Applying therapies and technologies to the treatment of dysgraphia: combining neuropsychological techniques and compensatory devices to enhance use of writing via the internet

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Abstract

University: The University of Manchester  
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Effective writing rehabilitation for people with acquired dysgraphia following a stroke could lead to more opportunities to communicate, reduce isolation and improve quality of life. Previous research has suggested that both impairment-focused spelling therapies and assistive technologies can support writing rehabilitation, although the strength of the evidence is limited. The central aim of this PhD study was to investigate whether a combined approach to writing therapy, including impairment-based therapies and assistive technologies, could improve the email writing of participants with varying severity of acquired dysgraphia. An email writing assessment was developed for outcome measurement and data from 42 control participants were collated to determine the neuro-typical range of email writing performance on this task. A within-participants, multiple case design was used to evaluate the effects of two different approaches to therapy with participants with dysgraphia. In the first study, two impairment-based therapies (uni-modal and multi-modal) were compared with eight participants with dysgraphia and the effects of these on spelling accuracy of treated and untreated words were measured. The functional outcomes (email writing, written picture description, writing frequency and perception of disability) of these therapies were also investigated in a second study. The third study evaluated the effects of training eight participants with dysgraphia (six of whom had participated in the first two studies) to use an assistive writing technology for functional writing. There was a wide range of performance in neuro-typical participants on email writing, with both age and education emerging as determinants of performance. Within the clinical studies, there were no significant differences between uni-modal and multi-modal therapies with respect to spelling accuracy, but these lexical therapies led to significant improvements to accuracy of treated and untreated words, written picture description and word length within emails. Training and use of assistive writing software resulted in significant improvements in spelling accuracy and word length within emails. All participants with dysgraphia showed some responsiveness to intervention. Both impairment-based and compensatory approaches to writing rehabilitation were found to have benefit, although the effects varied across participants and outcome measures. This study has highlighted the need for further research into assessments and therapies for writing inaphasia, specifically focusing on candidacy for specific approaches to writing rehabilitation.
Declaration

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Related presentations and publications

Parts of the content and text of this thesis appear in the following presentations and publications (listed chronologically):


The author

I obtained a BA (Hons.) in German and Linguistics at the University of Westminster in 2002 and then worked as an English language teacher in Germany for four years. I subsequently studied Speech and Language Therapy at the University of Manchester and qualified as a Speech and Language Therapist in 2010 at which time I was funded by the Economic Social Research Council to undertake a Masters in Research for Psychology and a PhD at the University of Manchester, supervised by Dr. Paul Conroy and Dr. Karen Sage. I am currently working as an adult community speech and language therapist at Bradford District Care Trust.
List of abbreviations

ACT: Anagram and copy treatment (Beeson, 1999)
Adj: Adjective
Adv: Adverb
ASHA: American Speech-Language-Hearing Association
BDAE: Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, & Barresi, 2001)
CADL-2: Communication Abilities of Daily Living (Holland, Frattali & Fromm, 1999)
CART: Copy and recall treatment (Beeson, 1999)
CAT: Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004)
CIATplus: Constraint-induced aphasia therapy (Attard, Rose & Lanyon, 2013)
CIU: Correct information units
CLQT: Cognitive Linguistic Quick Test (Helm-Estabrooks, 2001)
CSA: C-Speak Aphasia
CVA: Cerebrovascular accident
Exclam: Exclamation
FACS: Functional Assessment of Communication Skills for Adults (Frattali, Holland, Thompson, Wohl & Ferketic, 1995)
GBD: Graphemic buffer disorder
G-P: Grapheme to phoneme (conversion)
ICF: International classification of functioning (WHO, 2015)
LH: Left hemisphere
M: Mean
M-MAT: Multi-Modality Aphasia Treatment (Attard, Rose & Lanyon, 2013)
N: Noun
OANB: Object and Action Naming Battery (Druks & Masterson, 2000)
ONS: Office for National Statistics
ORT: Oral Reading Treatment (Orjada & Beeson, 2005)
PALPA: The Psycholinguistic Assessments of Language Processing in Aphasia (Kay, Lesser & Coltheart, 1992)

PEDro-P scale: Physiotherapy Evidence Database Scale adapted for PsycBITE (Perdices, Savage, Tate, McDonald, & Togher, 2009)

P-G: Phoneme to grapheme (conversion)

PICA: Porch Index of Communicative Ability (Porch, 1971)

PPA: Primary progressive aphasia

PPT: Pyramids and Palm Trees Test (Howard & Patterson, 1992)

SCED: Single-Case Experimental Design rating scale (Tate, McDonald, Perdices, Togher, Schultz, & Savage, 2008)

SD: Standard deviation

SV: Subject, verb (sentence)

SVO: Subject, verb, object (sentence)

TBI: Traumatic brain injury

T-CART: Text message copy and recall treatment (Beeson, Higginson & Rising, 2013)


V: Verb

VRS: Voice recognition software

WAB: Western Aphasia Battery (Kertesz, 1982)

WHO: World Health Organisation
Chapter 1. Introduction

This introductory chapter will provide a background to the thesis. The term *acquired dysgraphia* will be defined. The processes involved in neuro-typical spelling will be described and the methods of assessing acquired dysgraphia will be briefly outlined. This will then lead onto motivations for treating acquired dysgraphia and a short overview of existing treatment approaches. The chapter will conclude with the study design, research questions and an outline of the thesis structure and content.

1.1 Acquired dysgraphia

The term *acquired dysgraphia* describes an acquired impairment in writing skills (Weekes, 2005). It commonly occurs as a symptom of aphasia (Damasio, 1998), which is a multi-modal language disorder resulting from neurological conditions including stroke, traumatic brain injury, brain tumour, infection or surgical removal of brain tissue (Hallowell & Chapey, 2008). Dysgraphia can present in varying severities, from occasional spelling errors to major difficulty writing single words and sentences.

1.2 The processes involved in intact neuro-typical spelling

The complex task of spelling a word has been represented in cognitive models of language processing. The traditional dual-route models of spelling (e.g. Ellis & Young, 1988, 1996; Whitworth, Webster & Howard, 2005) outline two different routes for spelling to dictation (see Figure 1). The lexical-semantic (word meaning) route is used to access representations of familiar regular and irregular words from the orthographic output lexicon via semantics after phonological representations of words have been accessed in the phonological input lexicon (Beeson & Rapcsak, 2002). This route cannot access
spellings of non-words or unfamiliar words (for example, the word wii, representing a computer game system, was a ‘new’ word to the English language a few years ago in terms of this meaning and spelling) as they have not been previously stored as representations (Rapcsak, Henry, Teague, Carnahan & Beeson, 2007). Unfamiliar words and non-words (e.g. kib) are produced via the phonological (or non-lexical) route (from auditory phonological analysis to the graphemic buffer via phonological assembly), which converts phonemes into graphemes via sound to spelling correspondence rules (Rapcsak et al., 2007). Irregular words would be spelt incorrectly (e.g. trough would become trof) via this route. In the case of writing the word in response to an object, copying a written word or self-generation of a word (without a stimulus), the orthographic representation would again be retrieved from the orthographic output lexicon via the semantic system. However, when copying, words can be written by an alternative route from the orthographic input lexicon directly to the orthographic output lexicon that does not require semantic activation.

Once the orthographic string has been accessed by any of these routes, it is held in a short-term holding mechanism (graphemic buffer or orthographic output buffer) while the individual letter shapes are assigned (Hillis & Heidler, 2005; Rapp, 2005). These are then produced by the appropriate motor systems (Rapp, 2005). This type of model has been used both in research and clinically to guide the assessment and treatment of spelling disorders.

Dual-route models predict that spelling is a sequential process and that dysgraphia is caused by damage to spelling-specific components (Rapcsak, Beeson, Henry, Leyden, Kim, Rising, Andersen & Cho, 2009), with the exception of the semantic system which is shared across language processes. In contrast, connectionist models, such as the “triangle” model (Plaut, McClelland, Seidenberg & Patterson, 1996, Figure 2) posit that
reading and spelling impairments stem from impairments to semantics, phonology and/or orthography and, importantly, the interactions between these, which would also have an effect on other language tasks, such as naming and repetition. The “primary systems” hypothesis predicts that impairments in all language tasks arise because of damage to one or more of the three interacting primary systems: semantics, phonology and orthography (Patterson & Lambon Ralph, 1999). Proponents of this type of model argue that it is unlikely that reading and spelling depend on modality-specific cognitive components, firstly, because reading and spelling are acquired after other language skills have developed and require explicit instruction, and, secondly, because reading and spelling impairments rarely occur without impairments to other language domains (Patterson & Lambon Ralph, 1999). Although connectionist models have yet to be used to a great extent clinically, they can be used to simulate learning and design rehabilitation (Plaut, 1996; Welbourne & Lambon Ralph, 2005).
Figure 1. Lexical processing model: spelling routes (adapted from Ellis & Young, 1996 and Whitworth, Webster & Howard, 2005)
1.3 The classification of types of acquired dysgraphia

Spelling disorders have been categorised into syndromes which are used to describe participants with specific clusters of symptoms. For example, individuals with surface dysgraphia (first described by Beauvois and Dérousné, 1981) present with more reliable regular word and non-word spelling relative to spelling of irregular words (Rapcsak et al., 2007). A dual-route model hypothesises that when the lexical-semantic route is damaged stored representations cannot be accessed, which results in surface dysgraphia (Rapcsak, et al., 2007). Therefore, the phonological route has to be relied on for spelling, and regularisation errors occur, for example, a word such as *circus* may be spelt as *serkus* (Rapcsak, et al., 2007). Frequency effects, where high frequency words are spelt more accurately than low frequency words, are also associated with surface dysgraphia, as the orthographic output lexicon is sensitive to frequency (Rapp, 2005). Connectionist models have attributed surface dysgraphia and dyslexia to impaired semantic representations (Plaut et al., 1996) or reduced strength between semantic and phonological
representations (Patterson & Lambon Ralph, 1999), and therefore an inability to access the word form from its meaning. Woollams, Lambon Ralph, Plaut & Patterson (2007) showed that symptoms of surface dyslexia were displayed in participants with semantic dementia and were able to simulate these surface features in a computational model which disrupted semantic activation.

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). According to dual-route models, the cause of this impairment is a damaged phonological (non-lexical) route, thereby preventing the use of sound-to-spelling correspondence rules (Rapcsak et al., 2007). This leads to an over-reliance on the lexical-semantic route and a lexicality effect in which an attempt to spell an unfamiliar word results in the production of an orthographically similar stored word, for example, soap for soaf (Rapcsak, et al., 2009). Furthermore, spelling in phonological dysgraphia is often characterised by imageability effects, where low imageability words such as think are more difficult to spell than high imageability words such bread (Whitworth, Webster & Howard, 2005). Within a connectionist framework, this syndrome arises from impaired phonology (Patterson & Lambon Ralph, 1999), which has been supported by studies where participants with phonological dyslexia and dysgraphia also performed poorly on phonological tasks (Friedman, 1996, Crisp & Lambon Ralph, 2006; Rapcsak et al., 2009).

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 lion for tiger (Whitworth et al., 2005). Dual-route models predict that these symptoms are the result of both impaired lexical-semantic and phonological routes (Beeson &
Within a connectionist framework, deep dyslexia and dysgraphia are attributed to semantic and phonological deficits combined (Crisp & Lambon Ralph, 2006). Phonological dyslexia, dysgraphia and dysphasia are on a severity continuum with deep dyslexia, dysgraphia and dysphasia, where participants can present these symptom profiles in all output modalities (reading, writing and speaking) (Crisp & Lambon Ralph, 2006; Jefferies, Sage & Lambon Ralph, 2007; Behrns, Ahlsén & Wengelin, 2010).

The syndrome profiles that have been described so far (surface, phonological and deep dysgraphias), are caused by underlying linguistic deficits and are typically called ‘central’ dysgraphias (Ellis & Young, 1988). Problems can also occur to the post lexical, ‘peripheral’ parts of the spelling process which can still be detrimental to everyday writing. For example, graphemic buffer disorder (first described by Miceli et al., 1985) 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). Other 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. Additionally, other symptoms of stroke such as visual or motor impairments (e.g. deficits in fine motor skills required for using a pen or keyboard) that are also likely to impact on an individual’s writing ability must be considered when...
investigating the writing skills of individuals with aphasia resulting from a stroke.

1.4 The assessment of acquired dysgraphia

Assessments for evaluating writing skills in adults with acquired communication disorders are usually included in aphasia assessment batteries, such as the Boston Diagnostic Aphasia Examination (BDAE; Goodglass, Kaplan, & Barresi, 2001) the Western Aphasia Battery (WAB; Kertesz, 1982) and the Comprehensive Aphasia Test (CAT; Swinburn, Porter & Howard, 2004). These assessments are generally comprised of subtests such as letter or word copying and transcoding tasks to determine whether the patient has any peripheral writing difficulties, i.e. visual or motor impairments that affect their ability to produce correctly formed letter shapes. They typically also include tasks in writing to dictation and written picture naming of single words to establish whether participants can access orthographic representations (or use phoneme to grapheme conversion mechanisms) to write single words. Finally, there is, in most cases, a written picture description task to assess skills in writing words, phrases or sentences in a less constrained context. The information acquired in writing subtests then contributes to an overall profile of a participant’s language abilities and difficulties. The Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 1992) include spelling to dictation subtests that have been carefully devised with words with specific psycholinguistic characteristics so that clinicians can establish whether individuals have, for example, particular difficulties with low imageability, low frequency or exception words. These can be helpful in diagnosing dysgraphia types (see 1.2.2.).

Standardised aphasia assessments that evaluate functional communication skills such as the Functional Assessment of Communication Skills for Adults (ASHA FACS, Frattali, Holland,
Thompson, Wohl & Ferketic, 1995) and Communication Abilities of Daily Living (CADL-2, Holland, Frattali & Fromm, 1999) comprise more ecologically valid writing tasks such as completing forms and writing lists. Finally, writing is included into self-rating scales that measure an individual’s perception of their disability, for example the Comprehensive Aphasia Test Disability Questionnaire (Swinburn, et al., 2004), which asks how easy it is for that person to write in different contexts.

In contrast to standardised and particularly linguistic writing assessments, Parr (1992; 1995; 1996) advocated a social, patient-centred approach to reading and writing assessment, which focuses on the context and purpose of reading or writing rather than the cognitive and linguistic aspects. In an interview study (Parr, 1992), fifty healthy control participants were asked to rate reading and writing activities in terms of frequency and importance. When activities were then ranked using an index of importance, the highest ranking activities represented just a small percentage of each person’s total activities due to their large range of everyday literacy uses. It was also found that on the whole literacy uses could not be predicted on the basis of age, sex, class and marital status.

Then in a further study with twenty participants with mild to moderate aphasia, Parr (1995) investigated factors relating to functional reading and writing. Participants were interviewed about their pre-morbid and current roles (e.g. socialising, working and travelling) and reading and writing activities (e.g. writing a shopping list or reading a newspaper). The study found a large amount of variation across participants in their roles both before and after their stroke with a complex combination of reasons for role changes being given, including for example aphasia, loss of confidence, lack of money and motor problems. Moreover a large range of writing activities were described with none of the participants having the same combination of activities. Participants also described different types and levels of support from family members, friends and technologies in reading.
and writing activities. This study demonstrated the complexity of the interaction of factors such as personal patterns of pre-morbid reading and writing use, pre-morbid social roles, the reorganization of home, work, leisure and social roles and pre-morbid and current strategy use, that affect reading and writing in people with aphasia. The results of these studies emphasise the value of using interviews and coding techniques as part of initial assessments with people with aphasia so that their abilities and preferences can be established and appropriate therapy goals can be set.

1.5 The importance of writing rehabilitation for people with acquired dysgraphia

Through the increased use of the internet and mobile phones in recent years, writing has become a common and important means for communication in social, professional and educational spheres (Steyaert, 2002). According to the Office of National Statistics, in 2014 seventy six per cent (thirty eight million) of adults in Great Britain accessed the Internet every day (ONS, 2014). Although the most frequent internet users were young adults, adults of all ages have been increasing their computer use, with forty two percent of adults over 65 reporting using the internet daily in 2014. Email use is the most common internet activity in Great Britain (ONS, 2014) and is now considered to be essential for work and education (Conti-Ramsden, Durkin & Walker, 2012; Hair, Renaud & Ramsay, 2007).

Considering the importance of internet access in modern life, those who do not have access to it can be considerably disadvantaged (van Dijk, 2006). The term digital divide has been used to describe the gap between those who do and those who do not have internet access (Bonfadelli, 2002; Deurson & van Dijk, 2010). In people who do have physical access to the internet, internet skills, including literacy (Carvin, 2000) are a major factor in whether it is used (Deurson & van Dijk; ONS, 2014). In a recent survey, people with
aphasia reported that their aphasia was their main barrier to using the internet (Menger, Morris & Salis, 2014).

If people with aphasia were trained or supported in using the internet, it may create new opportunities to communicate. In many situations, written communication via email, text messages and social networking sites has become a more effortless and time efficient alternative to making a phone call. Therefore, somebody with more preserved writing skills than speech following a stroke may benefit from these new media. Todis, Sohlberg, Hood & Fickas (2005) found in a survey of people with acquired brain injury, that email is often preferred to the telephone as a mode of communication 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.

Apart from use of the internet and mobile phones, improving writing could have some really practical benefits for people with aphasia, including supporting face to face conversations, i.e. within a total communication approach. This may be particularly important for some people whose spoken communication impairments may be more resistant to treatment than writing (Beeson & Rapcsak, 2002). Furthermore, writing has many uses in everyday situations (shopping lists, telephone messages, diary entries, greetings cards) as well as for education and employment (Rapp, 2005). Retraining skills necessary for these tasks may increase independence and participation and reduce isolation.
1.6 The treatment of aphasia and acquired dysgraphia

There are, broadly, two approaches to the rehabilitation of acquired language impairments. The first concerns directly targeting the deficit with impairment-based therapies. In other words, patients relearn skills that were damaged due to the brain damage. In this case, treatment is often guided by assessment based on cognitive neuropsychological models (see 1.2.1.) Impairment-based therapies for people with dysgraphia are either lexical, meaning that single words are retrained through repetitive spelling to dictation, picture naming or copying tasks (e.g. Beeson, Higginson, & Rising, 2013; Raymer, Strobel, Prokup, Thomason & Reff, 2010; Thiel, Sage & Conroy, 2014), or aim to retrain phoneme grapheme conversion skills in participants whose writing has been affected by a phonological impairment (e.g. Beeson, Rising, Kim & Rapcsak, 2010; Tsapkini & Hillis, 2013, see Chapter 2 for a review of the writing therapy literature). Although these therapies have been shown to be successful in improving spelling of trained and sometimes untrained single words, training can be a time-consuming process and there has been little evidence to suggest that gains generalise to functional writing contexts.

The second approach to aphasia rehabilitation is a functional one which aims to maximise communication through making use of residual abilities. This can include compensating for impaired language through using other natural modes of communication such as writing, drawing or gesture (Hux, Manasse, Weiss, Beukelmann, 2001) or Alternative Augmentative Communication Systems such as Sentence Shaper (Linebarger, Schwartz, & Kohn, 2001) or C-Speak Aphasia (Nicholas & Elliott, 1998), or through focusing on the communication environment including training of communication partners (e.g. Kagan, 1998). Within the writing rehabilitation literature there has been considerably less focus on therapies that encourage functional use of language despite some preliminary research into bridging the gap between spelling therapies and functional writing
(e.g. Mortley, Enderby & Petheram, 2001; Robson, Marshall, Chiat & Pring, 2001) and into using assistive writing technologies to compensate for writing impairments (e.g. Behrns, Hartelius & Wengelin, 2009; Estes & Bloom, 2011). Parr (2005) stresses the importance of functional, ecologically valid therapy for reading and writing which addresses the levels of activities (i.e. those related to the individual’s home, domestic, work, leisure and social roles), strategies (e.g. supportive techniques or technologies) and adjustment (considering and addressing the psychodynamic changes resulting from the aphasia).

The International Classification of functioning, disability and health (ICF) is the World Health Organisation’s (WHO) framework for describing, measuring and organising information on health and disability (WHO, 2015). It comprises the following components: Body Functions and Structures, Activities and Participation, Environmental Factors and Personal Factors. The ICF is used by speech and language therapists as a framework to describe the impact of speech, language and communication disorders, including aphasia, and to guide assessment, goal-setting and therapy planning (ASHA, 2015; Australian Aphasia Rehabilitation Pathway, 2014; RCSLT, 2009; Simmons Mackie & Kagan, 2007; Worrall, Sherratt, Rogers, Howe, Hersh, Ferguson & Davidson, 2011). Aphasia therapies can aim to improve the person’s language function (e.g. score on a picture naming task) through impairment-based therapies, to improve their ability to carry out language activities or increase their level of participation (e.g. ability to read a letter, have a phone conversation or start volunteering for a charity) through impairment-based therapies or compensatory strategies, or can aim to adapt their environment to facilitate communication (e.g. through communication partner training).

There seems to be a role for both impairment-based therapy methods and compensatory strategies for improving writing activity (e.g. email writing) in people with aphasia. Impairment-based
therapies aim to target language function, while assistive technologies could maximise communication abilities by compensating for deficits and building on gains of impairment based therapies. However, there has been little evidence of any research attempts to harness both relearning and compensatory therapies within an integrated remediation approach targeting functional writing. It is predicted that in a combined approach to writing therapy that included both spelling therapies and assistive writing software, spelling therapies would improve spelling accuracy of single words, which may lead to small improvements in email writing accuracy but that assistive writing software would build on these gains by facilitating email writing through providing support with more difficult spellings and grammar, aiding monitoring and editing, and thus enabling more complex ideas to be conveyed.

The studies contained within this thesis represent a novel approach to dysgraphia therapy in the following ways:

- They represent, as far as we know, the first attempt to evaluate the effects of both impairment-based spelling therapies with assistive writing technologies within the same group of participants by measuring outcomes to both therapies separately within a sequential design.

- Seventy nine percent of dysgraphia therapy studies have had a sample size of between one and four and most have included participants with similar types or severities of dysgraphia. The studies presented in this thesis, therefore, represent one of the largest dysgraphia therapy investigations with regard to number of participants to date. Related to this, it has included participants with a range of types and severities of dysgraphia so as to be optimally clinically informative.
• A novel email assessment was developed to underpin the outcome measures utilised in the studies reported here. Although some previous published studies have reported measuring outcomes to email writing, no data on these has been presented.

1.7 Study design and recruitment

1.7.1 Design

The clinical studies contained within this thesis, as distinct from analysis and reporting of neuro-typical writing data, used a within-participants multiple case design. This allowed for participants’ and whole group assessment scores to be compared across time points and conditions. In total, ten participants were recruited. There were eight in the first study (Chapters 4 and 5) and eight in the second study (Chapter 6). Two participants withdrew after the lexical therapy study; therefore two more were recruited for the assistive technology study. Eight was considered to be an appropriate number for these studies as it was large enough to find patterns across aphasia and dysgraphia types and severities, but small enough for complex and time-consuming assessments and therapies to be administered for each participant within the available time-frame. Other multiple case studies with similar numbers have shown significant changes to language following therapies within the aphasia therapy literature (Conroy, Sage, & Lambon Ralph, 2009a, 2009b; Raymer et al., 2010). Appendix 1 shows the time scale and the individual stages of the study for the participants who took part in the whole project.
1.7.2 Recruitment

Participants with dysgraphia were recruited either directly from voluntary sector non-NHS services in Greater Manchester (e.g., stroke support groups) or through previous studies conducted at the University of Manchester, where they had expressed an interest in volunteering for further studies. In order to take part in the dysgraphia studies, participants were required to have a spelling impairment following a stroke and to be at the chronic stage of their brain injury (i.e. post six months). They were screened using the CAT writing to dictation and written picture naming subtests (Swinburn et al., 2004) and were accepted in the study if they had between 10% and 90% letters correct. The lower cut-off was established so that all participants in the study could retrieve at least part of a word at baseline, i.e. had some potential to learn to spell or to use assistive writing software. The upper cut-off of 90% was set so that all participants had at least some writing impairment, but this allowed for those with high level writing impairments to be included. These broad boundaries were chosen so that participants had a large range of spelling ability. They needed to have sufficient visual acuity and motor ability for writing, which was assessed through copying and transcoding subtests of the CAT (Swinburn et al., 2004) and by being observed typing words on a laptop. All participants were monolingual speakers of English.

