressed on five functional communication tasks (verbal and written)		for the writing tasks.

ACT = Anagram and Copy Treatment, CART = Copy and Recall Treatment, ORT = Oral Reading Treatment, P-G = phoneme-to-grapheme, G-P = grapheme- to-phoneme, SV = subject-verb, SVO = subject-verb-object, TBI = Traumatic Brain Injury, CVA = Cerebrovascular Accident; *Rated using either SCED (Tate et al., 2008) or PEDro-P (PsycBITE, 2014); **Not rated as neither rating scale was appropriate for evaluating the within-subject group study design.