Control participants were recruited through three sources. Retired staff from the university (aged 65+), who were previously approached to ask whether they would be happy to be contacted about psychological research, were contacted by phone or email and were tested at home. AS level students (aged 16-18) attending an outreach event at the university who consented to take part in research studies were tested at the university. Finally, to recruit participants between the ages of 18 to 65 the researcher first contacted her own friends and family members and then contacted any of their friends or family members who showed an interest in
taking part. Potential participants were excluded if they had had any history of neurological damage, learning disability, dyslexia or dysgraphia.
1.8 Research questions

1. What is the range of performance of email writing accuracy in healthy control participants?

2. Comparing multi-modal and uni-modal impairment-based therapies for dysgraphia: is there a difference in the effects on spelling accuracy?

3. Do impairment-based lexical spelling therapies lead to improvements in writing in people with acquired dysgraphia?

4. Do assistive writing technologies lead to improvements in writing in people with acquired dysgraphia?

5. Can a combined approach to writing therapy that includes both spelling practice and training in supportive computer technologies improve writing via the internet in participants with acquired dysgraphia?
1.9 Thesis outline

1.9.1. Alternative format thesis

An alternative format has been used for the presentation of this thesis. An alternative format thesis is comprised of chapters that are each written in a style suitable for submission to a journal. This was the most appropriate format for this thesis because the papers presented in Chapters 2, 3, 4, 5 and 6 had all been submitted to journals and have now either been published (Chapters 2, 3 and 4) or are awaiting peer review (Chapters 5 and 6). While Chapter 2 describes a review of the writing therapy literature, Chapters 3, 4, 5 and 6 report the results of different studies which together form a coherent thesis. This format has allowed for the thesis and research papers to be written simultaneously and for the author to start publishing this work before completion of the PhD. However, one disadvantage of this format is the repetition of information across chapters. Within this thesis, there has been some repetition of background information in introduction sections, descriptions of participants and assessment and therapy procedures (Chapters 4 and 5 describe different outcome measures of the same study). It was necessary for these sections to be repeated so that each self-contained journal article could be understood without referring to others. The following sections (1.9.2 – 1.9.7), which include the titles and abstracts of each chapter, show the structure of the thesis.

The work presented in this thesis was supervised by Dr Paul Conroy and Professor Karen Sage. The study designs, assessments and therapy protocols were developed collaboratively within supervision meetings, and the recruitment, assessments, therapies and data analyses were all carried out by the author. Papers were initially written by the author of the thesis but were then developed further with guidance from supervisors.
Chapter 2. Retraining writing for functional purposes: A review of the writing therapy literature

**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 mobile 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.
1.9.3 Chapter 3. Assessing spelling accuracy in email writing

*Background:* Email use is the most common internet-based activity in the UK and has become important to people of all ages for work, education and social participation. People with aphasia and acquired dysgraphia can be restricted from using the internet due to their communication impairment. There is currently no standardised assessment that allows us to measure the email writing skills of clinical groups such as people with aphasia.

*Aim:* The primary aim of this study was to determine the range of performance in email writing accuracy in healthy control participants, so that these data could be used for comparative purposes and as outcome measurement within clinical studies, such as evaluations of dysgraphia therapy. Two secondary aims were to test for stability of the measure and to investigate whether there was a relationship between email writing performance and the age and education of participants.

*Methods:* Forty two healthy control participants completed an email writing task within nine minutes, which entailed writing three separate three-minute emails on discreet topics. These data were then analysed for number of units, number of correct units and number of correct and informative units. Ten participants completed the assessment on two occasions and group means were compared statistically to determine whether there was test-retest reliability. A multiple regression analysis for each outcome measure and each task was conducted to establish whether they could be predicted by age and level of education.

*Results:* There was a broad range of performance on all three measures. All units were stable across time for all tasks. The factors age and education were significant predictors of all three measures, but only for tasks 2 and 3.

*Discussion:* These data will be used in the following clinical studies (Chapters 5 and 6) to measure outcomes from writing therapies for
people with aphasia. The relationship between writing accuracy and age and education implies that different norms should be developed for different age ranges so that individuals with neurological damage can be compared to an appropriate neuro-typical population. Both age and education are important variables in relation to the quantity and quality of written language with emails.
Chapter 4. Comparing uni-modal and multi-modal therapies for improving writing in acquired dysgraphia after stroke

Background: Writing therapy studies have been predominantly uni-modal in nature; i.e. their central therapy task has typically been either writing to dictation or copying and recalling words. There has not yet been a study that has compared the effects of a uni-modal to a multi-modal writing therapy in terms of improvements to spelling accuracy.

Aims: A multiple-case study with eight participants aimed to compare the effects of a uni-modal and a multi-modal therapy on the spelling accuracy of treated and untreated target words at immediate and follow-up assessment points.

Methods and Procedures: A cross-over design was used and within each therapy a matched set of words was targeted. These words and a matched control set were assessed before as well as immediately after each therapy and six weeks following therapy.

Outcomes and Results: The two approaches did not differ in their effects on spelling accuracy of treated or untreated items or degree of maintenance. All participants made significant improvements on treated and control items; however not all improvements were maintained at follow-up.

Conclusions: The findings suggested that multi-modal therapy did not have an advantage over uni-modal therapy for those with acquired dysgraphia. Performance differences were instead driven by participant variables.
Chapter 5. The role of learning in improving functional writing in stroke aphasia

Purpose: Improving writing in people with aphasia could improve ability to communicate, reduce isolation and increase access to information. One area that has not been sufficiently explored is the effect of impairment based spelling therapies on functional writing. A multiple case study was conducted with eight participants with aphasia subsequent to stroke. This aimed to measure the effects of spelling therapy on functional writing and perception of disability.

Method: Participants engaged in ten sessions of copy and recall spelling therapy. Outcome measures included spelling to dictation of trained and untrained words, written picture description, spelling accuracy and psycholinguistic quality within emails, a disability questionnaire and a writing frequency diary.

Results: All participants made significant gains on treated and untreated words. Group analyses showed significant improvements to written picture description, but not writing frequency or perceptions of disability. Within emails, spelling accuracy did not improve significantly for the group; however, there was a significant increase in the mean length of words in post therapy emails.

Conclusions: These results show that small doses of writing therapy can lead to large gains in specific types of writing. Gains did not extend to improvements in frequency of writing in daily living and improvements to spelling accuracy did not generalise to ecological measures of email writing. There is a need to develop bridging interventions between experimental tasks towards more multi-faceted and ecological everyday writing tasks.
1.9.6 Chapter 6. Promoting linguistic complexity, greater message length and ease of engagement in writing emails in people with aphasia: Initial evidence from a study utilising assistive writing software

Background: Improving email writing in people with aphasia could improve their ability to communicate, promote interaction and reduce isolation. Spelling therapies have been effective in improving single word writing. However, there has been limited evidence on how to achieve changes to everyday writing tasks such as email writing in people with aphasia. One potential area that has been largely unexplored in the literature is the potential use of assistive writing technologies, despite some initial evidence that training in assistive writing software can lead to qualitative and quantitative improvements to spontaneous writing.

Aims: This within-participants multiple case design study aimed to investigate the effects of training eight participants with dysgraphia related to aphasia to use assistive writing software to improve email writing.

Methods and Procedures: Eight participants worked through a hierarchy of writing tasks of increasing complexity within broad topic areas that incorporate the spheres of writing need of the participants: writing for domestic needs, writing for social needs and writing for business/ administrative needs. Through completing these tasks, participants learned to use the various functions of the software, such as predictive writing, word banks and text to speech. Therapy also included training and practice in basic computer and email skills to encourage increased independence. Outcome measures included email skills, keyboard skills, email writing and written picture description tasks and a perception of disability assessment.

Outcomes & Results: Four of the eight participants showed statistically significant improvements to spelling accuracy within emails when using the software. On a group level there was a significant increase in word length with the software, while four
participants showed noteworthy changes to the range of word classes used. Enhanced independence in email use and improvements in participants’ perceptions of their writing skills were also noted.

Conclusions & Implications: This study provided some initial evidence that assistive writing technologies can support people with aphasia in email writing across a range of important performance parameters. However, more research is needed to measure the effects of these technologies on the writing of people with aphasia, and to determine the optimal compensatory mechanisms for specific people given the linguistic-strategic resources they bring to the task of email writing.
1.9.7 Chapter 7. Discussion

This chapter will summarise the findings of this thesis and readdress the questions posed in Chapter 1, concluding with a discussion of study contributions, limitations, implications for clinical practice and directions for further research.
Chapter 2. Retraining writing for functional purposes: A review of the writing therapy literature


2.1 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.
2.2 Introduction

Acquired dysgraphia refers to an acquired disorder of writing (Weekes, 2005), which 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).

Writing 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 (Parr, 1992; 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?

2.3 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 (Physiotherapy Evidence Database Scale adapted for PsycBITE, Perdices, et al. 2009; PsycBITE, 2014), which is an 11 point rating scale for rating the internal validity of randomised and non-randomised controlled trials.

2.4 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

55
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).
Table 2. Summary of writing therapy studies

(Listed in alphabetical order according to first author)

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Rating*</th>
<th>Participants</th>
<th>Description of participants</th>
<th>Treatment method</th>
<th>Target</th>
<th>Statistical analysis</th>
<th>Treatment outcome</th>
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<tbody>
<tr>
<td>Aliminosa, McCloskey, Goodman-</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left CVA; aphasia; acquired dysgraphia</td>
<td>Delayed copying and spelling to dictation</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Improvement to trained words (statistics not reported for this measure). No significant improvement to untrained set</td>
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<td>Schulman, &amp; Sokol (1993)</td>
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<td>Ball, de Riesthal, Breeding &amp;</td>
<td>Multiple case</td>
<td>9</td>
<td>3</td>
<td>Left CVA.1: severe global aphasia; 2: global aphasia 3: severe conduction aphasia</td>
<td>ACT and CART with spoken repetition</td>
<td>Spoken and written naming of single words</td>
<td>x</td>
<td>Improved written naming of trained words but not spoken naming of trained words. Improved written naming of untrained items in 1 participant.</td>
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<tr>
<td>Study</td>
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<tr>
<td>Beeson (1999)</td>
<td>Single</td>
<td>7</td>
<td>1</td>
<td>Left CVA; Wernicke's aphasia; severe dysgraphia due to degraded orthographic representations, a phonological processing deficit and possible graphemic buffer disorder</td>
<td>ACT and CART</td>
<td>Written naming and functional use of words in conversation</td>
<td>✓</td>
<td>Improved written naming of trained words (not analysed statistically); no significant improvement to delayed copy of untreated words; increased use of writing to support conversational interactions</td>
</tr>
<tr>
<td>Beeson &amp; Egnor (2006)</td>
<td>Multiple</td>
<td>8</td>
<td>2</td>
<td>Severe dysgraphia1: Left CVA; conduction aphasia; global dysgraphia 2. Left frontal and brainstem</td>
<td>CART with spoken repetition vs. only spoken repetition</td>
<td>Spoken and written naming of single words</td>
<td>✓</td>
<td>Large effect sizes for written and spoken naming of trained words following CART with repetition; gains in spoken</td>
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<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>Beeson, Higginson &amp; Rising (2013)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>aneurysms and a subarachnoid haemorrhage; anomic aphasia; global dysgraphia</td>
<td>CART and T-CART: a texting version of CART</td>
<td>Spelling and oral naming of single words</td>
<td>✓</td>
<td>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</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<tr>
<td>Beeson, Hirsch, &amp; Rewega (2002)</td>
<td>Multiple case</td>
<td>7</td>
<td>4</td>
<td>Severe dysgraphia 1: Left CVA; global aphasia 2: Left CVA; global aphasia 3: Left CVA; non-fluent aphasia 4: haemorrhagic stroke; Broca's aphasia.</td>
<td>ACT and CART including some functional writing training</td>
<td>Single word spelling and functional writing</td>
<td>x</td>
<td>Improved spelling of trained words; increased use of writing for communication (e.g. email or face-to-face conversations) observed for all participants</td>
</tr>
<tr>
<td>Beeson, Rising, &amp; Volk (2003)</td>
<td>Multiple case</td>
<td>8</td>
<td>8</td>
<td>Left CVA and severe aphasia and dysgraphia; 7: Broca’s aphasia 1:</td>
<td>CART and written conversation training</td>
<td>Written naming and conversational use of target words</td>
<td>✓</td>
<td>Large effect sizes in written naming of trained items for 6 participants; small effect size for one participant</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<tr>
<td>Behrmann (1987)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; conduction aphasia; surface dysgraphia</td>
<td>Homophone retraining programme: pairing with pictorial representation</td>
<td>Spelling of homophone pairs</td>
<td>✓</td>
<td>Significant improvement in spelling trained homophones and untrained irregular words</td>
</tr>
<tr>
<td>Brown &amp; Chobor (1989)</td>
<td>Multiple case</td>
<td>7</td>
<td>10</td>
<td>Left CVA; 1: fluent aphasia; 9: non-fluent aphasia</td>
<td>Facilitating writing with the right arm using a limb prosthesis</td>
<td>Writing and other language tasks</td>
<td>x</td>
<td>Improved spelling accuracy and scores on a range of language and non-language tests; better performance with observations of use of target words in conversations</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Clausen &amp; Beeson (2003)</td>
<td>Multiple case</td>
<td>9</td>
<td>4</td>
<td>Left CVA; severe Broca's aphasia</td>
<td>CART and group treatment</td>
<td>Single word spelling and functional use of words in conversation</td>
<td>✓</td>
<td>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</td>
</tr>
<tr>
<td>Deloche, Dordain, &amp; Kremin (1993)</td>
<td>Multiple case</td>
<td>8</td>
<td>2</td>
<td>Meningeal haemorrhage 1: surface dysgraphia 2:</td>
<td>Written naming treatment with computer-delivered cues</td>
<td>Spoken and written naming</td>
<td>✓</td>
<td>Significant improvement in written naming of trained and untrained words</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>de Partz (1995)</td>
<td>Single case</td>
<td>6</td>
<td>1</td>
<td>Left CVA; deep dysphasia; graphemic buffer disorder</td>
<td>Delayed copy and lexical segmentation strategy</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significant improvement of trained words; significantly better performance on decomposable words</td>
</tr>
<tr>
<td>Hatfield (1983)</td>
<td>Multiple case</td>
<td>2</td>
<td>4</td>
<td>3: deep dysgraphia (2 with left CVA; 1 with TBI) 1: surface dysgraphia (subarachnoid haemorrhage and fluent aphasia)</td>
<td>Deep dysgraphia: Training function word spelling using key words, homophones and quasi-</td>
<td>Deep dysgraphia: function word spelling; Surface dysgraphia: doubling of consonants; single word spelling</td>
<td>x</td>
<td>Improved spelling accuracy of trained words; improved consonant doubling</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>Hillis &amp; Caramazza (1987)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; graphemic buffer disorder</td>
<td>Treating specific spelling of words vs. training a self-correction strategy</td>
<td>Single word spelling accuracy and detection of errors in narrative</td>
<td>x</td>
<td>Improved trained words following both methods; strategy also improved spelling of untrained words and self-correction in written narratives</td>
</tr>
<tr>
<td>Jackson-Waite et al. (2003)</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left CVA; jargon aphasia; severe dysgraphia</td>
<td>Anagrams, delayed copy and written naming; facilitation of written naming and functional use of words in conversation</td>
<td></td>
<td>✓</td>
<td>Significantly improved naming of trained words and responded to</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>Kapur &amp; Gordon (1975)</td>
<td>Single case</td>
<td>1</td>
<td>1</td>
<td>Gunshot wound in left posterior parietal area; dysgraphia</td>
<td>Letter writing practice</td>
<td>Accuracy of letter shape</td>
<td>x</td>
<td>Improved letter shapes</td>
</tr>
<tr>
<td>Mortley, Enderby, &amp; Petheram (2001)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; severe graphemic buffer disorder</td>
<td>Strategy using residual oral spelling skills; word prompt software</td>
<td>Spelling of single words and sentences; functional writing</td>
<td>✓</td>
<td>Significant improvement of untrained single words and generalisation to functional writing (e.g. letter writing)</td>
</tr>
<tr>
<td>Orjada &amp; Beeson (2005)</td>
<td>Single case</td>
<td>9</td>
<td>1</td>
<td>Left CVA; Broca's aphasia; phonological dyslexia; global dysgraphia</td>
<td>CART and ORT</td>
<td>Accuracy and rate of text reading and accuracy of single word spelling</td>
<td>✓</td>
<td>Large treatment effects for spelling of trained words as well as for reading accuracy;</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>Panton &amp; Marshall</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left CVA; buffer-level impairment</td>
<td>Spelling to dictation, copy and recall and note-taking practice</td>
<td>Writing to dictation of single words and note-writing ability</td>
<td>✓</td>
<td>small effect size for reading rate天堂 improved writing to dictation of trained and untrained words and note taking ability</td>
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<td>(2008)</td>
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<tr>
<td>Pizzamiglio &amp; Roberts</td>
<td>Group (between subjects)</td>
<td>5</td>
<td>20</td>
<td>Aphasia, predominantly expressive type; 18: thrombotic CVA; 1: haemorrhage; 1: cerebral trauma</td>
<td>Sentence completion and picture naming on a computer with feedback for correct responses. Comparison of treatment</td>
<td>Written naming and sentence accuracy</td>
<td>✓</td>
<td>Significantly more accurate responses on trained items following the 24 hour condition; all maintained improvements one week after therapy</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
<td>Treatment outcome</td>
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<tr>
<td>Pound (1996)</td>
<td>Single case</td>
<td>5</td>
<td>1</td>
<td>Left CVA; mildly anomic; severe dysgraphia (lexicality and length effects and buffer-type errors)</td>
<td>Strategy using residual oral spelling skills</td>
<td>Spelling of single words and sentences</td>
<td>✓</td>
<td>Significantly improved spelling of untrained single words; improved picture description and spontaneous writing</td>
</tr>
<tr>
<td>Rapp (2005)</td>
<td>Multiple case</td>
<td>9</td>
<td>3</td>
<td>Left CVA 1: orthographic lexicon impairment 2 &amp; 3: graphemic buffer disorder</td>
<td>Spell-study-spell treatment</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significantly improved trained words, maintained at follow-up; 2 participants with graphemic buffer disorder significantly</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
<td>Treatment outcome</td>
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<tr>
<td>Rapp &amp; Kane (2000)</td>
<td>Multiple case</td>
<td>9</td>
<td>2</td>
<td>Left CVA; moderate dysgraphia; 1. orthographic output lexicon damage 2. graphemic buffer disorder</td>
<td>Delayed copy treatment</td>
<td>Number of letters correct in single words</td>
<td>✓</td>
<td>Significantly improved spelling of trained words; participant with graphemic buffer disorder improved significantly on untrained words</td>
</tr>
<tr>
<td>Raymer, Cudworth, &amp; Haley (2003)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; severe aphasia; damage to orthographic output lexicon and graphemic buffer</td>
<td>CART with decreasing cues</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significantly improved spelling of trained words and generalisation to untrained words</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>Raymer, Strobel, Prokup, Thomason, &amp; Reff (2010)</td>
<td>Multiple case</td>
<td>9</td>
<td>4</td>
<td>CVA; 1: mild anomic aphasia; phonological dysgraphia 2: recovered anomic aphasia; severe dysgraphia at levels of buffer, sublexical and orthographic processing 3: moderately severe non-fluent aphasia; phonological dysgraphia 4: moderately severe non-fluent aphasia; deep dysgraphia</td>
<td>Errorless and errorful training</td>
<td>Single word spelling</td>
<td>✓</td>
<td>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.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
<td>Treatment outcome</td>
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<tr>
<td>Robson, Marshall, Chiat, &amp; Pring (2001)</td>
<td>Multiple case</td>
<td>7</td>
<td>6</td>
<td>Jargon aphasia 5: CVA 1: CVA and head injury</td>
<td>Written naming therapy (N.6) and message therapy (N.3)</td>
<td>Written picture naming and message production</td>
<td>✓</td>
<td>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</td>
</tr>
<tr>
<td>Robson, Pring, Marshall, Morrison, &amp; Chiat (1998)</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left CVA; jargon aphasia</td>
<td>Picture therapy, generalisation therapy and message therapy</td>
<td>Written picture naming and ability to respond to questions and produce messages using targeted words</td>
<td>✓</td>
<td>Significant gains in written picture naming of trained words, in questionnaire responses and in</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
<td>Treatment outcome</td>
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<tr>
<td>Sage &amp; Ellis (2006)</td>
<td>Single case</td>
<td>6</td>
<td>1</td>
<td>Left CVA; severe graphemic buffer disorder</td>
<td>Direct spelling therapy vs. therapy to orthographic neighbours of targets (indirect therapy)</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significant improvement to directly trained words, maintained at follow-up; significant improvement to indirectly trained words at follow-up</td>
</tr>
<tr>
<td>Schmalzl &amp; Nickels (2006)</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left temporal damage resulting from herpes simples encephalitis; damage to the semantic system and a deficit in</td>
<td>CART alone vs. CART with visual mnemonics</td>
<td>Spelling of irregular words</td>
<td>✓</td>
<td>Significant improvement in spelling of trained words following the CART with mnemonic condition only</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
<td>Target</td>
<td>Statistical analysis</td>
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<tr>
<td>Schwartz, Nemeroff, &amp; Reiss (1974)</td>
<td>Group (between subjects)</td>
<td>4</td>
<td>14</td>
<td>Left CVA</td>
<td>8 participants: writing and spelling tasks (experimental group); 6 participants: multi-modal therapy (control group)</td>
<td>Scores on Porch Index of Communicative Ability Screen</td>
<td>✔</td>
<td>Experimental group made significantly greater gains than control group</td>
</tr>
<tr>
<td>Seron, Deloche, Moulard, &amp; Rousselle (1980)</td>
<td>Multiple case</td>
<td>7</td>
<td>5</td>
<td>3 CVA 1: tumour 1: trauma</td>
<td>Typing words to dictation with feedback from computer for correct responses</td>
<td>Single word spelling</td>
<td>✔</td>
<td>Significantly improved spelling of untrained words</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Sugishita, Seki, Kabe, &amp; Yunoki (1993)</td>
<td>Multiple case</td>
<td>6</td>
<td>22</td>
<td>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.</td>
<td>Copy and spoken repetition in two treatments for two different word sets</td>
<td>Written and spoken naming</td>
<td>✓</td>
<td>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.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Thiel &amp; Conroy (2014)</td>
<td>Multiple case</td>
<td>9</td>
<td>4</td>
<td>1: Severe non-fluent aphasia; graphemic buffer disorder; 2: severe non-fluent aphasia; deep dysgraphia and graphemic buffer disorder; 3: Mild aphasia; phonological dysgraphia and graphemic buffer disorder; 4: fluent aphasia; deep dysgraphia and graphemic buffer disorder</td>
<td>Errorful and errorless training</td>
<td>Single word spelling accuracy</td>
<td>✓</td>
<td>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.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Weekes &amp; Coltheart (1996)</td>
<td>Single case</td>
<td>6</td>
<td>1</td>
<td>TBI; surface dyslexia and dysgraphia</td>
<td>Homophone training using mnemonics</td>
<td>Homophone spelling and reading</td>
<td>✓</td>
<td>Significantly improved spelling and reading of trained homophone pairs</td>
</tr>
<tr>
<td>Impairment-based therapy studies targeting single words: Phonological therapies</td>
<td>Beeson, et al. (2000)</td>
<td>Multiple case 8</td>
<td>2</td>
<td>1: Left CVA; mild anomic aphasia; damage to graphemic output lexicon and sublexical spelling route. 2: TBI; mild anomic aphasia; surface dysgraphia</td>
<td>Phonological treatment and use of electronic spelling aid</td>
<td>Single word spelling and text writing</td>
<td>✓</td>
<td>Significantly improved spelling of untrained words; significant reduction of errors in text writing</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Carlomagno &amp; Parlato (1989)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; mild to moderate aphasia and severe dysgraphia with damaged lexical and P-G routes</td>
<td>Phoneme-to-grapheme conversion and lexical relay strategy</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significant improvement to spontaneous writing and to spelling of untrained words and non-words, which was maintained 2 months after training</td>
</tr>
<tr>
<td>Conway, et al. (1998)</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left CVA; conduction aphasia; mild phonological alexia and mixed dysgraphia</td>
<td>Auditory Discrimination in Depth Programme</td>
<td>Phonological awareness, single word reading, sentence and textual reading and spelling to dictation</td>
<td>x</td>
<td>Large gains in phonological awareness, reading and spelling non-words and reading and spelling untrained words</td>
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<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<tr>
<td>Greenwald (2004)</td>
<td>Single case</td>
<td>9</td>
<td>1</td>
<td>Left CVA; transcortical motor aphasia; severe global agraphia</td>
<td>Phonological treatment and functional computer tasks including emailing</td>
<td>Single word and sentence spelling</td>
<td>✓</td>
<td>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</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<tr>
<td>Hillis &amp; Caramazza (1994)</td>
<td>Multiple case</td>
<td>8</td>
<td>2</td>
<td>Left CVA</td>
<td>Phonological treatment</td>
<td>Single word spelling</td>
<td>x</td>
<td>One participant improved spelling of all words (trained and untrained) and accuracy in narrative. The other only improved on trained verbs</td>
</tr>
<tr>
<td>Kiran (2005)</td>
<td>Multiple case</td>
<td>11</td>
<td>3</td>
<td>Left CVA; impaired lexical and sub-lexical spelling routes; 1: transcortical motor aphasia 2: Broca's aphasia 3: anomic aphasia; deep</td>
<td>Phoneme to grapheme conversion treatment</td>
<td>Oral naming, oral spelling, written naming and writing to dictation</td>
<td>✓</td>
<td>Significantly improved writing to dictation of trained and untrained words and written naming and oral spelling of trained words for 2 participants. No</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<td>Luzzatti,</td>
<td>Multiple case</td>
<td>9</td>
<td>2</td>
<td>Severe Broca's aphasia and severe dysgraphia 1: Left cerebral abscess 2: cerebral haemorrhage</td>
<td>Training identification of phonemes in words and P-G correspondences</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significant improvements for 1 participant.</td>
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<tr>
<td>Colombo, Frustaci, &amp; Vitolo</td>
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<td>(2000)</td>
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<tr>
<td>Schechter, Bar-Israel, Ben-Nun, &amp; Bergman (1985)</td>
<td>Group (within subjects)</td>
<td>Not rated**</td>
<td>51</td>
<td>31 CVA and 20 chronic cerebral insufficiency; 5: global aphasia; 15: Broca's aphasia; 12: Wernicke's aphasia; 14: anomic aphasia;</td>
<td>Phonemic analysis-synthesis treatment: training identification of phonemes in words and drilling P-G</td>
<td>Performance on subtests from the Israeli Loewenstein Aphasia Test: Phonemic analysis and writing a sentence from dictation</td>
<td>✓</td>
<td>All improved significantly</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Tsapkini &amp; Hillis (2013)</td>
<td>Multiple case</td>
<td>9</td>
<td>2 (compared PPA to stroke aphasia)</td>
<td>5: conduction aphasia</td>
<td>correspondences</td>
<td>Learning of phoneme-to-grapheme correspondences with help from key words</td>
<td>✓</td>
<td>Both made significant improvements in 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.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<td>Statistical analysis</td>
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<tr>
<td>Impairment-based therapy studies targeting</td>
<td>Multiple case</td>
<td>8</td>
<td>8</td>
<td>Left CVA; 3 x anomic, 3 x conduction; 2 x minimal aphasia. Range of dysgraphia types (phonological, surface and global)</td>
<td>Phonological treatment and interactive treatment (self-generation of phonologically plausible spellings and use of electronic spelling aid)</td>
<td>Spelling of regular and irregular words and non-words</td>
<td>✓</td>
<td>Significantly improved spelling of untrained regular and irregular words, but not non-words.</td>
</tr>
<tr>
<td>single words: Therapies with lexical and</td>
<td>Multiple case</td>
<td>9</td>
<td>2</td>
<td>Left CVA and phonological processing impairment 1. moderate conduction aphasia, 2: mild aphasia</td>
<td>Phonological treatment and interactive treatment (with electronic spelling aid)</td>
<td>Phonological processing ability and reading and spelling of words and non-words</td>
<td>✓</td>
<td>Significantly improved phonological processing and improved spelling and reading via the sub-lexical route; significantly improved spelling</td>
</tr>
<tr>
<td>phonological elements</td>
<td>Beeson, et al. (2008)</td>
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<td></td>
<td>Beeson, Rising, Kim, &amp; Rapcsak (2010)</td>
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<td>Study</td>
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<tr>
<td>Cardell &amp; Chenery (1999)</td>
<td>Single case</td>
<td>8 1</td>
<td></td>
<td>Subarachnoid haemorrhage; expressive aphasia; damage to lexical and sub-lexical routes and the graphemic assembly buffer</td>
<td>Segmentation hierarchy for non-words; semantic therapy for low imageability words</td>
<td>Spelling of low imageability words and non-words</td>
<td>✓</td>
<td>Improved writing of trained and semantically related low imageability words and trained and untrained non-words (not</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<tr>
<td>Carlomagno, Iavarone, &amp; Colombo (1994)</td>
<td>Multiple case</td>
<td>8</td>
<td>6</td>
<td>Mild to moderate aphasia 4: CVA; 2: surgically treated arterovenous malformation</td>
<td>Phonological treatment and visual-semantic strategy</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significantly improved spelling (untrained words) following phonological treatment for 3 participants, visual semantic treatment for 1 participant and both for 2 participants.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<td>de Partz, Seron, &amp; Vanderlinden (1992)</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Encephalitis; transcortical sensory aphasia; surface dysgraphia</td>
<td>Phonological treatment and visual imagery strategy</td>
<td>Spelling of regular, irregular and ambiguous words; spontaneous writing</td>
<td>✓</td>
<td>Significantly improved spelling of trained regular words following phonological treatment; significantly improved trained irregular and ambiguous words using visual imagery strategy</td>
</tr>
<tr>
<td>Hatfield &amp; Weddell (1976)</td>
<td>Multiple case</td>
<td>6</td>
<td>5</td>
<td>CVA; moderately severe or very severe aphasia</td>
<td>Visual-kinaesthetic memorising (2), auditory analysis (2) and global stimulation (1)</td>
<td>Single word spelling</td>
<td>✓</td>
<td>Significant improvement to trained words in 3 participants (following visual-kinaesthetic memorising or global)</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Impairment-based therapy studies targeting sentences</td>
<td>Jacobs &amp; Thompson (2000)</td>
<td>Multiple case</td>
<td>9</td>
<td>4</td>
<td>Left CVA; Broca’s aphasia; agrammatic</td>
<td>Linguistic Specific Treatment (N.2) and Comprehension training (N.2)</td>
<td>Comprehension and production of complex spoken and written sentences</td>
<td>x</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Mitchum, Haendiges, &amp; Berndt (1993)</td>
<td>Single case</td>
<td>7</td>
<td>1</td>
<td>Left CVA; severe non-fluent aphasia</td>
<td>Facilitation of written verb retrieval and facilitation of grammatical frame construction</td>
<td>Written action naming and written sentence production</td>
<td></td>
<td>Significantly improved naming of trained verbs, written sentence production and spoken sentence production and generalisation to spontaneous writing</td>
</tr>
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<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<td>Statistical analysis</td>
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<tr>
<td>Murray &amp; Karcher (2000)</td>
<td>Single case</td>
<td>9</td>
<td>1</td>
<td>Left CVA; moderate Wernicke's aphasia</td>
<td>Cueing hierarchy, word-prompt software and home practice</td>
<td>Verb naming and sentence construction</td>
<td>x</td>
<td>Improved accuracy of trained verbs and SVO sentences; generalisation to written discourse</td>
</tr>
<tr>
<td>Murray, Timberlake &amp; Eberle (2007)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; agrammatic aphasia</td>
<td>Modified treatment of underlying forms</td>
<td>Written sentence structures</td>
<td>x</td>
<td>Improved accuracy of trained and untrained exemplars of sentences. Generalised improvements to untrained related structures and to spoken</td>
</tr>
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<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<td>Salis &amp; Edwards (2010)</td>
<td>Single case</td>
<td>8</td>
<td>1</td>
<td>Left CVA; moderate to severe aphasia</td>
<td>Written picture naming and description; cue and copy</td>
<td>Written verb naming and sentence accuracy in picture description</td>
<td>✓</td>
<td>Significant improvement of trained transitive and intransitive verbs and SV and SVO sentences and significant improvement to untrained verbs and sentences</td>
</tr>
<tr>
<td>Assistive technology training Armstrong &amp; MacDonald (2000)</td>
<td>Single case</td>
<td>4</td>
<td>1</td>
<td>Subarachnoid haemorrhage; LH</td>
<td>Predictive writing and speech</td>
<td>Single word spelling, written sentences and</td>
<td>x</td>
<td>Improved spelling and improved</td>
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<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<tr>
<td>Behrns, Hartelius, &amp; Wengelin (2009)</td>
<td>Multiple case</td>
<td>10</td>
<td>3</td>
<td>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</td>
<td>Predictive writing or spell check software</td>
<td>Written text accuracy and length</td>
<td>✔</td>
<td>All made improvements to writing; however only 2 made significant improvements</td>
</tr>
<tr>
<td>Bruce, Edmundson, &amp; Coleman (2003)</td>
<td>Single case</td>
<td>3</td>
<td>1</td>
<td>Left CVA; fluent, mild-to-moderate aphasia</td>
<td>Voice recognition software</td>
<td>Written text accuracy and length</td>
<td>✗</td>
<td>Quantitative and qualitative improvements to written work;</td>
</tr>
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<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<td>Estes &amp; Bloom</td>
<td>Single case</td>
<td>6</td>
<td>1</td>
<td>Left CVA; conduction aphasia</td>
<td>Voice recognition software</td>
<td>Functional written communication including emailing</td>
<td>x</td>
<td>Improved quality of writing</td>
</tr>
<tr>
<td>King &amp; Hux</td>
<td>Single case</td>
<td>9</td>
<td>1</td>
<td>Haemorrhagic CVA; mild non-fluent aphasia</td>
<td>Speech synthesiser software</td>
<td>Ability to monitor and correct errors in written texts</td>
<td>✓</td>
<td>Reduction in error rate with and without software (not analysed statistically); improvement in quality of writing and independence in writing. Significant positive change in</td>
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<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
<td>Treatment method</td>
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<tr>
<td>Manasse, Hux, &amp; Rankin-Erickson (2000)</td>
<td>Single case</td>
<td>6</td>
<td>1</td>
<td>Severe TBI; mild cognitive-communication deficits</td>
<td>Voice recognition software</td>
<td>Accuracy in using software and correcting errors; accuracy and length of written texts</td>
<td>x</td>
<td>Learnt to use software and to correct errors quickly; quantitative and qualitative improvements to writing</td>
</tr>
<tr>
<td>Nicholas, Sinotte &amp; Helm-Estabrooks (2005)</td>
<td>Multiple case</td>
<td>8</td>
<td>5</td>
<td>Left CVA; severe non-fluent aphasia</td>
<td>C-Speak Aphasia programme</td>
<td>Amount of meaningful, relevant information each participant expressed on five functional communication</td>
<td>✓</td>
<td>Three participants communicated more information with CSA than without; CSA did not assist any of the participants with writing tasks.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Rating*</td>
<td>Participants</td>
<td>Description of participants</td>
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<tr>
<td>Nicholas, Sinotte &amp; Helm-</td>
<td>Multiple case</td>
<td>9</td>
<td>10</td>
<td>Left CVA; severe non-fluent</td>
<td>C-Speak Aphasia</td>
<td>Amount of</td>
<td>✓</td>
<td>Four participants communicated more information with CSA than without; only one participant benefited for the writing tasks.</td>
</tr>
<tr>
<td>Estabrooks (2011)</td>
<td></td>
<td></td>
<td></td>
<td>aphasia</td>
<td>programme</td>
<td>meaningful, relevant information each participant expressed on five functional communication tasks (verbal and written)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
2.4.1 Impairment-based writing therapies

Fifty four studies described impairment-based writing therapies which asked participants to ‘relearn’ pre-morbidly established skills. Forty nine of these aimed to improve single word writing, while a small group of five studies targeted written sentence production. These will be described in the following two sections.

2.4.1.1 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).

2.4.1.1.1 Lexical therapies

Forty 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) and/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 language impairment (Hatfield & Weddell, 1976), age (Sugishita et al., 1993) or a combination of cognitive, linguistic and peripheral writing impairments (Beeson et al., 2003). Of the 40 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 40 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.

2.4.1.1.2 Phonological therapies

Fifteen 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 slower 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 had finished. There were some exceptions to this.

2.4.1.1.3 Measuring generalisation to spontaneous writing

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.

2.4.1.1.4. 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.

2.4.1.1.5 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 a
word 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, 1987) and taking notes in response 
to recorded phone messages (Panton & Marshall, 2008). Some 
presented writing samples with descriptive reports (Beeson et al., 
2000; Mortley et al., 2001), while others have counted errors 
corrected (Hillis & Carramazza, 1987) 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.

2.4.1.1.6 Methodological Rating

Of the 49 impairment-based therapy studies 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 (Perdices, et al. 2009; 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.

2.4.1.2 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) treated 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 trained 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).

2.4.1.2.1 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).

2.4.1.2.2 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.
2.4.2 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) two 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.
2.4.2.1 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.
2.5 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 40 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 their methodological quality. 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 therapies have aimed to change participants' language function, and transfer to functional, everyday writing (i.e. activity and participation levels of the ICF) has been presumed to occur but has often not been directly assessed. 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. 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., 2000; 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 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 the 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.
Chapter 3. Assessing spelling accuracy in email writing


3.1 Abstract

*Background:* Email use is the most common internet-based activity in the UK and has become important to people of all ages for work, education and social participation. People with aphasia and acquired dysgraphia can be restricted from using the internet due to their communication impairment. There is currently no standardised assessment that allows us to measure the email writing skills of clinical groups such as people with aphasia.

*Aim:* The primary aim of this study was to determine the range of performance in email writing accuracy in healthy control participants, so that these data could be used for comparative purposes and as outcome measurement within clinical studies, such as evaluations of dysgraphia therapy. Two secondary aims were to test for stability of the measure and to investigate whether there was a relationship between email writing performance and the age and education of participants.

*Methods:* Forty two healthy control participants completed an email writing task within nine minutes, which entailed writing three separate three-minute emails on discreet topics. These data were then analysed for number of units, number of correct units and number of correct and informative units. Ten participants completed the assessment on two occasions and the results were compared statistically to determine whether there was test-retest reliability. A multiple regression analysis for each outcome measure and each
task was conducted to establish whether they could be predicted by age and level of education.

**Results:** There was a broad range of performance on all three measures. All measures were stable across time for all tasks. The factors age and education were significant predictors of all three measures, but only for tasks 2 and 3.

**Discussion:** These data will be used in the following clinical studies (Chapters 5 and 6) to measure outcomes from writing therapies for people with aphasia. The relationship between writing accuracy and age and education implies that different norms should be developed for different age ranges so that individuals with neurological damage can be compared to an appropriate neuro-typical population.
3.2 Introduction

Internet use has become important for people of all ages for participating in work, education and social communication (Steyaert, 2002; ONS, 2014). In 2014, 76% (thirty eight million) of adults in Great Britain accessed the internet every day (ONS, 2014). Although young adults (16-24 year olds) were the most frequent internet users, use was not restricted to this age group. Between 2006 and 2014 computer usage increased for all age groups with the largest increase being for adults over 65 (ONS, 2014).

Of all internet activities, email use is the most common (ONS, 2014). In 2014, 75% of all adults in the UK used email, which had increased from 57% in 2007. The age groups who used it most were those between 25 and 44 (86% for 25-34 and 35-44 year olds); however, email was still used by older adults with 75% of 55 to 64 year olds and 49% of adults over 65 using email. Despite the growth of social media in recent years and the particular popularity of these with young people, 80% of 16 to 24 year olds still used email in 2014 (although 91% of this age group and 54% of adults overall used social media).

Emails are used for a range of purposes including for social and domestic tasks (e.g. writing to the bank, booking a hotel, making plans with a friend) and are in many cases considered to be essential for work and education (Conti-Ramsden, Durkin & Walker, 2012; Hair, Renaud & Ramsay, 2007). For example, universities often require students to submit coursework via e-mail and professionals often communicate more frequently by email than face to face (Conti-Ramsden et al., 2012; Ducheneaut, & Bellotti, 2003). Email writing can comprise a range of discourse genres for example recount for telling a friend about a recent holiday or procedure for giving instructions on how to get to a certain place, narrative for
telling a friend a funny story or exposition for complaining about a hotel (Whitworth, Claessen, Leitão & Webster, 2015).

With internet access fast becoming essential for participating in modern life, those who do not have access can be considerably disadvantaged (Van Dijk, 2006). The term digital divide has been used to describe the gap between those who do and those who do not have internet access (Bonfadelli, 2002; Deurson & Van Dijk, 2010). In people who do have physical access to the internet, internet skills, including literacy (Carvin, 2000) are a major factor in whether it is used (Deurson & Van Dijk, 2010; ONS, 2014). In 2013 the Oxford Internet Survey (OXIS, 2013) found that although there were only slight differences in internet use between people with different levels of formal education, there was a large divide between those with and without formal education with only 40% of those without using the internet (compared to 84-95% of those with formal qualifications).

People with aphasia, an acquired multi-modal language disorder resulting from brain injury (Hallowell & Chapey, 2008), have significant difficulties with internet and email use due to their language impairment (Menger, Morris & Salis, 2014; Egan, Worrall & Oxenham, 2004; Elman, 2001). Although assessments have been developed or used in previous studies for measuring internet skills in people with and without brain injury (e.g. Bunz, 2009; Deursen & Van Dijk, 2010; Egan, Worrall & Oxenham, 2005) and writing skills in people with aphasia (e.g. Boston Diagnostic Aphasia Examination, Goodglass, Kaplan & Barresi, 2001; Psycholinguistic Assessments of Language Processing in Aphasia, Kay, Lesser, & Coltheart, 1992), there is no standardised measure of email writing. There has been an emphasis on measuring language function rather than ability to complete real-life writing activities, despite the fact that writing skills are used for a broad range of activities that vary from person to person depending on their individual pre-morbid and post-stroke abilities, roles and interests (Parr, 1992). Moreover, spoken and
written discourse tasks used with people with aphasia have been limited in their range of genres, with a focus on narrative (often recount) and picture description (Whitworth et al., 2015) with some of those used in everyday discourse such as recounting events, organising events and expressing an opinion being neglected (Whitworth et al., 2015).

Email writing skills in healthy individuals are likely to vary from person to person depending on factors such as experience, keyboard skills, education and age. For example, Stuart-Hamilton & Rabbitt (1997) showed that spelling ability declines with age. They compared participants in their 50s, 60s and 70s and found significantly lower scores for the higher age groups. Similarly, MacKay and Abrams (1998) found that older adults made more spelling errors than younger adults. Whitworth et al. (2015) investigated change in spoken discourse organisation across age groups. Overall, they found that organisational coherence was maintained; however, there were significantly fewer episodes or steps in the body of the discourse in older participants, which mirrored results from previous studies (North, Ulatowska, Macalus-Haynes & Bell, 1986; Wright, Capilouto, Wagovich, Cranfill & Davis, 2005). Regarding cohesion, they found that the number of specific referents (mentioned for the first time) reduced significantly with age within expositions as previous research had demonstrated (Obler, Au, Kugler, Melvold, Tocco & Albert, 1994; Ulatowska, Hayashi, Cannito & Fleming, 1986). It has been predicted that these changes relate to factors such as age-related cognitive decline (Whitworth et al., 2015).

There is a need for normative data to firstly understand what constitutes ‘neuro-typical’ email writing performance in order to determine whether an individual could be considered as impaired on such tasks. Normative email writing data could also be used as a cut off so that therapists and researchers can measure change following therapies using statistical methods. The current study aimed to begin to fill this evidence gap by collating email writing data from adults
sampled from across the age range, primarily to be used to measure outcomes in the clinical studies described in Chapters 5 and 6. It is unlikely that all of the participants recruited for the clinical studies write emails, particularly considering their aphasia and acquired dysgraphia. However, Parr (1995) found that both participants with neuro-typical spelling and with aphasia used literacy skills for a broad range of activities that were different across participants; therefore, it may be difficult to find any one task that is functional to all participants. Email tasks were chosen as the outcome measure for the following reasons. Firstly, the studies in this thesis aimed to reflect current uses of literacy, and email is the most common internet activity and is used by people of all ages. Secondly, although tasks were not tailored to participants’ individual roles and activities in these studies, the three different email tasks could be designed to reflect a range of ecologically valid activities across different genres (making plans with a friend, recounting a past event, and expressing concern about a problem).

The study aimed to answer the following questions:

1. On average, how many units (i.e. sequences of letters as attempts at words), correct units, and correct and informative units are produced by participants within timed emails?
2. Is there test-retest reliability for number of units, correct units and correct and informative units?
3. Is there a relationship between number of units, correct units or correct and informative units and the age and level of education of participants?
3.3 Method

3.3.1 Participants

Forty two participants were recruited to this study. Three different groups were approached: firstly, a database of retired university staff and other healthy adults who had expressed an interest in taking part in psychological studies, representing a range of professional background and years of education; secondly, secondary level school students (aged 16-18) who volunteered to participate in psychological research studies while taking part in a university outreach event; and finally, personal acquaintances of the first author were recruited, including friends and family members. Nine participants were male (21.4%) and 33 were female (78.6%). The mean age of participants was 45.64 (SD = 25.03) with a range of 16 to 88 years. In Table 2 participants have been grouped into age decades which reflect findings on age differences in spelling from the previous literature (Stuart-Hamilton & Rabbitt, 1997). The mean number of years of education was 13.36 (SD = 3.30) with a range of 9 to 24 years spent in education. Potential participants were excluded from the study if they had been diagnosed with a neurological condition, learning disability, dyslexia or dysgraphia.
Table 2. Age of healthy control participants

<table>
<thead>
<tr>
<th>Age-bracket</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-19</td>
<td>13</td>
</tr>
<tr>
<td>20-29</td>
<td>4</td>
</tr>
<tr>
<td>30-39</td>
<td>3</td>
</tr>
<tr>
<td>40-49</td>
<td>1</td>
</tr>
<tr>
<td>50-59</td>
<td>3</td>
</tr>
<tr>
<td>60-69</td>
<td>7</td>
</tr>
<tr>
<td>70-79</td>
<td>9</td>
</tr>
<tr>
<td>80-89</td>
<td>2</td>
</tr>
</tbody>
</table>

3.3.2 Task

Participants were either tested at the university or at home. They were asked to complete the following three email tasks in a Microsoft Word Document on a laptop computer with autocorrect turned off.

1. Write an email arranging to meet a friend at a certain time, place and date.

2. Write an email to a friend telling them about a recent holiday.

3. Write an email to your Member of Parliament (local political representative) about an issue of concern to you at the present time, e.g., library closure, state of the roads.

The three emails were chosen to firstly represent common email activities and secondly to reflect three levels of difficulty and three different purposes. Example emails were written by two members of the research team to establish that they were different in terms of vocabulary and/or number of words. The first task had the purpose of
arranging a meeting and could be written with relatively few frequent words. The second, to recount a recent event, used more complex (and past tense) grammatical forms and required a broader range of vocabulary and more words than the first. The third task, to complain or discuss an issue, required a similar number of words to the second task but more complex syntactic constructions (e.g. conditionals). Participants were timed by the first author. For each task, they were asked to stop writing after three minutes but could also stop before if they wished. On example trials written by two members of the research team, three minutes was adequate time to complete each email task.

3.3.3 Analysis

Emails were analysed using the measures listed below. Total scores across all three email tasks (within nine minutes) as well as scores for each individual email task (within three minutes) will be presented:

- Number of units: word-like sequences of letters which included all attempts at writing a word, regardless of whether or not it was complete or correct (e.g. correctly spelt ‘yesterday’ as well as incorrectly spelt ‘yetserday’).

- Number of correct units: This included all words that were spelt correctly. Words that were not used in a grammatically correct manner and words that had not been used appropriately/ were not informative were included in this count (e.g., if ‘to’ was used in place of the correct spelling ‘too’).

- Number of relevant and informative units: This was a count of all correctly spelt open class words (including personal and possessive pronouns) that were relevant and informative to the email. Words did not need to be used in a grammatically correct manner (e.g. ‘wish’ in ‘best wish’).
3.4 Results

3.4.1 On average how many units, correct units and correct and informative units are produced by participants within timed emails?

The descriptive statistics for units, correct units and correct and informative units from each task as well as the total scores of all three tasks are displayed in Table 3. For an example of a writing sample that was representative of the mean on these measures, see Appendix 2 (Participant 9).

Table 3. Descriptive statistics of number of units, correct units and correct and informative units in control participants’ emails

<table>
<thead>
<tr>
<th></th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>Mean</td>
<td>45</td>
<td>77.43</td>
<td>80.95</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>29.05</td>
<td>46.86</td>
<td>42.66</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>180</td>
<td>195</td>
<td>205</td>
</tr>
<tr>
<td>CU</td>
<td>Mean</td>
<td>44.55</td>
<td>76.71</td>
<td>80.19</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>29.05</td>
<td>47.16</td>
<td>42.96</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>6</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>180</td>
<td>195</td>
<td>205</td>
</tr>
<tr>
<td>CIU</td>
<td>Mean</td>
<td>27.76</td>
<td>49.79</td>
<td>45.10</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>18.85</td>
<td>29.65</td>
<td>24.67</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>121</td>
<td>130</td>
<td>119</td>
</tr>
</tbody>
</table>
3.4.2 Is there test-retest reliability for number of units, correct units and correct and informative units?

Ten participants were retested on the email writing tasks to determine whether there was test-retest reliability. The group who were selected for this were matched on age and education with the stroke aphasia participants who participated in the writing rehabilitation studies in Chapters 4-6. The mean units, correct units and correct and informative units for each task on the first and second email assessment trials are displayed in Table 4. There were no significant differences between the first and second trials for units (Task 1: Ws+ 40.5, \( p = .20 \); Task 2: Ws+ 23.5, \( p = .95 \); Task 3: Ws+ 46.5, \( p = .06 \); Total: Ws+ 45.5, \( p = .07 \), 2-tailed), correct units (Task 1: Ws+ 39.5, \( p = .24 \); Task 2: Ws+ 24.5, \( p = .80 \); Task 3: Ws+ 47.0, \( p = .05 \); Total: Ws+ 38.0, \( p = .07 \), 2-tailed) or correct and informative units (Task 1: Ws+ 31.5, \( p = .72 \); Task 2: Ws+ 23.5, \( p = .95 \); Task 3: Ws+ 31.0, \( p = .76 \); Total: Ws+ 27., \( p = 1.00 \), 2-tailed).
Table 4. Descriptive statistics of two trials for 10 healthy control participants

<table>
<thead>
<tr>
<th></th>
<th>1&lt;sup&gt;st&lt;/sup&gt; trial</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; trial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 1</td>
<td>42.00</td>
<td>24.87</td>
</tr>
<tr>
<td>Task 2</td>
<td>63.10</td>
<td>47.81</td>
</tr>
<tr>
<td>Task 3</td>
<td>69.40</td>
<td>31.38</td>
</tr>
<tr>
<td>Total</td>
<td>174.50</td>
<td>94.89</td>
</tr>
<tr>
<td>Correct units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 1</td>
<td>41.70</td>
<td>24.52</td>
</tr>
<tr>
<td>Task 2</td>
<td>62.40</td>
<td>47.99</td>
</tr>
<tr>
<td>Task 3</td>
<td>69.00</td>
<td>31.40</td>
</tr>
<tr>
<td>Total</td>
<td>173.10</td>
<td>94.93</td>
</tr>
<tr>
<td>Correct and informative units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 1</td>
<td>24.70</td>
<td>12.65</td>
</tr>
<tr>
<td>Task 2</td>
<td>40.10</td>
<td>29.37</td>
</tr>
<tr>
<td>Task 3</td>
<td>37.20</td>
<td>18.21</td>
</tr>
<tr>
<td>Total</td>
<td>102.00</td>
<td>56.68</td>
</tr>
</tbody>
</table>

3.4.3 Is there a relationship between number of units, correct units or correct and informative units and the age and level of education of participants?

Standard multiple regression analyses were conducted for the dependent variables: units, correct units and correct and informative units for each task and for total scores across tasks to determine whether age or education predicted these measures. Age and years of education were entered into each model simultaneously.
3.4.3.1 Number of units

When the total unit scores were entered into the multiple regression analysis as the dependent variable with age and education as predictors, the model accounted for 28.3% (adjusted $R^2 = 24.6\%$) of the variance, which was significant ($F(2, 39) = 7.70, p = .002$). Table 5 shows the regression coefficients for the model. Only age significantly predicted number of units, indicating that younger participants tended to produce more units.

Table 5. Coefficients for units in all tasks for healthy control participants

<table>
<thead>
<tr>
<th></th>
<th>$B$</th>
<th>$SE$</th>
<th>$B$</th>
<th>$T$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-2.13</td>
<td>.58</td>
<td>-0.49</td>
<td>-3.65</td>
<td>.001</td>
</tr>
<tr>
<td>Education</td>
<td>6.38</td>
<td>4.43</td>
<td>0.20</td>
<td>1.44</td>
<td>.16</td>
</tr>
</tbody>
</table>

Separate multiple regression analyses were conducted for Tasks 1, 2 and 3. Neither age nor education predicted the number of units produced in Task 1 and the model was not able to predict the outcome ($F(2, 39) = 1.86, p < .17$). However, a regression model for Task 2 accounted for 37.4% of variance (adjusted $R^2 = 34.2\%$), which was significant ($F(2, 39) = 11.66, p < .001$), and both age and education predicted the number of units (see Table 6 below). The same was true for Task 3. The regression model accounted for 29.4% of the variance (adjusted $R^2 = 25.7\%$), which was again significant ($F(2, 39) = 11.66, p < .001$), with both factors predicting number of units (see Table 7).

Table 6. Coefficients for units in Task 2 for healthy control participants

<table>
<thead>
<tr>
<th></th>
<th>$B$</th>
<th>$SE$</th>
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</tbody>
</table>
Table 7. Coefficients for units in Task 3 for healthy control participants

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE B</th>
<th>B</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
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<td>.23</td>
<td>-.45</td>
<td>-3.32</td>
<td>.002</td>
</tr>
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<td>Education</td>
<td>3.96</td>
<td>1.74</td>
<td>.31</td>
<td>2.27</td>
<td>.03</td>
</tr>
</tbody>
</table>

3.4.3.2 Number of correct units

A model which included the total number of correct units across tasks as the dependent variable accounted for 31.6% (adjusted R² = 28.1%) of variance, which was significant (F (2, 39) = 9.03, p = .001). The regression coefficients are presented in Table 8. Both age and education predicted number of correct units. Therefore, participants who were younger and had more years of education generally wrote a higher number of correctly spelt words.

Table 8. Coefficients for correct units in all tasks for healthy control participants

<table>
<thead>
<tr>
<th></th>
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<th>B</th>
<th>t</th>
<th>p-value</th>
</tr>
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<td>Education</td>
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<td>.33</td>
<td>2.51</td>
<td>.02</td>
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</table>

When a separate model was constructed for Task 1, again the model was not successful at predicting the number of correct units (F (2, 39) = 2.03, p< .15) and neither age nor education contributed significantly to the model. However, the model constructed for Task 2 was able to predict the number of correct units (F (2, 39) = 11.77, p< .001). The model accounted for 37.6% of the variance (adjusted R² = 34.4%), with both variables being significant predictors (see Table 9). The Task 3 model accounted for 29.8% of variance (adjusted R² = 26.2%), which was significant (F (2, 39) = 8.28, p= .001). Again both age and education predicted the number of correct units (see Table 10).
Table 9. Coefficients for correct units in Task 2 for healthy control participants

<table>
<thead>
<tr>
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Table 10. Coefficients for correct units in Task 3 for healthy control participants

<table>
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<th>B</th>
<th>t</th>
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<tbody>
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<td>-.45</td>
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<td>Education</td>
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<td>.30</td>
<td>2.24</td>
<td>.03</td>
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</tbody>
</table>

3.4.3.3 Number of correct and informative units

A model including the total number of correct and informative units as the dependent variable accounted for 35.9% (adjusted $R^2 = 32.6\%$) of the variance, which was highly significant ($F(2, 39) = 10.90, p < .001$). Both age and education predicted number of correct and informative units (Table 11), demonstrating that participants who were younger and had more years in education tended to write more correctly spelt informative open class words.

Table 11. Coefficients for correct and informative units in all tasks for healthy control participants

<table>
<thead>
<tr>
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<th>SE B</th>
<th>B</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
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<td>2.76</td>
<td>.42</td>
<td>3.27</td>
<td>.002</td>
</tr>
</tbody>
</table>
As was the case for units and correct units, the model for Task 1 was unsuccessful for predicting number of correct and informative units (F (2, 39) = 2.75, p=.08). However, the model for Task 2 was successful (F (2, 39) = 12.49, p< .001). The model accounted for 39% of variance (adjusted R² = 32.6%) and both variables were significant predictors (see Table 12). Moreover, the Task 3 model was able to predict the number of correct and informative units (F (2, 39) = 9.06, p= .001), with the model accounting for 31.7% of the variance (adjusted R² = 28.2%) and both factors making a significant contribution to the model (see Table 13).

Table 12. Coefficients for correct and informative units in Task 2 for healthy control participants

<table>
<thead>
<tr>
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<th>SE B</th>
<th>B</th>
<th>t</th>
<th>p-value</th>
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<td>.004</td>
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Table 13. Coefficients for correct and informative units in Task 3 for healthy control participants

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<th>SE B</th>
<th>B</th>
<th>T</th>
<th>p-value</th>
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<td>-.48</td>
<td>-3.66</td>
<td>.001</td>
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<tr>
<td>Education</td>
<td>2.15</td>
<td>.99</td>
<td>.29</td>
<td>2.17</td>
<td>.04</td>
</tr>
</tbody>
</table>
3.5 Discussion

The primary aim of this study was to collate normative data on the mean number of units, correct units and correct and informative units written within timed emails. Email writing data were collected from forty two healthy control participants and is being made available for use by clinicians and researchers. The second aim was to establish whether these measures were stable across multiple testing trials. All three measures were found to be stable across trials.

The third aim of the study was to determine whether there is a relationship between writing productivity and accuracy and the factors age and education. Both age and education were successful in predicting the number of units, correct units and correct and informative units in Tasks 2 and 3, but not Task 1. This is an interesting finding considering that all three tasks were designed to simulate email writing and were written within the same time limit. In fact, the three tasks were selected as they represented different purposes and topics and were expected to differ in terms of their level of difficulty. As expected, responses to Task 1 (making an arrangement) were markedly shorter than responses to Tasks 2 (recounting an event) and 3 (expressing a concern), whereas Tasks 2 and 3 were, on average, similar in length. Task 1 was expected to be shorter and to require simpler (more frequent) vocabulary and less complex syntactic structures. These results indicate that when tasks become more challenging in terms of length, complexity and therefore time restrictions, that differences between different age groups and levels of education become more noticeable.

Therefore, at least for some email tasks, it seems that age and education are factors that affect spelling productivity and accuracy within emails. This study thus contributes to the existing evidence that level of education is a factor in internet skill and use (Bonfadelli, 2002; Deursen & van Dijk, 2010; OXIS, 2015) and that there is an age-related decline in the skills necessary for or related to writing.
emails, including spelling ability (MacKay & Abrams, 1998; Stuart-Hamilton & Rabbitt, 1997), word-retrieval (Griffin & Spieler, 2006; Burke, MacKay, Worthley, & Wade, 1991), number of ideas produced within utterances (Kemper, Greiner, Marquis, Prenovost, & Mitzner, 2001) naming accuracy (Borod, Goodglass, & Kaplan, 1987; Kaplan, Goodglass, & Weintraub, 1983; Nicholas, Brookshire, MacLennan, Schumacher, & Porrazzo, 1989), word retrieval speed (Spieler & Griffin, 2006), discourse structure (Whitworth et al., 2015), and general internet skills (Deursen & van Dijk, 2010). A further related factor may be frequency of internet and email use, considering that younger adults use the internet (including email and social networking sites) more frequently than older adults (ONS, 2014; OXIS, 2015), and may therefore have more practice in generating and typing these types of messages. These findings have important implications for clinical practice. They suggest that reduced writing productivity or accuracy may be related to an individual’s age or level of education, not just to their neurological condition. This implies that, firstly, different norms should be used for different age ranges and levels of education so that individuals with neurological damage can be compared to an appropriate neuro-typical population and, secondly, that appropriate, ecologically valid tasks should be selected for particular age ranges.

One limitation of this study was the potential bias in the sample with it being largely female (only 21.4% were male), consisting of high levels of 16-18 year olds and over 65s, and being relatively well-educated (mean of 13 years). This reflects the difficulties in recruiting healthy control participants in a university setting, where volunteers (here predominantly retired university staff, outreach students, and colleagues, friends and family members of the first author) often have a higher level of education than the general population. Particularly people of working age can be difficult to recruit because of time commitments.
A further limitation was the fact that the discourse measures chosen for this task were all similar in that they only allowed for a lexical-level analysis. If this assessment were to be used with people with aphasia who are likely to have difficulties with other levels of language processing, normative data on different aspects of writing production would be useful, for example, on the psycholinguistic characteristics of words (e.g. imageability and frequency ratings) syntax (range of syntactic constructions) and discourse structure (i.e. coherence and cohesion). There is also scope for more content based measures of informativeness, for example, with independent assessors rating the emails on how well the message was conveyed or how many units of information were produced. Alternatively, participants could rate their own performance within interviews or rating scales. As the aim of writing an email is to convey a message, then measures of informativeness and success may be more appropriate than length and accuracy, particularly considering that in email writing brevity can be an advantage and errors are becoming more acceptable. Another potential difficulty with this assessment as a functional outcome measure is that the tasks chosen will not necessarily reflect the functional writing activities of all potential patients. As Parr (1996) notes, a difficulty with assessments that pre-select ‘functional tasks’ (e.g. Communicative Abilities in Daily Living, Holland, 1999) is that they do not represent the activities of all patients, and there is perhaps more clinical value in selecting tasks relating to individual spelling needs and preferences.

In this study, a set of neuro-typical email data has been analysed in terms of productivity and spelling accuracy to be used to measure activity-level outcomes in the clinical studies reported in Chapters 5 and 6. The measures were stable across trials for ten participants matched to participants with aphasia (described in the following chapters), suggesting that these measures are a reliable method for measuring the therapy outcomes of these patients with spelling difficulties. This study has also shown that different email tasks with
different topics and purposes can elicit different responses, even in terms of the number of words produced. This implies that discourse elicitation methods should be considered carefully for people with aphasia. Furthermore, it follows that a range of tasks should be used to measure the patients’ language skills, and, finally, that tasks should be analysed separately (Whitworth et al., 2015) as particular genres are characterised by specific language features (Butt, Fahey, Spink, & Yallop, 1999; Coehlo, 2002). Future studies could build on this set of preliminary data with a greater range of writing tasks and discourse measures (informed by a large number of people with aphasia) and greater numbers of healthy control and stroke participants so that an ecologically valid functional writing assessment for people with aphasia can be developed.
Chapter 4. Comparing uni-modal and multi-modal therapies for improving writing in acquired dysgraphia after stroke


4.1 Abstract

Background: Writing therapy studies have been predominantly uni-modal in nature; i.e. their central therapy task has typically been either writing to dictation or copying and recalling words. There has not yet been a study that has compared the effects of a uni-modal to a multi-modal writing therapy in terms of improvements to spelling accuracy.

Aims: A multiple-case study with eight participants aimed to compare the effects of a uni-modal and a multi-modal therapy on the spelling accuracy of treated and untreated target words at immediate and follow-up assessment points.

Methods and Procedures: A cross-over design was used and within each therapy a matched set of words was targeted. These words and a matched control set were assessed before as well as immediately after each therapy and six weeks following therapy.

Outcomes and Results: The two approaches did not differ in their effects on spelling accuracy of treated or untreated items or degree of maintenance. All participants made significant improvements on treated and control items; however not all improvements were maintained at follow-up.

Conclusions: The findings suggested that multi-modal therapy did not have an advantage over uni-modal therapy for the participants in this study. Performance differences were instead driven by participant variables.
4.2 Introduction

A substantial body of research has investigated the effects of deficit-focused writing therapies for people with aphasia (e.g. Beeson, 1999; Luzzatti, Colombo, Frustaci, & Vitolo, 2000; Rapp, 2005; Raymer, Strobel, Prokup, Thomason, & Reff, 2010; Schmalzl & Nickels, 2006). These therapies have been shown to be successful in improving single-word writing in people with a range of types and severities of dysgraphia. One factor that has not yet been investigated is the effect of multi-modality within writing therapy tasks.

The concept of people with aphasia relearning a target word through completing tasks in different modalities, i.e. through saying the word, gesturing, writing the word and making semantic, phonological or orthographic decisions about the word, is certainly not novel. Howard, Patterson, Franklin, Orchard-lisle and Morton (1985) advocated a multi-modal approach to eliciting words from patients within a spoken naming therapy. They investigated the effects of semantic and phonological cues as prompts in picture naming and showed through different experiments that naming could be improved by asking participants to carry out spoken word to picture matching tasks, as well as written word to picture matching, semantic judgement, repetition and rhyme judgement tasks and through being shown a picture together with a spoken word that rhymes with the target. More recently, a study by Weill-Chounlamountry, Capelle, Tessier & Pradat-Diehl (2013) investigated the effects of a computer-delivered phonological multi-modal therapy for naming. The participant with fluent aphasia was presented with a picture of an object and then completed a sequence of tasks including rearranging the letters, verbally repeating the syllables, graphemes and whole word, copying letters, syllables and the whole word, delayed copying, writing the name and then finally saying the word. This therapy led to
significant improvements to oral naming of trained and untrained items, which was maintained at 3 month follow up.

Rose and colleagues (e.g. Attard, Rose & Lanyon, 2013; Rose & Douglas, 2008; Rose, Douglas & Matyas, 2002; Rose, Attard, Mok, Lanyon & Foster, 2013) have investigated the efficacy of combining verbal and gesture tasks to improve naming. Rose & Douglas (2008) and Rose et al. (2002) found this combined approach to be equally as effective as both verbal and gesture therapies for participants with both lexical-semantic and phonological naming impairments.

Recently, Rose et al. (2013) compared constraint-induced therapy (CIATplus) to a multi-modal treatment (M-MAT, Rose & Attard, 2011) for their effects on naming accuracy in 11 participants with aphasia. M-MAT employed a cueing hierarchy, in which participants were asked to gesture, draw, copy and repeat the target words. CIATplus consisted of a cueing hierarchy of phonemic and written cues, with participants only being asked to name the item. It was found that both treatment approaches were equally efficacious in terms of mean effect size across participants for noun and verb naming, although 6 participants expressed a preference for M-MAT, whereas only 3 preferred CIATplus.

Some writing therapy studies have also demonstrated successful outcomes following therapy approaches that have been multi-modal (Ball, de Riesthal, Breeding, & Mendoza, 2011; Beeson and Egnor, 2006; Behrmann, 1987; Cardell & Chenery, 1999; Carlomagno, Iavarone, & Colombo, 1994; de Partz, Seron, & Vanderlinden, 1992; Hatfield & Weddell, 1976; Schmalzl & Nickels, 2006; Weekes & Coltheart, 1996). For example, Ball et al. (2011) modified Anagram and Copy Treatment (ACT) and Copy and Recall Treatment (CART) for three participants with aphasia by incorporating naming and spoken repetition. Within sessions, participants were first asked to name a drawing. If they could not do this, they were asked to repeat the word spoken by the therapist three times. They then continued
with ACT, which involved writing the picture name, arranging letters of the word into the correct order, copying the written word and then writing the word from memory. At home, participants were encouraged to repeat target words that they heard in video clips and then to proceed with CART (copying words and then writing them from memory). All participants improved their written naming accuracy of treated items and one participant showed generalisation to untreated words.

There has been one published study which has compared uni-modal and multi-modal writing therapies. Schwartz, Nemeroff and Reiss (1974) compared an “experimental” writing therapy given to eight people with aphasia to a “control” condition of multi-modal therapy provided to six people with aphasia who were matched on age, months post brain injury, education and pre-therapy scores on the Porch Index of Communicative Ability (PICA; Porch, 1971). In the experimental condition, participants completed a range of writing tasks for each item, including writing the alphabet from memory, written picture naming, writing to dictation after hearing the word once or three times and, finally, writing words that had been placed into a spoken sentence. The multi-modal therapy incorporated the following tasks: spoken picture naming, spoken word-to-picture matching, reading aloud, written picture naming and repetition. The same words were targeted in both conditions. However, within each condition, sets of words were split between different tasks. For example in the multi-modal condition, some words were trained with spoken picture naming while others were trained with reading aloud. Therefore, in the multi-modal therapy individual words were not targeted in different modalities. Success in therapy was measured using the PICA. No significant difference was found between the two groups’ scores. However, the experimental group made more improvement compared to baseline than the control group.
These studies provide initial evidence that a multi-modal therapy can be effective for improving writing in people with dysgraphia; however, they do not indicate whether a multi-modal approach is more effective than a uni-modal approach for improving writing, i.e. leads to greater accuracy scores across matched sets. Multi-modal treatments are often viewed as being more effective than uni-modal treatments by speech and language therapists, although there is a lack of evidence to support this claim (Rose & Douglas, 2008). Lexical writing therapies that have been uni-modal in nature in which participants copy and recall words or write words from dictation with cues (e.g. Beeson, 1999; Schmalzl & Nickels, 2006) have been shown to be successful in terms of gains to treated items; however these gains have often not been maintained and have seldom led to generalisation to untreated words (exceptions have usually been to participants with graphemic buffer disorder, e.g. Mortley et al., 2001 Panton & Marshall, 2008; Pound, 1996; Rapp, 2005; Rapp & Kane; 2002; Raymer, Cudworth & Haley, 2003; Sage & Ellis, 2006; Thiel & Conroy, 2014).

Connectionist theories of language processing, such as the Primary Systems Hypothesis (Patterson & Lambon, 1999) and the Triangle model (Plaut, McClelland, Seidenberg & Patterson, 1996, see Figure 3) have conceptualised specific skills such as reading and writing as being underpinned by an interaction between the three core underlying systems: semantics, phonology and orthography. Therefore, disruption to any of these core systems due to brain damage will result in a disruption to reading and writing. Despite a rich and complex literature, there have been relatively few studies which have applied connectionist principles to neurorehabilitation. The few available language-focused studies have tended to address anomia (e.g. Abel, Willmes & Huber, 2007; Abel, Huber & Dell, 2009) and compared different connectionist models in terms of their utility for treating symptoms and predicting therapy gains. Similar to work within connectionist modelling of reading and dyslexia, studies on
dysgraphia have modelled spelling acquisition and breakdown in simulations of brain damage (e.g. Loosemore, Brown & Watson, 1991) but not yielded treatment principles and investigations.

At least three hypotheses can be proposed to support the contention that multi-modal therapy may be distinct from and potentially more beneficial than uni-modal in terms of variables such as extent of accuracy achieved, likelihood of generalisation, or maintenance of therapy gains. Firstly, it is hypothesised, that consistent with connectionist models of language processing and distributed representations (e.g. Welbourne & Lambon Ralph, 2007), in a multi-modal therapy, distributed semantic, phonological and orthographic representations will be activated for each target word, which will strengthen connections and weight adaptations between language-related units (semantics, phonology, orthography). This may lead to more interactive and robust processing, and therefore more accurate and lasting learning of written words relative to a uni-modal therapy in which words have just been copied and recalled. Secondly, as a consequence, however, because each word will be copied less frequently, multi-modal processing may well have the potential disadvantage of showing a slower trajectory of increasing accuracy scores relative to uni-modal therapy, i.e. fewer items may be ‘relearnt’ over set timeframes. Finally, it is hypothesised that targeting phonology, semantics and orthography will strengthen these underlying systems, which may result in improved writing accuracy for untreated words, i.e. greater evidence of generalisation effects following multi- as opposed to uni-modal therapy.
The aim of this within-participants multiple case study was to answer the following questions:

1. Is a multi-modal therapy more effective than a uni-modal therapy in improving spelling accuracy across matched sets?
2. Does a multi-modal therapy lead to a greater degree of generalisation to untreated words than a uni-modal therapy?
3. Is a multi-modal therapy more effective than a uni-modal therapy in terms of maintenance of learning effects across matched sets once treatment has concluded?
4.3 Method

4.3.1 Recruitment

Eight participants were recruited to this study. To be included participants had to have acquired dysgraphia, defined as an acquired spelling impairment as a symptom of aphasia, following a stroke. They had to be at the chronic stage of their brain injury (i.e. post six months). They had to have sufficient visual acuity and motor ability for handwriting. Finally they needed to be monolingual speakers of English. They were screened using writing subtests from the Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004) and were accepted into the study if they had between 10% and 90% letters correct. The lower cut-off was established so that all participants in the study could retrieve at least part of a word at baseline. The upper cut-off of 90% was set so all participants had at least some writing impairment, but this allowed for those with high level writing impairments to be included. These broad boundaries were chosen so that participants had a large range of spelling ability. Each potential participant was considered for inclusion into the study by the research team based on individual assessment findings and spelling profiles.
4.3.2 Participants

4.3.2.1 Background Assessments

The participants completed a battery of linguistic and writing assessments. Tables 14, 15, 16 and 17 display participants’ demographic information, screen scores, spelling and language assessment results and aphasia and dysgraphia characteristics. Participants have been ordered according to total baseline spelling scores on the PALPA word spelling subtests, with the most impaired to the left and the least impaired to the right. These tables are followed by a description of each participant’s language and writing skills. All assessments were administered by the first author. A small sample of participants’ responses to the PALPA 44 (Regularity and Spelling Test) have been presented in Appendix 3. Tables 35 to 37 show an error analysis and total numbers of error types found in this sample.
Table 14. Demographic data and screen scores of 8 participants in lexical spelling therapy study

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<tr>
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<td>22</td>
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Table 15. BDAE and PPT scores of 8 participants in lexical spelling therapy study

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<th>KR</th>
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<tr>
<td>Fluency</td>
<td>21</td>
<td>11</td>
<td>3</td>
<td>13</td>
<td>4</td>
<td>21</td>
<td>21</td>
<td>17</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Conversation</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>7</td>
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<td>7</td>
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</tr>
<tr>
<td>Auditory</td>
<td>23</td>
<td>20</td>
<td>21</td>
<td>30</td>
<td>27</td>
<td>24</td>
<td>26</td>
<td>30</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Articulatory comprehension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Articulatory agility</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Recitation</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Repetition</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Naming</td>
<td>18</td>
<td>30</td>
<td>1</td>
<td>20</td>
<td>22</td>
<td>27</td>
<td>36</td>
<td>31</td>
<td>37</td>
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<td>Reading</td>
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<tr>
<td>Writing</td>
<td>57</td>
<td>58</td>
<td>52</td>
<td>40</td>
<td>43</td>
<td>63</td>
<td>62</td>
<td>66</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>PPT</td>
<td>36</td>
<td>52</td>
<td>51</td>
<td>49</td>
<td>46</td>
<td>43</td>
<td>49</td>
<td>48</td>
<td>52</td>
<td>49/52</td>
</tr>
</tbody>
</table>

Table 16. PALPA scores of 8 participants in lexical spelling therapy study

<table>
<thead>
<tr>
<th>Participants</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
<th>Cut-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALPA 39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Letter</td>
<td>6/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>-</td>
</tr>
<tr>
<td>4-Letter</td>
<td>5/6</td>
<td>6/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>4/6</td>
<td>6/6</td>
<td>6/6</td>
<td>-</td>
</tr>
<tr>
<td>5-Letter</td>
<td>1/6</td>
<td>5/6</td>
<td>4/6</td>
<td>4/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>5/6</td>
<td>-</td>
</tr>
<tr>
<td>6-Letter</td>
<td>1/6</td>
<td>3/6</td>
<td>2/6</td>
<td>3/6</td>
<td>4/6</td>
<td>3/6</td>
<td>2/6</td>
<td>5/6</td>
<td>-</td>
</tr>
<tr>
<td>PALPA 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Imageability, High Frequency</td>
<td>7/10</td>
<td>6/10</td>
<td>7/10</td>
<td>5/10</td>
<td>6/10</td>
<td>7/10</td>
<td>8/10</td>
<td>9/10</td>
<td>9.0</td>
</tr>
<tr>
<td>High Imageability, Low Frequency</td>
<td>4/10</td>
<td>2/10</td>
<td>6/10</td>
<td>4/10</td>
<td>6/10</td>
<td>6/10</td>
<td>7/10</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Low Imageability, High Frequency</td>
<td>2/10</td>
<td>1/10</td>
<td>1/10</td>
<td>3/10</td>
<td>3/10</td>
<td>5/10</td>
<td>5/10</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>Low Imageability, Low Frequency</td>
<td>2/10</td>
<td>1/10</td>
<td>1/10</td>
<td>5/10</td>
<td>3/10</td>
<td>5/10</td>
<td>5/10</td>
<td>4/10</td>
<td>6.4</td>
</tr>
<tr>
<td>PALPA 44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular Words</td>
<td>12/20</td>
<td>12/20</td>
<td>13/20</td>
<td>13/20</td>
<td>15/20</td>
<td>18/20</td>
<td>14/20</td>
<td>13/20</td>
<td>-</td>
</tr>
<tr>
<td>Exception Words</td>
<td>6/20</td>
<td>9/20</td>
<td>10/20</td>
<td>8/20</td>
<td>10/20</td>
<td>7/20</td>
<td>13/20</td>
<td>12/20</td>
<td>-</td>
</tr>
<tr>
<td>PALPA 45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-word Spelling</td>
<td>9/24</td>
<td>0/24</td>
<td>0/24</td>
<td>10/24</td>
<td>2/24</td>
<td>19/24</td>
<td>0/24</td>
<td>4/24</td>
<td>-</td>
</tr>
</tbody>
</table>

PALPA = Psycholinguistic Assessments of Language Processing in Aphasia (Kay, Lesser, & Coltheart, 1992), PALPA 39 = Letter Length Spelling, PALPA 40 = Imageability and Frequency Spelling, PALPA 44 = Regularity and Spelling
### Table 17. Aphasia and dysgraphia characteristics of 8 participants in lexical spelling therapy study

<table>
<thead>
<tr>
<th>Assessment</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluent/ Non-fluent</td>
<td>Fluent</td>
<td>Non-fluent</td>
<td>Non-fluent</td>
<td>Fluent</td>
<td>Non-fluent</td>
<td>Fluent</td>
<td>Fluent</td>
<td>Fluent</td>
</tr>
<tr>
<td>Effects in writing</td>
<td>Imageability; length</td>
<td>Imageability</td>
<td>Imageability; length</td>
<td>None</td>
<td>None</td>
<td>Regularity; lexicality</td>
<td>None</td>
<td>Imageability</td>
</tr>
<tr>
<td>Spelling error types</td>
<td>Omission, substitution, &lt;50% of target; semantic (occasional)</td>
<td>Omission, substitution, &lt;50% of target; semantic (occasional)</td>
<td>Transposition, addition, omission, &lt;50% of target; semantic (occasional)</td>
<td>Addition, substitution; omission; addition, omission; &lt;50% of target; morph.</td>
<td>Substitution; addition, omission; transposition, phonological</td>
<td>Addition; omission</td>
<td>Addition; omission</td>
<td>Addition; morphological</td>
</tr>
<tr>
<td>Dysgraphia type</td>
<td>Surface</td>
<td>Deep</td>
<td>Deep</td>
<td>GBD</td>
<td>Phonological</td>
<td>Surface</td>
<td>Phonological</td>
<td>Phonological</td>
</tr>
</tbody>
</table>

*Phonological = Affected by the sound of the target word: includes phonologically similar words and phonologically plausible non-words. Letter additions, substitutions, transposition (movement) and omission errors only include responses with at least 50% letters of target word. <50% of target letters = Errors with less than 50% of letter in target word; does not include responses that are phonologically or semantically related to target; semantic = responses with an associated meaning to the target word. Morph = morphological error, i.e. a response with an additional morpheme added (e.g. plural s). GBD = graphemic buffer disorder*
4.3.2.2 Description of participants’ linguistic and writing skills

JP suffered a stroke in 2004 subsequent to surgical removal of a brain tumour in 1999. She presented with unimpaired spoken language within conversation, although her scores on the BDAE revealed impairments across all language skills. She scored 36/52 on the Pyramids and Palm Trees Test (matching pictures; Howard & Patterson, 1992), which indicated impaired semantics. When writing words to dictation, she converted sounds to letters aloud (a strategy she had learnt in previous therapy). She wrote 9/24 non-words to dictation and showed a significant length effect, when 3 and 4 letter words on the PALPA 39 were compared statistically to 5 and 6 letter words (\( p < .001 \), Fisher’s exact test) and a significant imageability effect (\( p = .02 \), Fisher’s exact test). She demonstrated a marked disparity in her ability to write regular and irregular words (although the difference was not statistically significant). Furthermore, she often regularised irregular words (e.g. ‘serkle’ for circle, ‘clok’ for clock) and made omission, substitution and transposition errors. Her difficulty with irregular words, her tendency to rely on phoneme to grapheme conversion rules as opposed to stored representations and her resulting regularisation errors suggested that she had surface dysgraphia. Relative to the other participants she had a low score (18/27) on the CAT copying task (Swinburn, Porter & Howard, 2004), also suggesting damage to the peripheral components of writing.

DM had non-fluent aphasia following a stroke in 2007. He communicated effectively with spoken language, however, predominantly with nouns due to agrammatism. He showed a significant imageability effect on the PALPA 40 (Kay, Lesser & Coltheart, 1992) (\( p = .03 \), Fisher’s exact test), was unable to write any non-words to dictation and made occasional semantic errors (e.g. ‘dish’ for spoon and ‘post’ for letter) as well as letter omission and substitution errors. Some of his responses were unrelated to the target with less than 50% letters correct, e.g. ‘hidder’ for think. He
had more difficulty writing verbs than nouns, and in many cases could not retrieve any of the word. His writing impairment could best be described as deep dysgraphia due to his inability to write non-words, his semantic errors and his imageability effect.

KR presented with severe non-fluent aphasia caused by a stroke in 2008. She communicated by producing a few single spoken words, writing single words and short sentences, and drawing. On the PALPA 40 (Imageability and Frequency Spelling) she scored significantly lower on low imageability words than high imageability words ($p < .001$, Fisher's exact test) and on the PALPA 39 she showed a length effect ($p = .03$, Fisher's exact test). KR’s errors on these assessments included transposition, addition, omission and occasional semantic errors (e.g. ‘hand’ for glove). Many of her responses consisted of less than 50% of the letters in the target word. She did not write any non-words correctly on the PALPA 45. Based on her difficulty in spelling non-words, her imageability effects and her semantic errors, KR has been classified as having deep dysgraphia. Furthermore her length effect and errors were characteristic of graphemic buffer disorder.

AD had severely impaired expressive language following a stroke in 2009. Her speech was fluent but with frequent phonological errors. Her errors on word and non-word spelling assessments included letter additions, omissions, substitutions and morphological errors. Some of her responses contained less than 50% of the target letters. She correctly spelled 10 non-words to dictation, indicating that she had some ability to convert phonemes to graphemes. Her symptoms did not point clearly towards any one dysgraphic syndrome. However, her errors and the fact that her words and non-words were similarly affected (41.7% correct non-words; 53.8% correct words) suggest that she may have had a graphemic buffer disorder (Rapp, 2005; Sage & Ellis, 2006), although she did not show an effect of length.
Since suffering a stroke in 1995, JB presented with aphasia, but also severe dysarthria. Her writing, which she had learnt to do with her non-dominant left hand, was very slow, effortful and often quite unintelligible. She only managed to write two non-words to dictation and sometimes lexicalised them (e.g. ‘fond’ for fon and ‘pearl’ for birl). Her incorrect responses either included less than 50% of the letters in the target word, or were letter substitution, addition or omission errors. Her impaired non-word writing and her unrelated responses were characteristic of phonological dysgraphia.

SR had a stroke in 2007 and then another in 2010. His language skills appeared to be intact within conversations; however background language assessments revealed impaired naming, auditory comprehension and semantic access. He also had residual writing difficulties. He had more difficulty with spelling exception words than regular words on the PALPA 44 ($p < .001$, Fisher's exact test). Furthermore, he was able to spell 19/24 non-words correctly. The majority of his errors were either letter substitution, addition, omission or transposition errors or were regularisations of low frequency exception words (e.g. ‘sigaret’ for cigarette, ‘nefew’ for nephew). Based on these assessment results, SR’s spelling impairment can be described as surface dysgraphia.

MB had a stroke in 2010, which resulted in fluent aphasia with occasional word-finding difficulties. His errors on spelling tests were a mixture of letter omission and addition errors. He did not spell any non-words to dictation correctly and on ten occasions showed lexicality effects (e.g. ‘hug’ for cug, ‘fog’ for fon). These assessments suggest that his predominant difficulty was with converting phonemes to graphemes with the absence of a stored representation of the word. He therefore fitted the profile of phonological dysgraphia.

Following a stroke in 2010, EB had fluent speech with occasional phonological errors and word finding difficulties. She showed an imageability effect on the PALPA 40 ($p = .02$, Fisher's exact test) and
only wrote four non-words correctly to dictation, indicating a more severe impairment in spelling non-words compared to words. Her responses often consisted of correct initial and final spellings with the middle of the word being incorrect. This was especially true for longer words that could be segmented into morphemes (e.g. 'accondation' for accommodation). Many of her incorrect responses were letter omission, addition or substitution errors; however, she also frequently added grammatical morphemes onto dictated words. The difficulties with converting phonemes to graphemes within non-words and the imageability effect suggest that EB had phonological dysgraphia.

In summary, the participants had a broad range of dysgraphia severities and types, with surface, phonological and deep dysgraphias being represented and two participants showing possible symptoms of graphemic buffer disorder. Some had mixed types of dysgraphia, with symptoms of more than one syndrome. It is important to note that many people who present with dysgraphic symptoms do not fit neatly into any one category. According to Beeson and Rapscak (2002) the subcategories of dysgraphia can be useful for communicating clusters of symptoms, but are best supplemented with descriptions of impaired and preserved processes. For information on participants’ writing activities, preferences and goals see Chapter 5

4.3.3 Therapy

4.3.3.1 Baseline Spelling Assessment

With the assistance of the first author and family members, participants generated a list of functionally useful words for therapy. Additionally, the first author generated three word lists of 100 words each with either easy, medium or difficult words. 70 of these (in each list) were nouns, 20 were verbs and 10 were adjectives. Words considered easier were those with higher imageability and frequency
ratings and those that were shorter in letter length. The words were partly taken from spelling, reading and picture naming assessments, such as the Object and Action Naming Battery (OANB, Druks & Masterson, 2000) for easier words and the Baxter and Warrington Spelling Test (1994) for more difficult words. Only items considered to be useful for everyday writing tasks were selected. The author added to these lists with words she considered to be useful for email writing for this group of participants based on information gathered on interests and activities during initial assessment sessions (e.g. meeting, appointment, holiday, stroke, volunteer, shopping, restaurant). Based on the severity of their dysgraphia (gauged by results of the screen and PALPA subtests) participants were asked to spell to dictation one or two of these word lists as well as the self-chosen items on three occasions. Responses were considered correct and were given a score of 1 if each letter was in the correct place. Incorrectly spelt words were scored as 0. A 20 second cut-off was given for participants to respond to each word. 120 words that were spelt incorrectly on two or three occasions were selected for three word lists for each participant which were divided in the following way: two lists were used for the two therapy manipulations and one list was not treated at all (control condition). These sets were matched for word length (phonemes and letters), word frequency, imageability, regularity and word class (i.e. number of nouns, verbs and adjectives).
4.3.3.2 Procedure

Two different therapies were provided to each participant: multi-modal therapy and uni-modal therapy. In order to control for order of therapy effects, these therapies were provided within a cross-over design (see Figure 4). Half of the eight study participants (Group 1) had uni-modal therapy and then multi-modal therapy, and the remaining participants (Group 2) had the therapies in reverse order. Participants received 5 hourly sessions of each therapy (10 hours in total) which took place over three weeks with a two week break between the two types of therapy.

Figure 4. Study design of uni-modal and multi-modal comparison study

4.3.3.3 Uni-Modal Therapy

A schematic representation of uni-modal therapy can be seen in Figure 5. First, the participant was asked to copy the written target word from a card. The first author then gave feedback on the accuracy of the response (correct or incorrect). If it was copied incorrectly or no response was given within 20 seconds, the therapist asked the participant to copy the word from the card two more times. The second time, she commented on its accuracy. If the word was copied correctly on the first attempt, the target word and the participant’s response were covered and the participant was asked to write it from memory. Feedback was then given by the therapist on whether the production was accurate or inaccurate. If this second
response was incorrect or no response was given after 20 seconds, the card was shown once more and the participant was asked to copy from it. If it was correct, all correct versions of the word were covered and the participant was again instructed to write the word from memory. The therapist did not give feedback after this third attempt. After each attempt to write the word, the therapist produced the word verbally; however, the participant was instructed not to say the word at any time. After three attempts at writing the word (either copying or writing the word from memory) the therapist proceeded to the next item. The session ended after exactly one hour and the therapist noted which word was the last so the next session could begin with this item.

Uni-modal therapy was adapted from Copy and Recall Therapy (CART; Beeson, Rising & Volk, 2003). In both CART and the current study the participants copied and recalled words and the therapist provided the spoken form of the word before each writing attempt. However, they differed in several ways. In CART the participant was first asked to write the name of a picture. The written form of the word was only shown to the participant for copying if the attempt at written naming was incorrect. In this study, a more errorless approach was chosen, with participants being shown the correct written version of the word in the first instance. This decision was made based on previous research by Thiel & Conroy (2014) which found similar effects for errorless and errorful writing therapies. In CART if the participant made an incorrect attempt at recalling the word he/she would then repeat the copying and recalling steps for the same word, whereas in the current study, participants were asked to recall again if correct and to copy again if incorrect. Again, this design was chosen to reduce the number of errors and the related frustration for participants. The aim was that by ending each trial on a correctly written (copied) word, the correct spellings would be reinforced. Finally, the two therapies differed in their dosage. Beeson et al.’s (2003) therapy lasted around 4-5 months (when
assessments were included) and also had daily homework tasks, whereas only five sessions of uni-modal and five sessions of multi-modal therapy were provided in this study. This amount was chosen to reflect the amount of therapy that is likely to be given to stroke patients within NHS clinical care. Homework tasks were not included as with a large group of participants it could not be guaranteed that they would all complete it, which may have introduced variation between participants and/or conditions.

Figure 5. Uni-modal therapy
4.3.3.4 Multi-Modal Therapy

Figure 6 shows a schematic representation of multi-modal therapy. For each target word the following tasks were completed before the participant progressed to the next word.

1. Semantic distractors task: The participant was shown three written words with similar or associated meanings, one of which was the target word (e.g. painting, picture, art). The therapist said the target word, and the participant was instructed to point to the correct word. The therapist provided feedback on whether the answer was correct. Regardless of whether it was right or wrong, the participant was then asked to say and then copy the correct word. Feedback was given on the accuracy of the copied word.

2. Phonological task: The participant was asked to listen to the therapist saying three words or non-words and then to pick the word that was different from the other two. A piece of paper consisting of three drawn boxes was placed in front of the participant, each representing a word that the therapist was about to produce. The participant was instructed to point to the box of the word that was different from the other two. The therapist said three words or non-words that sounded similar to each other and pointed to a box for each word. Two of the words, including the middle one were the same. The other word that the participant had to identify as being different was the target word. The therapist gave feedback on whether the choice was correct. The participant was then instructed to say the word and then to write it from memory. The therapist then gave feedback about the accuracy of the written production of the target word. The phonological distractor for this task was a word or non-word with either a substituted phoneme (vowel or consonant) or consonant cluster (e.g. ‘mocolate’ for chocolate or ‘stoctor’ for doctor) or an added or omitted phoneme (e.g. ‘duncle’ for uncle and ‘appoinment’ for appointment). The
position of the addition, omission or substitution within the word varied (i.e. word initial, medial or final).

3. Orthographic distractors task: The participant was shown three written words. One of them was the correctly spelt target word. The others were distractors. The therapist said the target word, and the participant was instructed to point to the correct word. The therapist provided feedback on whether the answer was correct. Regardless of whether it was right or wrong, the participant was then asked to say and then copy the correct version of the word. Feedback was not given on the accuracy of the copied word. Distractors were generated by either adding, substituting, omitting or transposing one or two letters. It was, however, still recognisable as similar to the target word.

As in uni-modal therapy, the session ended after exactly one hour. The therapist noted which word was the last to be treated, and the next word was the first to be treated in the next session. At the beginning of the first multi-modal therapy session some practice items were used to ensure that participants understood the tasks.

This multi-modal therapy was designed to match the uni-modal therapy in as many ways as possible, so that any differences in therapy effects could be attributed to the uni-modal/ multi-modal distinction. In both therapies participants wrote the word three times with the first attempt being copied and the second attempt being recalled. Also, in both therapies the therapist said the word each time and gave feedback after the first two attempts. The tasks were inspired by the Triangle model (Plaut et al., 1996, described above) and aimed to strengthen the underlying systems necessary for spelling and the connections between these systems. Specifically, the semantic distractor task was designed to encourage semantic
activation, the phonological task was designed to improve phonological processing, the orthographic distractor and writing tasks were designed to strengthen orthographic representations, while the spoken production of the word aimed to strengthen phonological representations.

Figure 6. Multi-modal therapy
4.3.4 Post-therapy Assessment

Participants were assessed by the first author on spelling accuracy for all 120 items from multi-modal, uni-modal and control sets directly post therapy (two to four days after the last session) to measure immediate therapy effects, and six weeks post-therapy to establish whether any therapy effects had been maintained. Words from each condition were randomised within the post-therapy list to control for any order effects. If no response was provided within 20 seconds, then the therapist proceeded to the next word.

4.4 Results

The results will be set out as follows to directly answer the research questions.

1. Accuracy immediately post-therapy
2. Accuracy of untreated items
3. Accuracy at follow-up

4.4.1 Accuracy scores immediately post therapy

*Research Question 1:* Is a multi-modal therapy more effective than a uni-modal therapy in improving spelling accuracy across matched sets?

4.4.1.1 Group 1: JP, KR, AD and MB

As Group 1 had uni-modal then multi-modal therapy, the following sections will describe the post uni-modal and then the post multi-modal therapy results for each of these sets. Two sets of figures have been used to display these results. Figures 7 and 11 show the scores of all three sets at each time point (post uni-modal therapy
and post multi-modal therapy). Figures 8, 9 and 10 present the scores of each therapy or control set individually across time.

4.4.1.1.1. Post uni-modal therapy

To establish whether uni-modal therapy was effective and whether there was any generalisation to the untreated multi-modal and control sets, these scores were compared to baseline. For all sets, the baseline score was 0/40, as items included into therapy and control sets had to be failed at baseline on two or three occasions. The mean score of the uni-modal sets (25.5) was significantly higher at immediate assessment compared to baseline ($X^2 = 34.12, df= 1, p < .001, 1$-tailed). All participants improved significantly on uni-modal sets (McNemar 1-tailed, $p < .001$ for all participants). Furthermore, the mean control score (9.8/40) and (untreated) multi-modal score (11.3/40) were significantly higher than baseline at immediate assessment (control: $X^2 = 8.89, df= 1, p = .003$; multi-modal: $X^2 = 10.80, df= 1, p = .001, 1$-tailed), and each participant’s control and multi-modal scores improved significantly (Control: JP: McNemar 1-tailed, $p < .001$; KR: McNemar 1-tailed, $p = .01$; AD: McNemar 1-tailed, $p = .002$; MB: McNemar 1-tailed, $p = .002$; Multi-modal: JP: McNemar 1-tailed, $p < .001$; KR: McNemar 1-tailed, $p = .02$ AD: McNemar 1-tailed, $p < .001$; MB: McNemar 1-tailed, $p = .03$).

A comparison of mean uni-modal and (untreated) multi-modal therapy set scores (see Figure 7) shows that at this stage there was a significant difference between performance on the sets ($X^2 = 8.66, df= 1, p = .003$). This was the case for JP ($X^2 = 17.45, df= 1, p < .001$), KR ($X^2 = 15.22, df= 1, p < .001$) and MB ($X^2 = 14.13, df= 1, p < .001$). However, AD did not perform better on the uni-modal compared to multi-modal words ($X^2 = 0.85, df= 1, p = .36$). The same pattern emerged when comparing uni-modal scores to control scores. The means of each were significantly different ($X^2 = 7.02, df=$
1, \( p = .01 \), which reflected the scores of JP (\( \chi^2 = 31.80, \text{df} = 1, p < .001 \)), KR (\( \chi^2 = 13.31, \text{df} = 1, p < .001 \)) and MB (\( \chi^2 = 7.49, \text{df} = 1, p = .01 \)); however, AD’s uni-modal score did not differ significantly from her control score (\( \chi^2 = 2.76, \text{df} = 1, p = .10 \)). Control scores and multi-modal scores did not differ significantly for any participants.

4.4.1.1.2. Post multi-modal therapy

The mean score of the multi-modal sets (25.3/40) was significantly higher at immediate assessment than at baseline (\( \chi^2 = 33.71, \text{df} = 1, p < .001 \)). All participants improved significantly on multi-modal sets (McNemar 1-tailed, \( p < .001 \) for all participants). The multi-modal set score had already improved significantly after uni-modal therapy (see above) indicating some generalised effects. However, at this assessment point, the multi-modal set also increased significantly when compared to post uni-modal therapy (\( \chi^2 = 8.41, \text{df} = 1, p < .004 \), see Figure 8). This was also the case for JP, KR and MB (McNemar 1-tailed, \( p < .001 \) for all). However, AD’s score did not change significantly compared to post uni-modal therapy (McNemar 1-tailed, \( p = .50 \)).
The mean uni-modal score decreased to 18.8/40 (from 25.5/40 at post uni-modal assessment, see Figure 9) but this change was not significant ($X^2 = 1.62, df = 1, p = .20$), which was also the case for MB (McNemar 1-tailed, $p = .13$). However the scores of JP, KR and AD decreased significantly (JP: McNemar 1-tailed, $p = .008$; KR: McNemar 1-tailed, $p = .004$; AD: McNemar 1-tailed, $p = .002$). The mean uni-modal score was still significantly higher than baseline at this assessment point ($X^2 = 21.75, df = 1, p < .001$), which reflected the performance of all participants (JP: McNemar 1-tailed, $p < .001$; KR: McNemar 1-tailed, $p < .001$; AD: McNemar 1-tailed, $p = .004$; MB: McNemar 1-tailed, $p < .001$). The mean control score (13.3/40) was, again, significantly higher than baseline ($X^2 = 13.47, df = 1, p < .001$), which was also true for each participant’s control score (JP: McNemar 1-tailed, $p < .001$; KR: McNemar 1-tailed, $p = .002$; AD: McNemar 1-tailed, $p < .001$; MB: McNemar 1-tailed, $p < .001$). Considering that control scores had already improved significantly following uni-modal therapy, there was no further significant improvement following multi-modal therapy for the group ($X^2 = 0.80, df = 1, p < .37$) or for KR, AD or MB individually (KR: McNemar 1-tailed, $p = .25$; AD: McNemar 1-tailed, $p = .06$; MB: McNemar 1-tailed, $p = .25$). However, JP’s score improved further (JP: McNemar 1-tailed, $p < .001$, see Figure 10).
Figure 8. Group 1 spelling to dictation scores on multi-modal words across time

Figure 9. Group 1 spelling to dictation scores on uni-modal words across time
Post multi-modal spelling scores for each participant are shown in Figure 11. There was no significant difference between mean uni-modal and multi-modal therapy set scores ($X^2 = 1.51$, df = 1, $p = .22$). This was the case for JP ($X^2 = 1.67$, df = 1, $p < .20$), AD ($X^2 = 1.02$, df = 1, $p < .31$) and MB ($X^2 = 0.05$, df = 1, $p < .82$). However, KR performed significantly better on the multi-modal words ($X^2 = 11.57$, df = 1, $p = .001$). The mean multi-modal score did differ significantly from the mean control score ($X^2 = 5.98$, df = 1, $p = .01$), which reflected JP’s score ($X^2 = 8.57$, df = 1, $p = .003$) and KR’s score ($X^2 = 23.91$, df = 1, $p < .001$). The other two participants did not perform better on multi-modal words compared to control words (AD: $X^2 = 0.06$, df = 1, $p = .81$; MB: $X^2 = 2.58$, df = 1, $p = .11$). The mean uni-modal score did not differ from the mean control score ($X^2 = 1.04$, df = 1, $p = .31$), nor did it differ for any of the participants.
4.4.1.2. Group 2: DM, JB, SR and EB

Group 2 had multi-modal therapy before uni-modal therapy. Therefore, this section will describe the post multi-modal and then the post uni-modal therapy results for Group 2. As for Group 1, two sets of Figures have been used to present these results. Figures 12 and 16 display the scores of all three sets at each time point (post multi-modal therapy and post uni-modal therapy). Figures 13, 14 and 15 show the scores of each therapy or control set individually across time.

4.4.1.2.1. Post multi-modal therapy

Scores on each word list were compared to a baseline of 0/40. The mean multi-modal score of this group (17.3) was significantly higher than the mean baseline score (0/40) ($X^2 = 19.27, df = 1, p < .001$) This was also true for individual participants (DM: McNemar 1-tailed, $p < .001$; JB: McNemar 1-tailed, $p = .01$; EB: McNemar 1-tailed, $p < .001$; SR: McNemar 1-tailed, $p < .001$). The mean (untreated) uni-modal (8.25/40) and control scores (8.25/40) were also significantly higher than baseline (Uni-modal and Control: $X^2 = 7.01, df = 1, p = .01$), which reflected the scores of all participants (Uni-modal: DM:

The mean multi-modal score did not differ significantly from the mean uni-modal and control scores (which were both 8.25/40, see Figure 12) ($X^2 = 3.64$, $df = 1$, $p = .06$). Individuals had mixed results. JB and EB both scored the same on each untreated list (uni-modal and control), and these scores were not significantly different to their multi-modal set scores (JB: $X^2 = 0.00$, $df = 1$, $p = 1.00$; EB: $X^2 = 1.47$, $df = 1$, $p = .23$ for both conditions). SR’s multi-modal score was significantly higher than his uni-modal score ($X^2 = 5.52$, $df = 1$, $p = .02$), but was not higher than his control score ($X^2 = 2.58$, $df = 1$, $p = .11$). DM scored higher on his multi-modal set than both uni-modal and control sets (Uni-modal: $X^2 = 14.31$, $df = 1$, $p < .001$; Control: $X^2 = 20.06$, $df = 1$, $p < .001$). There was no difference between mean scores on uni-modal and control sets at this stage ($X^2 = 0.08$, $df = 1$, $p = .78$), nor between individual scores on these sets.
Post uni-modal therapy

The mean uni-modal score for this group (19/40) was significantly higher than the mean baseline score of 0/40 ($X^2$= 22.08, $df$= 1, $p < .001$), which was the case for all participants (DM: McNemar 1-tailed, $p < .001$; JB: McNemar 1-tailed, $p = .001$; EB: McNemar 1-tailed, $p < .001$; SR: McNemar 1-tailed, $p < .001$). Uni-modal words had already improved significantly when tested after multi-modal therapy. However, when these accuracy scores were compared across these two time points the mean score improved significantly following uni-modal therapy ($X^2$= 5.17, $df$= 1, $p = .02$, see Figure 13). This was also true for DM (McNemar 1-tailed, $p < .001$), SR (McNemar 1-tailed, $p = .008$) and EB (McNemar 1-tailed, $p < .001$), but not for JB (McNemar 1-tailed, $p = .06$).

The mean score of the (treated) multi-modal sets had decreased to 13.3/40 (from 17.3) since the post multi-modal assessment, but was still significantly higher than the baseline score of 0/40 ($X^2$= 13.47, $df$= 1, $p < .001$) as were participants’ individual scores (DM: McNemar 1-tailed, $p < .001$; JB: McNemar 1-tailed, $p = .002$; EB: McNemar 1-tailed, $p = .001$; SR: McNemar 1-tailed, $p < .001$). The mean multi-modal set score was maintained (since the post multi-modal assessment point) at this assessment point ($X^2$= 0.47, $df$= 1, $p = .49$, see Figure 14), which was the case for DM (McNemar 1-tailed, $p = .13$) and JB (McNemar 1-tailed, $p = .50$), but not SR (McNemar 1-tailed, $p = .008$) or EB (McNemar 1-tailed, $p = .03$).

Finally, the mean (9.5/40) and individual control scores had increased significantly from the baseline control scores of 0/40 (Mean: $X^2$= 8.52, $df$= 1, $p = .004$; DM: McNemar 1-tailed, $p < .001$; JB: McNemar 1-tailed, $p = .03$; EB: McNemar 1-tailed, $p = .004$; SR: McNemar 1-tailed, $p < .001$). It had already increased following multi-modal therapy but there was no further significant increase at this stage on a group level ($X^2$= 0.00, $df$= 1, $p = .96$) or for JB, SR or EB.
(McNemar 1-tailed, p = .50 for all, see Figure 15). However, DM showed further significant improvement to his control set.

Figure 13. Group 2 spelling to dictation scores on uni-modal words across time

Figure 14. Group 2 spelling to dictation scores on multi-modal words across time
Mean uni-modal and multi-modal scores did not differ significantly from one another at this stage ($\chi^2 = 1.16$, $df = 1$, $p = .28$, see Figure 16). This reflected the scores of three participants (DM: $\chi^2 = 0.00$, $df = 1$, $p = 1.00$; JB: $\chi^2 = 0.69$, $df = 1$, $p = .41$; SR: $\chi^2 = 0.22$, $df = 1$, $p = .64$); however, EB’s uni-modal score was significantly higher than her multi-modal score ($\chi^2 = 9.83$, $df = 1$, $p = .002$). Although the mean uni-modal score (19/40) was higher than the mean control score (9.5/40), this difference was not quite significant ($\chi^2 = 3.89$, $df = 1$, $p = .05$). DM and EB did have significantly higher uni-modal scores compared to control (DM: $\chi^2 = 7.11$, $df = 1$, $p = .01$; EB: $\chi^2 = 13.04$, $df = 1$, $p < .001$); however, JB and SR did not (JB: $\chi^2 = 1.30$, $df = 1$, $p = .26$; SR: $\chi^2 = 0.22$, $df = 1$, $p = .64$). The mean multi-modal score of this group did not differ significantly to the mean control score ($\chi^2 = 0.46$, $df = 1$, $p = .50$), which was representative of three participants’ scores (JB: $\chi^2 = 0.00$, $df = 1$, $p = 1.00$; EB: $\chi^2 = 0.07$, $df = 1$, $p = .79$; SR: $\chi^2 = 0.60$, $df = 1$, $p = .81$); however, DM had a significantly higher score on his multi-modal set than his control set ($\chi^2 = 5.99$, $df = 1$, $p = .01$).
4.4.1.3 Comparison of multi-modal and uni-modal scores

Figure 17 shows scores on uni-modal words directly after uni-modal therapy compared to scores on multi-modal words directly following multi-modal therapy for all participants. The mean scores (22.3/40 for uni-modal and 21.3/40 for multi-modal) were not significantly different from each other (Ws+ 22.0, 1-tailed, p = .31), which was also the case for all participants’ individual scores (JP: $\chi^2 = 0.26$, df = 1, $p = .61$; DM: $\chi^2 = 0.06$, df = 1, $p = .81$; KR: $\chi^2 = 2.88$, df = 1, $p = .09$; AD: $\chi^2 = 0.47$, df = 1, $p = .49$; JB: $\chi^2 = 0.30$, df = 1, $p = .59$; SR: $\chi^2 = 0.45$, df = 1, $p = .50$; MB: $\chi^2 = 0.20$, df = 1, $p = .66$; EB: $\chi^2 = 4.0$, df = 1, $p = .05$, 1-tailed).
Research Question 2: Does a multi-modal therapy lead to a greater degree of generalisation to untreated words than a uni-modal therapy?

In order to determine whether one therapy resulted in more generalisation than another, mean and individual control scores were compared across therapies (Figure 18). The mean post multi-modal control score (10.8/40) was not significantly higher than the mean post uni-modal control score (9.6/40) (Ws+ 12.0, 1-tailed, \( p = .22 \)). For seven participants, individual control scores also did not differ significantly following the two therapies (DM: \( \chi^2 = 1.65, df = 1, p = .20 \); KR: \( \chi^2 = 0.08, df = 1, p = .78 \); AD: \( \chi^2 = 0.56, df = 1, p = .46 \); JB: \( \chi^2 = 0.00, df = 1, p = .100 \); SR: \( \chi^2 = 0.00, df = 1, p = 1.00 \); MB: \( \chi^2 = 0.07, df = 1, p = .80 \); EB: \( \chi^2 = 0.00, df = 1, p = 1.00 \), 1-tailed). However, JP had a significantly higher control score following multi-modal therapy than uni-modal therapy (\( \chi^2 = 4.94, 1\)-tailed, \( df = 1, p = .03 \)). As she had multi-modal therapy after uni-modal therapy, it could be that her
generalisation following multi-modal therapy was due to the combined effects of uni-modal and multi-modal therapies.

Figure 18. Spelling accuracy scores of untreated control items post uni-modal and multi-modal therapies

4.4.3 Accuracy at follow-up assessment

Research Question 3: Is a multi-modal therapy more effective than a uni-modal therapy in terms of maintenance of learning effects across matched sets?

In order to determine whether any effects of therapies had been maintained, follow-up uni-modal scores were compared to scores on uni-modal words directly following uni-modal therapy and follow-up multi-modal scores were compared to scores on multi-modal words directly following multi-modal therapy. Both the mean uni-modal and the mean multi-modal scores decreased significantly at follow-up (Uni-modal: Ws+ 21.0, 1-tailed, \( p = .02 \); Multi-modal: Ws+ 28.0, 1-tailed, \( p = .01 \)), indicating that therapy effects had not been maintained. However, individual results were mixed. DM, EB and JB maintained both their multi-modal and their uni-modal scores at
follow-up (Multi-modal: DM: McNemar 1-tailed, $p = .13$; JB: McNemar 1-tailed, $p = .13$; EB: McNemar 1-tailed, $p = .06$; Uni-modal: DM: McNemar 1-tailed, $p = 1.00$; JB and EB: McNemar 1-tailed, $p = .06$). Both KR’s uni-modal and multi-modal scores decreased significantly at follow-up assessment (McNemar 1-tailed, $p < .001$ for both uni-modal and multi-modal therapy sets). JP and AD’s multi-modal therapy scores were not significantly different at follow-up (JP: McNemar 1-tailed, $p = .25$; AD: McNemar 1-tailed, $p = 1.00$); however, their uni-modal scores were significantly lower (McNemar 1-tailed, $p = .02$ for both). MB’s and SR’s multi-modal scores, on the other hand, did decrease significantly at follow-up (McNemar 1-tailed, $p = .03$ for MB and SR), whereas their uni-modal scores did not (MB: McNemar 1-tailed, $p = .25$; SR: McNemar 1-tailed, $p = 1.00$).

Follow-up control scores were compared to scores on control words both immediately after uni-modal therapy and multi-modal therapy. The mean control score was significantly higher at follow-up (13.5/40) compared to the mean control score immediately after uni-modal therapy (9.6/40; $W_s + 2.5$, 1-tailed, $p = .02$), but not multi-modal therapy (10.8/40; $W_s + 7.0$, 1-tailed, $p = .07$). Follow up control scores did not differ for most of the participants when compared to post uni-modal assessment (KR, AD, JB and MB: McNemar 1-tailed, $p = .50$; SR and EB: McNemar 1-tailed, $p = .13$) or post multi-modal assessment control scores (KR: McNemar 1-tailed, $p = .50$; AD: McNemar 1-tailed, $p = .13$; MB: McNemar 1-tailed, $p = .50$; SR: McNemar 1-tailed, $p = .06$; JB and EB: McNemar 1-tailed, $p = .25$), indicating that improvements to untreated words were maintained. However, DM’s control score increased to 21/40 from 7/40 after multi-modal therapy and 13/40 after uni-modal therapy, which was statistically significant in both cases (Multi-modal: McNemar 1-tailed, $p < .001$; Uni-modal: McNemar 1-tailed, $p = .004$). Furthermore, JP’s control scores increased to 29/40 at follow-up (from 14/40 following
uni-modal therapy and from 25/40 post multi-modal therapy); however this score only increased significantly from the post uni-modal control score (McNemar 1-tailed, $p < .01$).

Figure 19 shows the individual follow-up scores for the three conditions. Similar to immediate post-therapy scores, mean follow-up scores for the uni-modal and multi-modal conditions were not significantly different to each other (Ws+ 22.5, 1-tailed, $p = .29$). This reflected the results of seven participants (JP: $X^2 = 0.10$, df = 1, $p = .76$; DM: $X^2 = 0.00$, df = 1, $p = 1.00$; KR: $X^2 = 0.06$, df = 1, $p = .81$; AD: $X^2 = 0.06$, df = 1, $p = .81$; JB: $X^2 = 0.11$, df = 1, $p = .74$; SR: $X^2 = 0.00$, df = 1, $p = 1.00$; MB: $X^2 = 1.26$, df = 1, $p = .26$, 1-tailed).

However, EB had a significantly higher score on uni-modal words than multi-modal words at follow-up ($X^2 = 4.17$, 1-tailed, $df = 1$, $p = .04$). The mean control score was significantly lower than the mean multi-modal score (Ws+ 20.0, 1-tailed, $p = .03$); however for individual participants there was no significant difference between these conditions (JP: $X^2 = 1.93$, df = 1, $p = .17$; DM: $X^2 = 0.45$, df = 1, $p = .50$; KR: $X^2 = 1.55$, df = 1, $p = .21$; AD: $X^2 = 0.24$, df = 1, $p = .62$; JB: $X^2 = 0.14$, df = 1, $p = .71$; SR: $X^2 = 0.00$, df = 1, $p = 1.00$; MB: $X^2 = 0.53$, df = 1, $p = .47$; EB: $X^2 = 0.06$, df = 1, $p = .80$, 1-tailed). The mean control score was also lower than the mean uni-modal score (Ws+ 28.0, 1-tailed, $p = .01$), which was true for MB and EB (MB: $X^2 = 4.27$, 1-tailed, $df = 1$, $p = .04$; EB: $X^2 = 4.17$, 1-tailed, $df = 1$, $p = .04$) but not the other six participants (JP: $X^2 = 0.64$, df = 1, $p = .43$; DM: $X^2 = 0.81$, df = 1, $p = .37$; KR: $X^2 = 0.59$, df = 1, $p = .44$; AD: $X^2 = 0.00$, df = 1, $p = 1.00$; JB: $X^2 = 0.11$, df = 1, $p = .74$; SR: $X^2 = 0.05$, df = 1, $p = .82$, 1-tailed).
Figure 19. Spelling accuracy scores of uni-modal, multi-modal and control items at 6 week follow-up

Number of words correct

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<th>Multi-modal words</th>
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*p < .05
4.5 Discussion

A within-participants multiple case study was conducted with eight participants with acquired dysgraphia. Two approaches to spelling therapy were compared: a uni-modal therapy, in which participants copied, covered and recalled written words and a multi-modal therapy, which required participants to select the word from semantic, phonological and orthographic distracters, to say the word, to copy the word and to write the word from memory. The effects of each of these therapies on spelling accuracy were compared to a control (no therapy) condition. All participants had had their stroke at least one year prior to commencement of the study; therefore, it was unlikely that any improvements could be attributed to spontaneous recovery. It was predicted that multi-modal therapy may show a slower learning trajectory than uni-modal, but would be more effective than uni-modal therapy in terms of maintenance of learning and generalisation to untreated control items.

The results showed that all participants improved significantly on treated and untreated words following both therapies compared to baseline. On a group level, effects were not maintained six weeks later. However, on an individual basis, the results were varied; although DM, EB and JB maintained their gains to both therapy sets, there was a significant decrease in spelling accuracy of KR’s uni-modal and multi-modal words, AD and JP’s uni-modal words and MB’s and SR’s multi-modal words compared to immediately post therapy. Control scores were all maintained or increased.

During the follow-up assessment, participants were asked by the therapist about their therapy preferences. Importantly, all participants expressed a preference for multi-modal therapy due to the variation of tasks. Despite this, there were no significant differences between the effects of uni-modal and multi-modal therapies on spelling accuracy immediately post therapy. Furthermore, a comparison of
immediately post-therapy control scores showed no significant
differences between the extent to which the two therapies resulted in
generalisation to untreated items. JP had larger gains to control
items following multi-modal therapy; however, as this was her second
therapy these larger gains may be due to the cumulative effects of
both therapies. For the majority of participants, neither therapy had
an advantage over the other in terms of maintenance of learning. An
exception to this was EB. She had a significantly better follow-up
score for uni-modal words than multi-modal words. EB had had uni-
modal therapy much more recently than multi-modal therapy by the
time she completed the follow-up assessment, which might be the
reason for her higher scores on uni-modal words. However, she
actually also performed better directly following uni-modal therapy
than directly following multi-modal therapy. Although this difference
was not quite significant, it is further support that uni-modal therapy
was a more successful therapy method for EB. She seemed to
benefit from a therapy with more emphasis on writing practice than
on improving other linguistic skills.

There are several possible explanations to explain the similarity in
effects between the two therapies. Firstly, multi-modality may not be
an important enough factor in relearning to outweigh the advantage
of more frequent repetitions of a word. The two therapies were
matched for session length in order to provide a useful comparison to
clinicians about the type of therapy that would provide the most gains
when provided within standard therapy sessions. However, as each
therapy differed in time spent on each task, this meant that there was
a marked contrast between number of items treated per session for
each participant and, therefore, the number of times each item was
practised throughout the block of therapy. The mean number of
words treated per session in uni-modal therapy was 56; whereas the
mean number treated in multi-modal therapy was only 32. Therefore,
whereas uni-modal words were practised an average of 6.5 times;
multi-modal words were only practised an average of 3.6 times.
across the 5 sessions. It seems likely that the more frequent opportunities to write the word in uni-modal therapy balanced out any expected advantages of using other modalities in multi-modal therapy.

Another reason for the similar results could be that the therapies were not sufficiently distinct from one another. In both therapies, participants saw the word, copied the word, and heard the word. In multi-modal therapy, participants were instructed to say the word, whereas in uni-modal therapy, they were not. However, some participants automatically repeated or read the word as they heard it, although they were discouraged from doing this as it narrowed any differences between the therapies. Moreover, the multi-modal therapy may not have been sufficiently multi-modal as participants completed tasks in different modalities sequentially. A different interpretation of ‘multi-modal’ could be the simultaneous use of different modalities. For example, people with and without aphasia often communicate ideas by saying and gesturing a word at the same time. Furthermore, in the semantic distractor task, the participants were able to quickly select the spoken word by recognising the correct letters, as they all had sufficient reading ability to do this. For these participants, this might not have led to any more semantic activation of target words by participants than just hearing the spoken word or looking at the written word, which happened in both therapies. A semantic decision or semantic generation task might have been more successful at strengthening the representation of the target word. Boyle and Coelho (1995) have suggested that semantic tasks requiring participants to generate information about the target may lead to more lasting effects than a more passive semantic task.

A crossover design was used for this study to control for any order effects. For this reason JP’s higher scores on control words following
multi-modal therapy and EB’s higher follow-up scores following uni-modal therapy need to be interpreted with caution as in both cases the more effective therapy was the second one. One of the difficulties with having one therapy after another is that improvements to words targeted in the second therapy may have at least partly resulted from the first therapy. By using a cross-over design these order effects can be more clearly separated from effects of a particular therapy. The separate analysis on the two groups showed that for both groups the target words for the second therapy already improved significantly following the first therapy, but then that there were further significant improvements when these words were treated in the second therapy (except for JB and AD who had therapies in a different order to each other). In contrast, untreated control word sets improved significantly for all following the first therapy but there were no further significant changes on group or individual level following the second therapy, apart from for JP and DM, who had the therapies in a different order to each other. These results are further support that, firstly, both therapies were effective in improving spelling accuracy and, secondly, that neither therapy was more effective than the other.

Although there were no differences between the effects of the two therapies, there was substantial variation in the performance of individual participants. Some patterns did emerge. Firstly, the participants who made the most gains were those with the lowest pre therapy spelling scores (JP, DM, and KR). JP also had a relatively low score on the CAT copying task (Swinburn et al., 2004), indicating impairment in peripheral writing skills, which can be an indicator of a poor response to writing treatment (Beeson. Rising & Volk, 2003). The successful performance of these participants could reflect the fact that they had more room for change. Furthermore, their therapy items were shorter, higher imageability and higher frequency (e.g. guitar, stroke, family, house) which may have been easier to relearn than the therapy items that were selected for the higher level
participants (e.g. politician, disagree, Wednesday, interesting) who did not fail these easier items at baseline. Another explanation could be that the participants with more severe language and writing difficulties had a clearer motivation for improving in therapy as they wanted to be able to communicate more effectively (e.g. using writing to support face to face conversations), which led to more effort being put into sessions; whereas less severely impaired participants such as MB or EB could already use their writing skills to send text messages or write a note.

Secondly, some of the higher performing participants showed evidence of the development and use of a strategy. The most noticeable was the strategy used by JP, a participant with surface dysgraphia, who, in previous therapy, had been encouraged to segment target words and to convert phonemes to graphemes. Within the therapies in this study, she segmented words and then remembered the segments the next time she heard them. For example, she remembered ‘chicken’ as ‘chic’ ‘ken’, ‘wife’ as ‘wife’ ‘ee’ and ‘father’ as ‘fat’ ‘her’. In other words, she would store a different phonological representation of the word that helped her to remember the correct orthographic one, so that she would be able to convert these sound segments into written segments. She verbalised these strategies when she first used them, but was discouraged from speaking about the words during these therapies. However, she reported that she then said these to herself internally after this. She made substantial gains following both therapies and generalisation to untreated words, and personally felt that the increased strategy use and the repetitive use of these strategies on the target words during this time was partly responsible for these gains. DM left spaces within words for letters (usually word-medial) that he could not remember. He then wrote the word again, inserting different letters into the space until he found the correct letter. He used this strategy successfully within therapy and assessment.
This study provided further evidence that lexical therapies can be effective in improving single word writing in people with aphasia, as other studies have shown (e.g. Ball et al., 2001; Beeson, 1999; Clausen & Beeson, 2003; Jackson-Waite et al., 2003; Rapp, 2005). The fact that all participants demonstrated some improvement to untreated control items following both types of therapy was positive. One of the disadvantages to lexical therapies for writing is that they often do not result in generalisation (Beeson & Rapscak, 2002). The exceptions to this have usually been studies in which the participants have a graphemic buffer disorder (Rapp, 2005; Rapp and Kane, 2002; Raymer, Cudworth and Haley, 2003; Sage & Ellis, 2006). In this study, the improvements to untreated items in participants with a range of different dysgraphia types could be attributed to such factors as strengthened phonological, orthographic or semantic systems or a strengthened graphemic buffer (Rapp & Kane, 2002). DM believed that his increase in control item scores at follow-up assessment was due to improved ability to process the spoken word in spelling to dictation tasks (i.e. improved phonological processing). This was a skill that could have improved in both therapies, but was more explicitly encouraged in multi-modal therapy.

Alternatively, participants' improved control scores could be attributed to general improvements to non-linguistic factors such as effort, attention, motivation or self-monitoring skills. Writing differs to speech in that most people with aphasia, regardless of their severity, will continue to engage in efforts at verbal communication. It is easier to become disengaged from the experience of writing, however, through simple avoidance or delegation of writing tasks. The majority of the participants in this study had not attempted to write very often since their stroke, which may explain why during a period of increased writing and increased effort, they demonstrated some generalised improvements. The participants who made the most substantial improvements to untreated items were JP and DM.
In both cases, it is likely that they improved their strategy use throughout therapy and were able to use these on untreated words. JP, DM and KR all reported that they noticed improvements when trying to complete everyday writing tasks, such as emailing or writing shopping lists and that they had been writing more often since therapy started. This could further explain their improvement to control items. Again, these participants had been learning functional, high frequency words, such as names of family members, which were likely to be useful in everyday writing activities.

A limitation of this study was that both therapies and assessments were administered by the first author; therefore blinding was not possible. According to Tate, McDonald, Perdices Togher, Schultz & Savage (2008), using the same person to provide assessment and therapy introduces a risk of observer bias into a study. A further limitation of this study was that with relatively small numbers it has not been possible to conduct correlation analyses to investigate whether therapy success can be predicted by the nature of a participant’s spelling, language or cognitive impairment, as has been the case in the anomia literature, where 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). Future studies should use larger numbers so that individual factors can be investigated. Clinicians will then be able to use this information to determine which patients will benefit from certain therapies.

Overall, the findings have clinical implications in that they have suggested that relatively brief episodes of simple behavioural treatments and practice can be effective in improving spelling accuracy in adults with a range of linguistic and spelling impairments. An interesting observation was that where there was flexibility within therapy tasks, participants may often initiate strategies and make
proactive use of their processing strengths to find ways of enhancing and maintaining spelling accuracy.
Chapter 5. The role of learning in improving functional writing in stroke aphasia


5.1 Abstract

*Purpose:* Improving writing in people with aphasia could improve ability to communicate, reduce isolation and increase access to information. One area that has not been sufficiently explored is the effect of impairment based spelling therapies on functional writing. A multiple case study was conducted with eight participants with aphasia subsequent to stroke. This aimed to measure the effects of spelling therapy on functional writing and perception of disability.

*Method:* Participants engaged in ten sessions of copy and recall spelling therapy. Outcome measures included spelling to dictation of trained and untrained words, written picture description, spelling accuracy and psycholinguistic quality within emails, a disability questionnaire and a writing frequency diary.

*Results:* All participants made significant gains on treated and untreated words. Group analyses showed significant improvements to written picture description, but not writing frequency or perceptions of disability. Within emails, spelling accuracy did not improve significantly for the group; however, there was a significant increase in the mean length of words in post therapy emails.

Conclusions: These results show that small doses of writing therapy can lead to large gains in specific types of writing. Gains did not extend to improvements in frequency of writing in daily living and improvements to spelling accuracy did not generalise to ecological measures of email writing. There is a need to develop bridging interventions between experimental tasks towards more multi-faceted and ecological everyday writing tasks.
5.2 Introduction

In recent years, written communication via the internet and mobile phones has become an increasingly important part of everyday life in social, educational and professional spheres (Steyaert, 2002; Deursen & van Dijk, 2010). Among the multiple disabilities that can result from brain injury, one that could significantly impede access to the internet is dysgraphia, an acquired disorder of writing (Weekes, 2005). Dysgraphia frequently occurs as one symptom of aphasia (Damasio, 1998), an acquired multi-modal language disorder caused by traumatic brain injury, brain tumour, surgery, infection, or most commonly, stroke (Hallowell & Chapey, 2009). A recent survey study conducted by Menger, Morris & Salis (2014) found that people with aphasia use the internet less than people with stroke and no aphasia. Moreover, people with aphasia reported that their aphasia was the main barrier to using the internet.

The writing rehabilitation literature is dominated by single case studies evaluating model-driven impairment-based therapies, such as copy and recall therapy (Beeson, 1999) and strategies such as visual-imagery (de Partz, Seron & Vanderlinden, 1992) or phoneme to grapheme conversion (i.e., sounds to letters) (Kiran, 2005). The aim of many of these therapies has been to improve single word writing (i.e. language function), and the effects on functional, everyday writing activities (e.g. letters, emails, text messages, shopping lists) have not usually been measured. However, there have been some exceptions. Several studies have encouraged participants to generalise gains of impairment-based spelling therapies 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). For example, Mortley, Enderby and Petheram (2001) conducted a single
case study with a participant with severe writing difficulties and residual oral spelling skills. The therapy programme consisted of spelling to dictation and oral spelling practice, the development of a strategy of orally spelling words and then writing them letter-by-letter, and then practising this strategy on a computer which provided feedback and letter choices for errors. The participant learnt to use a dictionary and word prompt software to find words that he could not spell, to write these words in sentences and to use the strategies for real-life tasks such as diary and letter writing. Therapy resulted in improved single word spelling of treated and untreated items and significant improvements to all post-therapy writing tasks at immediate and follow-up assessment points. The participant was also able to write letters to his daughter, which he could not do before therapy.

One question that has not been addressed to a great extent is whether impairment-based therapies lead to improvements to functional writing tasks (i.e. to the ICF activity level) without a transfer phase, despite the fact that some initial findings have indicated that gains from lexical spelling therapies can generalise to untreated items (Ball, de Riesthal, Breeding & Mendoza, 2011; Rapp & Kane, 2000; Raymer, Cudworth & Haley, 2003) and spontaneous writing. To date, just four studies have measured the effects of impairment-based spelling therapies on spontaneous writing or written picture description (Carlomagno & Parlato, 1989; Hillis & Caramazza, 1994; Pound, 1996; Raymer et al., 2003). Carlomagno & Parlato (1989) found significant improvements to spelling in spontaneous writing in a participant with severe dysgraphia following training in phoneme grapheme conversion and development of a lexical relay strategy, where key words (which the participant could already spell, e.g. Roma for ro) were used to cue a particular syllable. Similarly, Hillis & Caramazza (1994) also trained their participant to use her phonological spelling route and to use key words to cue a particular letter. She was able to use this approach to improve her spelling
accuracy within narratives. Pound’s (1996) participant learnt an oral spelling strategy, which led to gains in spontaneous writing a picture description. Finally, Raymer, Cudworth and Haley (2003) provided a copy and recall treatment with increasing cues to a participant with damage to the orthographic output lexicon and graphemic buffer, which improved his spelling within written picture description.

Whether or not therapy does lead to improvements to functional writing, it would be useful to determine whether any changes in participants’ daily lives occur, i.e. whether participants are writing more often than before and are feeling happier about their own writing skills. Although this has been another neglected area within the writing therapy literature, some studies have measured changes to the impact of the communication disability following writing therapies. For example, Estes & Bloom (2011) used the American Speech and Hearing Association’s (ASHA) Quality of Communication Life Scale (QCL) (Frattali, Thompson, Holland, Wohl & Ferketic, 1995) to assess the impact of the participant’s aphasia on her relationships, communication, interactions, participation in social, leisure, work and education activities, and overall quality of life. It was found that following therapy (training to use voice recognition software to treat dysgraphia) there was change to one item on the assessment: “I meet the communicative needs of my job [or school]” as the participant felt that she was more productive and useful at work. Similarly, Murray & Karcher (2000) asked their participant and his wife to complete the Communicative Effectiveness Index (CETI) (Lomas, Pickard, Bester, Elbard, Finlayson & Zoghaib, 1989) to investigate whether any changes in his daily communication had occurred following a treatment targeting written verb and sentence production. The average ratings of both the participant and his wife increased after therapy, including the item concerning daily writing tasks, suggesting that they both perceived his level of disability in daily communication and activities to have decreased. These issues will also be addressed in the current study.
The aim of this study was to answer the following questions:

1. Do impairment-based lexical spelling therapies result in any significant improvements in spelling accuracy of treated and untreated words?
2. Do impairment-based lexical spelling therapies result in any significant changes to spelling accuracy and psycholinguistic quality within in emails?
3. Do impairment-based lexical spelling therapies result in any significant improvements to written picture description?
4. Do impairment-based lexical spelling therapies result in a significant increase in frequency of writing?
5. Do impairment-based lexical spelling therapies result in any significant improvements to perception of disability?

5.3 Method

5.3.1 Recruitment

Eight participants were recruited to this study. To be included, participants had to have an acquired spelling impairment following a stroke. They had to be at the chronic stage of their brain injury (i.e., at least six months since the stroke occurred). They had to have sufficient visual acuity and motor ability for writing. Finally they needed to be monolingual speakers of English. They were screened using writing subtests from the Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004).
5.3.2 Background Assessments

The participants completed a battery of linguistic and writing assessments. Tables 18, 19, 20 and 21 display participants’ demographic information, screen scores, spelling and language assessment results and writing characteristics, activities and goals. They have been ordered according to total baseline spelling scores on the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA, Kay, Lesser & Coltheart, 1992) word spelling subtests, with the most impaired to the left and the least impaired to the right. These tables are followed by a description of each participant’s language and writing skills.
Table 18. Demographic data and screen scores of 8 participants in lexical spelling therapy study

<table>
<thead>
<tr>
<th>Participants:</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>52</td>
<td>50</td>
<td>58</td>
<td>74</td>
<td>80</td>
<td>47</td>
<td>66</td>
<td>50</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Female</td>
<td>Female</td>
<td>Male</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Education (years)</td>
<td>13</td>
<td>16</td>
<td>11</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Occupation</td>
<td>News crew coordinator</td>
<td>Building surveyor</td>
<td>Personal assistant</td>
<td>Administrator</td>
<td>Factory supervisor</td>
<td>Factory worker</td>
<td>Lorry driver</td>
<td>Care manager</td>
</tr>
<tr>
<td>Event</td>
<td>Tumour; surgery; CVA</td>
<td>CVA</td>
<td>CVA</td>
<td>CVA</td>
<td>CVA</td>
<td>CVA</td>
<td>CVA</td>
<td>CVA</td>
</tr>
<tr>
<td>Years; months since CVA</td>
<td>8; 3</td>
<td>4; 8</td>
<td>3; 8</td>
<td>2; 2</td>
<td>17; 1</td>
<td>1; 10</td>
<td>1; 8</td>
<td>1; 9</td>
</tr>
<tr>
<td></td>
<td>Written picture naming</td>
<td>15/21</td>
<td>19/21</td>
<td>17/21</td>
<td>13/21</td>
<td>17/21</td>
<td>18/21</td>
<td>21/21</td>
</tr>
<tr>
<td></td>
<td>Written picture description</td>
<td>-3</td>
<td>2</td>
<td>15</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>-1</td>
</tr>
</tbody>
</table>

CAT: Comprehensive Aphasia Test (Swinburn et al., 2004).
Table 19. BDAE and PPT scores of 8 participants in lexical spelling therapy study

<table>
<thead>
<tr>
<th>Participants</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
<th>Maximum Score</th>
<th>Cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Conversation</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>21</td>
<td>21</td>
<td>17</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Auditory comprehension</td>
<td>23</td>
<td>20</td>
<td>21</td>
<td>30</td>
<td>27</td>
<td>24</td>
<td>26</td>
<td>30</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Articulatory agility</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Recitation</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Repetition</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Naming</td>
<td>18</td>
<td>30</td>
<td>1</td>
<td>20</td>
<td>22</td>
<td>27</td>
<td>36</td>
<td>31</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>12</td>
<td>36</td>
<td>20</td>
<td>28</td>
<td>31</td>
<td>35</td>
<td>34</td>
<td>37</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>57</td>
<td>58</td>
<td>52</td>
<td>40</td>
<td>43</td>
<td>63</td>
<td>62</td>
<td>66</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>PPT</td>
<td>36</td>
<td>52</td>
<td>51</td>
<td>49</td>
<td>46</td>
<td>43</td>
<td>49</td>
<td>48</td>
<td>52</td>
<td>49/52</td>
</tr>
</tbody>
</table>

BDAE = Boston Diagnostic Aphasia Examination: short version (BDAE, Goodglass, Kaplan & Barresi, 2001); PPT = Pyramids and Palm Trees Test (Howard & Patterson, 1992)
Table 20. PALPA scores of 8 participants in lexical spelling therapy study

<table>
<thead>
<tr>
<th>Participants</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
<th>Cut-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALPA 39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Letter</td>
<td>6/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>-</td>
</tr>
<tr>
<td>4-Letter</td>
<td>5/6</td>
<td>6/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>4/6</td>
<td>6/6</td>
<td>6/6</td>
<td>-</td>
</tr>
<tr>
<td>5-Letter</td>
<td>1/6</td>
<td>5/6</td>
<td>4/6</td>
<td>4/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>5/6</td>
<td>-</td>
</tr>
<tr>
<td>6-Letter</td>
<td>1/6</td>
<td>3/6</td>
<td>2/6</td>
<td>3/6</td>
<td>4/6</td>
<td>3/6</td>
<td>2/6</td>
<td>5/6</td>
<td>-</td>
</tr>
<tr>
<td>PALPA 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Imageability, High Frequency</td>
<td>7/10</td>
<td>6/10</td>
<td>7/10</td>
<td>5/10</td>
<td>6/10</td>
<td>7/10</td>
<td>8/10</td>
<td>9/10</td>
<td>9.0</td>
</tr>
<tr>
<td>High Imageability, Low Frequency</td>
<td>4/10</td>
<td>2/10</td>
<td>6/10</td>
<td>4/10</td>
<td>6/10</td>
<td>6/10</td>
<td>6/10</td>
<td>7/10</td>
<td>8.5</td>
</tr>
<tr>
<td>Low Imageability, High Frequency</td>
<td>2/10</td>
<td>1/10</td>
<td>1/10</td>
<td>3/10</td>
<td>3/10</td>
<td>5/10</td>
<td>5/10</td>
<td>5/10</td>
<td>7.7</td>
</tr>
<tr>
<td>Low Imageability, Low Frequency</td>
<td>2/10</td>
<td>1/10</td>
<td>1/10</td>
<td>5/10</td>
<td>3/10</td>
<td>5/10</td>
<td>5/10</td>
<td>4/10</td>
<td>6.4</td>
</tr>
<tr>
<td>PALPA 44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular Words</td>
<td>12/20</td>
<td>12/20</td>
<td>13/20</td>
<td>13/20</td>
<td>15/20</td>
<td>18/20</td>
<td>14/20</td>
<td>13/20</td>
<td>-</td>
</tr>
<tr>
<td>Exception Words</td>
<td>6/20</td>
<td>9/20</td>
<td>10/20</td>
<td>8/20</td>
<td>10/20</td>
<td>7/20</td>
<td>13/20</td>
<td>12/20</td>
<td>-</td>
</tr>
<tr>
<td>PALPA 45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-word Spelling</td>
<td>9/24</td>
<td>0/24</td>
<td>0/20</td>
<td>10/24</td>
<td>2/24</td>
<td>19/24</td>
<td>0/24</td>
<td>4/24</td>
<td>-</td>
</tr>
</tbody>
</table>

PALPA = Psycholinguistic Assessments of Language Processing in Aphasia (Kay et al., 1992); PALPA 39 = Letter Length Spelling, PALPA 40 = Imageability and Frequency Spelling, PALPA 44 = Regularity and Spelling.
Table 21. Writing characteristics, activities and goals of 8 participants in lexical spelling therapy study

<table>
<thead>
<tr>
<th>Assessment</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects</td>
<td>Imageability; length</td>
<td>Imageability length</td>
<td>Imageability length</td>
<td>None</td>
<td>none</td>
<td>Regularity; lexicality</td>
<td>None</td>
<td>Imageability</td>
</tr>
<tr>
<td></td>
<td>Omission, substitution, transposition, phonological</td>
<td>Omission, substitution, &lt;50% of target; semantic (occasional)</td>
<td>Transposition, addition, omission, &lt;50% of target; semantic (occasional)</td>
<td>Addition, omission, substitution &lt;50% of target; morph.</td>
<td>Substitution; addition, omission, &lt;50% of target</td>
<td>Substitution, addition, omission, transposition, phonological</td>
<td>Addition; omission</td>
<td>Addition; omission; substitution; morphological</td>
</tr>
<tr>
<td>Spelling error types</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>Surface</td>
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<td>Supporting conversation; emails; shopping lists</td>
<td>Supporting conversation; emails</td>
<td>Emails with support</td>
<td>No frequent activities</td>
<td>Occasional text messages</td>
<td>Calendar entries; shopping lists</td>
<td>Email; Facebook</td>
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<tr>
<td>Writing goals</td>
<td>More independent email use</td>
<td>Improved spelling for email writing</td>
<td>Improved spelling for email writing and conversations</td>
<td>More independent email use</td>
<td>Greetings cards; letters</td>
<td>Improved accuracy of text messages</td>
<td>Internet; text messages; shopping lists</td>
<td>More elaborate email and Facebook messages</td>
</tr>
</tbody>
</table>

Phonological = Affected by the sound of the target word: includes phonologically similar words and phonologically plausible non-words. Letter additions, substitutions, transposition (movement) and omission errors only include responses with at least 50% letters of target word. <50% of target letters = Errors with less than 50% of letter in target word; does not include responses that are phonologically or semantically related to target; semantic = responses with an associated meaning to the target word. Morph = morphological error, i.e. a response with an additional morpheme added (e.g. plural s).
5.3.3 Description of participants’ linguistic and writing skills

JP suffered a stroke in 2004 subsequent to surgical removal of a brain tumour in 1999. She presented with unimpaired spoken language within conversation, although her scores on the BDAE revealed impairments across all language skills. She scored 36/52 on the Pyramids and Palm Trees Test (matching pictures; Howard & Patterson, 1992), which indicated impaired semantics. When writing words to dictation, she converted sounds to letters aloud (a strategy she had learnt in previous therapy). She wrote 9/24 non-words to dictation and showed a significant length effect, when 3 and 4 letter words on the PALPA 39 were compared statistically to 5 and 6 letter words ($p < .001$, Fisher’s exact test) and a significant imageability effect ($p = .02$, Fisher’s exact test). She demonstrated a marked disparity in her ability to write regular and irregular words (although the difference was not statistically significant). Furthermore, she often regularised irregular words (e.g. ‘serkle’ for circle, ‘clok’ for clock) and made omission, substitution and transposition errors. Her difficulty with irregular words, her tendency to rely on phoneme to grapheme conversion rules as opposed to stored representations and her resulting regularisation errors suggested that she had surface dysgraphia. Relative to the other participants she had a low score (18/27) on the copying task on the CAT (Swinburn, Porter & Howard, 2004), also suggesting damage to the peripheral components of writing. JP used the internet including email to communicate, to book restaurants and holidays and to do shopping, but wanted to improve her writing so that she could do these things more easily and more independently.

DM had non-fluent aphasia following a stroke in 2007. He communicated effectively with spoken language, however, predominantly with nouns due to agrammatism. He showed a significant imageability effect on the PALPA 40 (Kay, Lesser & Coltheart, 1992) ($p = .03$, Fisher’s exact test), was unable to write
any non-words to dictation and made occasional semantic errors (e.g. ‘dish’ for *spoon* and ‘post’ for *letter*) as well as letter omission and substitution errors. Some of his responses were unrelated to the target with less than 50% letters correct, e.g. ‘hidder’ for think. He had more difficulty writing verbs than nouns, and in many cases could not retrieve any of the word. His writing impairment could best be described as deep dysgraphia due to his inability to write non-words, his semantic errors and his imageability effect. DM used his writing skills to support face to face conversations and to write shopping lists and emails, but was motivated to work on his writing so that he could improve the spelling accuracy within emails.

KR presented with severe non-fluent aphasia caused by a stroke in 2008. She communicated by producing a few single spoken words, writing single words and short sentences, and drawing. On the PALPA 40 (Imageability and Frequency Spelling) she scored significantly lower on low imageability words than high imageability words (*p* < .001, Fisher's exact test) and on the PALPA 39 she showed a length effect (*p* = .03, Fisher's exact test). KR’s errors on these assessments included transposition, addition, omission and occasional semantic errors (e.g. ‘hand’ for *glove*). Many of her responses consisted of less than 50% of the letters in the target word. She did not write any non-words correctly on the PALPA 45. Based on her difficulty in spelling non-words, her imageability effects and her errors, KR has been classified as having deep dysgraphia. Furthermore her length effect and errors are characteristic of graphemic buffer disorder. KR’s dominant modality for communication was writing; therefore she wanted to improve her spelling to aid face to face conversations. She already wrote short emails and wanted to improve the accuracy and speed of these.

AD had severely impaired expressive language following a stroke in 2009. Her speech was fluent but with frequent phonological errors. Her errors on word and non-word spelling assessments included
letter additions, omissions, substitutions and morphological errors. Some of her responses contained less than 50% of the target letters. She correctly spelled 10 non-words to dictation, indicating that she had some ability to convert phonemes to graphemes. Her symptoms do not point clearly towards any one dysgraphic syndrome. However, her errors and the fact that her words and non-words were similarly affected (41.7% correct non-words; 53.8% correct words) suggest that she may have had a graphemic buffer disorder (Rapp, 2005; Sage & Ellis, 2006), although she did not show an effect of length. Before the start of the study, AD enjoyed searching the internet and sending emails but needed full support with these tasks. Her goal was to become more independent at communicating via the internet.

Since suffering a stroke in 1995, JB presented with aphasia, but also severe dysarthria. Her writing, which she had learnt to do with her non-dominant left hand, was very slow, effortful and often quite unintelligible. She only managed to write two non-words to dictation and sometimes lexicalised them (e.g. ‘fond’ for fon and ‘pearl’ for birl). Her incorrect responses were either included less than 50% of the letters in the target word, or were letter substitution, addition or omission errors. Her impaired non-word writing and her unrelated responses were characteristic of phonological dysgraphia. Before the study JB did not often carry out writing tasks. She wanted to improve her writing so that she could write greetings cards and letters to friends.

SR had a stroke in 2007 and then another in 2010. His language skills appeared to be intact within conversations; however background language assessments revealed impaired naming, auditory comprehension and semantic access. He also had residual writing difficulties. He had more difficulty with spelling exception words than regular words on the PALPA 44 ($p < .001$, Fisher’s exact test). Furthermore, he was able to spell 19/24 non-words correctly.
The majority of his errors were either letter substitution, addition, omission or transposition errors or were regularisations of low frequency exception words (e.g. ‘sigaret’ for cigarette, ‘nefew’ for nephew). Based on these assessment results, SR’s spelling impairment can be described as surface dysgraphia. Since his stroke, SR handed most writing activities over to his wife although wrote occasional text messages. He wanted to improve his writing so that he could write more accurate text messages to friends and family members.

MB had a stroke in 2010, which resulted in fluent aphasia with occasional word-finding difficulties. His errors on spelling tests were a mixture of letter omission and addition errors. He did not spell any non-words to dictation correctly and on ten occasions showed lexicality effects (e.g. ‘hug’ for cug, ‘fog’ for fon). These assessments suggest that his predominant difficulty was with converting phonemes to graphemes with the absence of a stored representation of the word. He therefore fitted the profile of phonological dysgraphia. Before the study, MB’s writing activities were limited to writing shopping lists and writing appointments into his calendar. His writing goals were to be able to complete everyday writing tasks such as writing shopping lists and text messages more easily and to start using the internet.

Following a stroke in 2010, EB had fluent speech with occasional phonological errors and word finding difficulties. She showed an imageability effect on the PALPA 40 (p = .02, Fisher’s exact test) and only wrote four non-words correctly to dictation, indicating a more severe impairment spelling non-words compared to words. Her responses often consisted of correct initial and final spellings with the middle of the word being incorrect. This was especially true for longer words that could be segmented into morphemes (e.g. ‘accondation’ for accommodation). Many of her incorrect responses were letter omission, addition or substitution errors; however, she also frequently added grammatical morphemes onto dictated words. The difficulties
with converting phonemes to graphemes within non-words and the imageability effect suggest that EB had phonological dysgraphia. EB already used the internet (Facebook and email) to keep in touch with friends and family members, but wanted to improve her spelling so that she could write longer and more elaborate messages.

In summary the participants presented with a range of dysgraphia types and severities. Participants all varied in their pre-morbid and post stroke writing activities and abilities and their motivations for improving writing. Email writing was a pre-morbid activity for JP, DM, KR, AD, SR and EB. Five participants (JP, DM, KR, AD and EB) wrote emails since their stroke, and six participants (JP, DM, KR, AD, MB and EB) were motivated to improve their writing so that they could write emails. SR and JB wanted to improve their writing skills but not necessarily for email writing.
5.3.4 Therapy

Each participant completed two lexical spelling therapies: a multi-modal therapy and a uni-modal therapy (see Figures 20 and 21 for schematic representations). They received 5 hourly sessions of each therapy (ten hours in total) which took place over three weeks with a two week break between the two therapies. More detailed descriptions of the therapies and the results of this comparison study are reported elsewhere (Thiel, Sage & Conroy, 2015b; Chapter 4). In the present study, we were interested in the functional consequences of the therapies; therefore, only the combined results following both therapies have been reported.

5.3.4.1 Target words

With the assistance of the first author and family members, participants generated a list of functionally useful words for therapy. Additionally, the first author generated three word lists of 100 words each with either easy, medium or difficult words. 70 of these (in each list) were nouns, 20 were verbs and 10 were adjectives. Words considered easier were those with higher imageability and frequency ratings and those that were shorter in letter length. The words were partly taken from spelling, reading and picture naming assessments, such as the Object and Action Naming Battery (OANB, Druks & Masterson, 2000) for easier words and the Baxter and Warrington Spelling Test (1994) for more difficult words. Only items considered to be useful for everyday writing tasks were selected. The author added to these lists with words she considered to be useful for email writing for this group of participants based on information gathered on interests and activities during initial assessment sessions (e.g. meeting, appointment, holiday, stroke, volunteer, shopping, restaurant). Based on the severity of their dysgraphia (gauged by
results of the screen and PALPA subtests) participants were asked to spell to dictation one or two of these word lists as well as the self-chosen items on three occasions. Responses were considered correct and were given a score of 1 if each letter was in the correct place. Incorrectly spelt words were scored as 0. A 20 second cut-off was given for participants to respond to each word. 120 words that were spelt incorrectly on two or three occasions were selected for three word lists which were divided in the following way: two lists were used for the two therapy manipulations (40 words in each) and one list was not treated at all (40 words). These sets were matched for word length (phonemes and letters), word frequency, imageability, regularity and word class (i.e. number of nouns, verbs and adjectives).

5.3.4.2 Uni-Modal Therapy

Each participant was asked to copy the written target word from a card. If the response was incorrect, they had to copy the word two more times. If the initial response was correct, the card was covered and the participant attempted writing the word from memory. If this was response was correct, they wrote from memory a second time; otherwise they copied the word again. The therapist provided feedback on accuracy after the first two attempts. After each attempt to write the word, the therapist produced the word verbally.
5.3.4.3 Multi-Modal Therapy

For each target word the following steps were completed before the participant progressed to the next word.

1. The participant was instructed to select the target word from written semantic distractors (e.g. tennis, football, rugby) in response to the spoken word, then to say and copy the correct word.
2. The participant listened to three words or non-words (e.g. mocolate, mocolate, chocolate). A piece of paper consisting of three drawn boxes was placed in front of the participant, each representing a word that the therapist was about to produce. The participant was instructed to point to the box of the word that was different from the other two, i.e. the target word. The participant was then instructed to say the word and then to write it from memory.
3. The participant was instructed to select the target word from two written orthographic distractors (i.e. incorrectly spelt forms...
such as ‘elehpant’ and ‘ellephant’ for elephant) in response to
the spoken word, then to say and copy the correct word.

After the first two attempts at writing the word (in steps 1 and 2)
feedback on accuracy was provided. On the third attempt (step
3), it was not.

Figure 21. Multi-modal therapy
5.3.5 Outcome Measures

5.3.5.1 Single-word Spelling

Participants were tested on the 120 words (80 treated and 40 control) at baseline on three occasions, directly after their second therapy and at two follow-up assessment points: 6 weeks following therapy and then 6 or 12 months following therapy. The results for treated and untreated words will be reported separately below.

5.3.5.2 Email writing

Each participant was asked to write three emails in response to the following instructions, each within 3 minutes.

1. Write an email arranging to meet a friend at a certain time, place and date.

2. Write an email to a friend telling them about a recent holiday.

3. Write an email to your MP about an issue of concern to you at the present time.

Participants were asked to complete this task on four occasions: twice at baseline, directly following therapy and then at 6-12 month follow up. Emails were analysed using the following measures:

- Number of correct units: This included all words that were spelt correctly. Words that were not used in a grammatically correct manner and words that have not been used appropriately/ were not informative were included in this count.
- Number of correct and informative units: This was a count of all correctly spelt open class words (including personal and possessive pronouns) that were relevant and informative to the email. Words did not need to be used in a grammatically correct manner.
Psycholinguistic characteristics of words within emails: Four psycholinguistic variables were investigated: frequency, imageability, length (in letters) and word class. All correctly spelt words were included into the analysis. Imageability, frequency and word length ratings were calculated using N Watch (Davis, 2005) and the mean of each of these was then calculated. The word class analysis was conducted by the author. These analyses were carried out on emails written directly before therapy and directly after therapy.

5.3.5.3 Written picture description

The participants were asked to write a description of the Cookie theft picture (Goodglass, Kaplan & Barresi, 2001), a subtest of the BDAE, within a time limit of three minutes, at three assessment points: baseline, immediately post therapy and at 6-12 month follow-up. For each description, two methods of analysis were used. Firstly, the number of correct words and the number of correct and informative units were counted (as above). Secondly, the scoring method used in the Boston Diagnostic Aphasia Examination narrative writing subtest was used. Each description was given a score for mechanics (0-2), written vocabulary access (0-3), syntax (0-3) and adequacy of content (0-3). The highest possible score was therefore 11.

5.3.5.4 Frequency of Writing

Each participant was given a diary to record each time a writing activity was undertaken within a week at baseline, post therapy and 6-12 month assessment points. The diary consisted of a page for each day of the week. Each page had a list of writing activities, for example, email, shopping list and letter. The participant was required to tick next to the writing activity every time they completed one.
5.3.5.5 Perception of Disability

Participants completed the Comprehensive Aphasia Test Disability Questionnaire (Swinburn et al., 2004) at three assessment points: baseline, post therapy and 6 or 12 month follow-up. Two scores were of interest in this study: The overall disability score and the score of the writing section.

5.4 Results

5.4.1 Do impairment-based lexical spelling therapies result in any significant improvements in spelling accuracy of treated and untreated words?

Accuracy scores directly post therapy (after both therapies had been completed) for all participants are displayed in Figure 22. Uni-modal and multi-modal therapy sets have been collapsed for this analysis (for a comparison of the two therapy approaches see Thiel et al., 2015b; Chapter 4). For all participants the baseline score was 0/80, as items included into therapy sets had to be failed at baseline on two or three occasions. On a group level, there was a significant improvement directly following therapy (Ws+ 0.0, 1-tailed, \( p = .01 \)), which was maintained at six week and 6-12 month follow-up. On an individual level there were significant improvements to treated words for all participants (McNemar1-tailed, \( p < .001 \) for all). For six participants these were maintained at 6 week follow-up (JP, DM, AD, SR, MB & EB); however for JB and KR they were not (JB: McNemar1-tailed, \( p = .02 \); KR: McNemar1-tailed, \( p < .01 \)). One participant’s improvements were maintained at 6-12 month follow-up (SR), and one participant’s score increased significantly at 6-12 month follow-up (AD: McNemar1-tailed, \( p < .01 \)), which may reflect the fact that she had reported continuing to practise her therapy items after therapy had finished.
Figure 23 shows the scores on untreated items at the end of therapy (when both therapies had been completed). A whole group analysis showed significant improvements to untreated items ($W_{s+} = 36.0$, 1-tailed, $p = .01$), which were maintained at six week and 6-12 month follow-up. Individual analyses showed that there were significant improvements to untreated words for all participants (McNemar 1-tailed, $p < .05$). These were maintained at 6 week follow-up. DM’s control score increased significantly to 21/40 from 13/40 (McNemar 1-tailed, $p = .01$) at 6 week follow-up. At 6-12 month follow-up most participants’ improvements to control items were maintained (compared to immediately post therapy). However, three participants had significantly higher scores (AD: McNemar 1-tailed, $p = .01$; EB: McNemar 1-tailed, $p = .02$; SR: McNemar 1-tailed, $p = .03$).
Do impairment-based lexical spelling therapies result in any significant changes to spelling accuracy and psycholinguistic quality within in emails?

5.4.2.1 Number of correct units

The total counts across the three email tasks are presented in Figure 24. Forty two healthy control participants were asked to complete the same task (see Thiel, Sage & Conroy, 2015c; Chapter 3) and the mean number of correct units from this group (201.45) was used as the cut off for individual Chi Square analyses. On a group level there was no significant difference between the number of correct units at baseline (mean of two baseline trials) and post therapy assessment points. Furthermore, follow-up scores did not differ significantly from baseline or immediately post therapy scores. On an individual level one participant, JP, improved significantly ($X^2= 9.39$, 1-tailed, $df= 1$, $p$...
= .002) and this was maintained at follow-up. SR’s follow up score was significantly higher than his immediately post therapy score ($X^2= 5.15$, 1-tailed, $df= 1$, $p = .02$) and his baseline score ($X^2= 6.07$, 1-tailed, $df= 1$, $p = .01$).

5.4.2.2 Number of correct and informative units

The total counts across the three email tasks are presented in Figure 25. These counts were again compared across the time points: baseline (mean), immediately post therapy and 6-12 months following therapy. The mean number of correct and informative units from the control group (122.40) was used as the cut off for individual Chi Square analyses. The mean number of correct and informative units did not increase significantly for the group and the mean follow up score did not differ significantly to baseline or the immediately post therapy assessment. On an individual level, only JP improved significantly directly after therapy ($X^2= 4.75$, 1-tailed, $df= 1$, $p = .03$) although this was not maintained. SR’s follow up score was
significantly higher than his immediately post therapy score \( (X^2 = 4.26, \text{ 1-tailed, } df = 1, p = .04) \) and his baseline score \( (X^2 = 5.69, \text{ 1-tailed, } df = 1, p = .02) \).

5.4.2.3 Psycholinguistic quality of emails

Mean imageability and frequency ratings and number of letters in correctly spelt words within emails were compared pre therapy to post therapy. There were no significant differences between the mean imageability and frequency ratings of the two conditions. However, the mean length of words used within emails (Figure 26) did increase significantly for the group \( (Ws + 4.0, \text{ 1-tailed, } p = .03) \).
Words within emails were categorised according to word class. The categories included noun, verb, adjective, adverb, exclamation (e.g. hi), number (e.g. 12pm; 17th) and a general function word category, which included pronouns, prepositions, determiners and auxiliary verbs. The proportion of each word class per email for each participant is displayed in Table 22. For most participants no substantial differences were observed between the pre and post therapy conditions. AD, who had fluent aphasia, produced less nouns and more function words post therapy. JB, who had non-fluent aphasia, produced more adjectives and less function words. DM who also had non-fluent aphasia and whose pre-therapy emails consisted primarily of nouns, demonstrated a larger range of word classes post-therapy, including verbs adjectives and function words.
Table 22. Proportion of each word class in pre and post lexical therapy emails

<table>
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<tr>
<th>Participant</th>
<th>N</th>
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<th>Adv</th>
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5.4.3 Do impairment-based spelling therapies result in any significant improvements to written picture description?

5.4.3.1 Correct units

The number of correct units at baseline, post therapy and follow-up assessment points are displayed in Figure 27. A group analysis showed a significant increase in the number of correct units after therapy (Ws+ 1.0, 1-tailed, \( p = .01 \)), which was maintained. All participants except AD showed increased numbers of correct units following therapy.

![Figure 27. Number of correct units in written picture description task before and after lexical therapies](image-url)
5.4.3.2 Correct and informative content units

Correct and informative content units at baseline, post therapy and follow up assessment points are displayed in Figure 28. There was a significant increase in the number of correct and informative content units ($W_s+ 1.0$, 1-tailed, $p = .01$), which was maintained at follow-up. Again, all participants except AD showed increased numbers of correct and informative content units following therapy.

![Figure 28. Number of correct and informative units in written picture description before and after lexical therapies](chart.png)
5.4.3.3 BDAE written picture description score

Each participant’s score (out of a possible 11) on the BDAE narrative writing subtest is displayed in Figure 29. The mean post therapy score was significantly higher than the mean pre therapy score (Ws+ 1.5, 1-tailed, $p = .02$) and this was maintained at follow-up. When individual scores were compared across time using the Fisher’s Exact Test and a cut off of 11, there were no significant improvements for any of the participants despite a positive trend for six participants (JP, DM, JB, MB, SR and EB).

![Figure 29. BDAE narrative writing scores before and after lexical therapies](image)
5.4.4 Do impairment-based spelling therapies result in a significant increase in frequency of writing?

Figure 30 shows the number of writing activities reported by each participant over the course of one week both before and directly after therapy. A group analysis comparing pre and post writing frequency showed no significant difference between the two time points (Ws+ 29.5, 1-tailed, \( p = .06 \)).
5.4.5 Do impairment-based spelling therapies result in any significant improvements to perception of disability?

Participants’ ratings on the writing section of the CAT Disability Questionnaire (Swinburn et al., 2004) are presented in Figure 31. Lower scores represent more positive ratings. On a group level, no significant differences were found between pre and post therapy scores (Ws+ 17.5, 1-tailed, \( p = .30 \)) or between pre therapy and follow up scores (Ws+ 10.5, 1-tailed, \( p = .46 \)). On an individual level no participants had significantly more positive ratings on this subtest following therapy. However, KR’s rating was significantly more negative when comparing baseline to 6-12 month follow-up scores \( (X^2 = 4.38, df = 1, p = .04) \).

Figure 32 shows the total scores on the CAT Disability Questionnaire (Swinburn et al., 2004). No significant differences were found between the group pre therapy and post therapy scores (Ws+ 20.5, 1-tailed, \( p = .39 \)) or between pre therapy and follow up scores (Ws+...
28.5, 1-tailed, \( p = .08 \)). However, on an individual level, some participants’ ratings did change significantly. One participant, EB, had lower (more positive) scores immediately post therapy compared to baseline \( (X^2 = 7.18, 1\text{-tailed}, df = 1, p = .001) \). This decreased further at follow up \( (X^2 = 6.11, 1\text{-tailed}, df = 1, p = .01) \). Some participants did not have more positive ratings immediately after therapy, but did at follow-up, either when compared to baseline (JP: \( X^2 = 10.88, 1\text{-tailed}, df = 1, p = .001 \); MB: \( X^2 = 4.72, 1\text{-tailed}, df = 1, p = .03 \)) or to immediately post therapy (JP: \( X^2 = 4.17, 1\text{-tailed}, df = 1, p = .04 \); AD: \( X^2 = 8.10, 1\text{-tailed}, df = 1, p = .004 \); MB: \( X^2 = 12.61, 1\text{-tailed}, df = 1, p < .001 \)). KR’s score increased (became more negative) significantly between post therapy and follow-up assessment points \( (X^2 = 7.10, 1\text{-tailed}, df = 1, p = .001) \).
5.5 Discussion

This study evaluated the effects of lexical writing therapies in terms of changes to spelling accuracy of treated and untreated words, written picture description and emails. Furthermore, it also measured the outcomes on writing frequency and perception of disability. The results showed that therapy led to significantly improved accuracy of treated words for all participants. Furthermore, there was generalisation to untreated words for all participants and to accuracy within written picture description for the group. One participant (JP) also demonstrated significant improvements to accuracy within emails and the group produced significantly longer words within post therapy emails. There were no significant improvements to writing frequency or to disability questionnaire ratings for the group directly following therapy. However, one participant (EB) had a significantly more positive disability rating, which decreased (became significantly more positive) at follow-up.

The positive outcomes following these lexical therapies have mirrored results from previous studies (e.g. Beeson, 1999; Behrmann, 1987; Rapp, 2005; Raymer, Strobel, Prokup, Thomason, & Reff, 2010). They provide evidence that a small amount of spelling practice can lead to relatively large gains in spelling accuracy. The participants who made the most substantial improvements were those with the lowest pre therapy spelling scores (JP, DM, and KR). This could reflect the fact that there was more room for change in these participants. Furthermore, their therapy items were shorter, more imageable and more frequent (e.g. target words such as ‘guitar’, ‘stroke’, ‘family’, ‘house’) which may suggest that they were easier to relearn than the therapy items selected for the higher level participants (e.g. ‘politician’, ‘disagree’, ‘Wednesday’, ‘interesting’) who could write these easier items at baseline.
The fact that all participants improved on untreated words is slightly more surprising. Although a number of other studies have demonstrated generalisation to matched control words following lexical spelling therapies (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). This has either been attributed to the development and use of a strategy (Deloche et al., 1993; Hillis & Caramazza, 1994; Mortley et al., 2001; Pound, 1996) or a strengthened graphemic buffer in participants with 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). The two therapies provided in this study did not explicitly train use of a strategy and the participants did not all have symptoms of graphemic buffer disorder.

One explanation could be that the underlying phonological, orthographic or semantic systems were strengthened as a result of therapy, particularly because the multi-modal therapy had aimed to do this through combining phonological, semantic and orthographic tasks. In fact, DM attributed his increase in control scores at follow-up assessment to an improved ability to listen to and recognise the word in spelling to dictation. This mirrors findings in a study by Behrmann (1987) who hypothesised that her participant’s improvements to untreated items following a homophone training programme were due to improved lexical and visual processing. Alternatively, participants’ improved control scores could be attributed to general improvements to non-linguistic factors such as effort, attention, motivation or self-monitoring skills. It seems likely that as most participants had not engaged much in writing activities prior to the study that the increased effort in writing during the study (both in assessments and therapy) would have generalised effects to words not treated in therapy.
A second surprising positive result was the improvement to written picture description following therapy. This contributes more support to the limited existing evidence that impairment-based writing therapies can lead to generalisation to spontaneous writing (Carlomagno & Parlato, 1989; Hillis & Caramazza, 1994; Pound, 1996; Raymer et al., 2003). Three of the existing studies had trained a strategy (either phoneme grapheme conversion or oral spelling) that could be used on words not trained in therapy. In the case of this study and the study by conducted by Raymer et al. (2003) participants learnt words through repeated practise and it therefore might have been expected that gains would be item-specific. As discussed above, these improvements may be due to strengthened underlying linguistic or cognitive systems or to improved effort, attention, motivation or self-monitoring skills.

The fact that the majority of participants did not improve significantly on spelling accuracy within the email writing task reflects findings in the naming therapy literature where spoken picture naming therapy has led to more substantial improvements to spoken picture description tasks than to less supported tasks such as narrative or conversation (Conroy, Sage & Lambon Ralph, 2009c). Written and spoken picture description are relatively constrained tasks which are less demanding and more supportive at the message generation stage of writing or speaking than tasks such as narrative or conversation (Carragher, Conroy, Sage & Wilkinson, 2012; Marshall & Cairns, 2005) or in this case, email writing. Marshall & Cairns (2005) point out that pictures provide assistance in ‘thinking for speaking’ (or here, writing) through providing the main concepts with which a grammatical sentence can be constructed, leaving out the details, and hence allowing more resources to be used for additional linguistic processing (Carragher, Conroy, Sage & Wilkinson, 2012; Boo & Rose, 2011).
A further difference between written picture description and email writing concerns the types of words that are used. Email writing usually requires the retrieval of low imageability words and a range of word classes, including both lexical and function words, compared to picture description in which many of the required items are concrete nouns. In this study, nouns, verbs and adjectives were trained. However, verbs have been shown to be more difficult to retrieve than nouns within spontaneous speech due to factors such as the requirement to generate morphological verb inflections (in agrammatic speakers) (Bastiaanse & Jonkers, 1998) and higher cognitive demands of naming verbs than nouns (Conroy, Sage & Lambon Ralph, 2009c; Silveri, Salvigni, Cappa, Della Vedova & Puopolo, 2003).

Finally, the email task required participants to use a keyboard rather than pen and paper. Although writing on a keyboard still requires the retrieval of an orthographic form from semantics (or letters converted from sounds), the peripheral level skills are different (Beeson, Higginson & Rising, 2013). Handwriting requires knowledge of letter shapes and the grapho-motor skills to produce letters, whereas to select letters on a keyboard, spatio-motor skills are important (Beeson et al., 2013). This skill is likely to be less well established than those required for handwriting in some of the individuals in this study. In fact the participants varied in their prior use and competency in computer and keyboard use, with some having used a computer both before and since their stroke (JP, AD, DM, KR, EB) and others having little or no experience of computers (SR, JB, MB). Some participants had marked difficulties in using a keyboard due to their hemiplegia or apraxia (AD, JB), but were still able to type one handed, albeit slowly and with effort.

One participant, JP, made significant gains in email writing, in terms of both correct and correct and informative units. She was the highest scorer on treated and untreated words and also made
substantial gains to spelling accuracy within picture description, a task that she found very difficult before therapy (only four correct units and two correct and informative units at baseline). JP was the participant with the lowest spelling scores at baseline on words from PALPA subtests. In contrast, she scored highest on correct and correct and informative units within email tasks of all of the participants. This indicates that despite difficulty with pen and paper writing that she was able to write to a much higher level on a computer. JP reported before therapy that she wrote emails frequently to friends and family members and that she felt much happier with email writing than other writing tasks. Because she had a relatively more severe spelling deficit, her therapy sets consisted of more functional, high frequency words such as names of family members, which were likely to be useful in everyday writing activities. This could be one reason for changes to performance on functional tasks. Interestingly, she attributed her high scores within therapy and her generalisation to untreated words and spontaneous writing to strategies that she developed within therapy. Although the writing tasks focused on copying and recalling words, JP also segmented words. For example, when she saw and copied the word ‘chicken’, she deliberately segmented it into ‘chic’ and ‘ken’, and actively tried to store the words separately so that she could then retrieve these parts when the word ‘chicken’ was dictated or when she wrote the word from memory. As she had good phoneme-grapheme conversion skills she was able to do this successfully. This strategy use might explain her gains to email writing as well as to untreated items and picture description.

Although there were no changes on a group level to spelling accuracy within emails, there were changes to the types of words that were used. Firstly, the participants wrote longer words. As only correct words were counted in this analysis, this suggests that due to therapy, participants were more able to spell longer words after therapy. Secondly, one participant, DM, who had non-fluent,
agrammatic speech and writing wrote a greater range of word classes following therapy, including verbs, adjectives and function words, which he had not written at all in pre-therapy emails. Some of his target words in therapy were verbs and adjectives, which may explain these improvements. There were also changes to the types of words written in the emails of AD and JB; however, neither of these seemed to be helpful: AD, who had fluent aphasia, produced less nouns and more function words post therapy, which, considering her more pronounced difficulties with naming nouns might not have been useful. JB, who had non-fluent aphasia, produced more adjectives and less function words, which was also not necessarily a positive outcome for her. Results of these analyses suggested that it is beneficial to conduct fine-grained analyses of a participant’s speech or writing, as whole word accuracy scores may not provide the full picture.

There was no change to reported frequency of writing. Considering participants all showed improvements to control words and picture description, it might have been expected that there would be some transfer of writing skills into everyday life activities. This may be because both of these tasks (writing to dictation and describing a picture) are more constrained and less cognitively demanding than real life tasks such as writing shopping lists, note writing or diary entries. Secondly, perhaps perceptions of writing need to change as well as accuracy for writing to become more frequent and for levels of activity and participation to change. For example, some individuals may have handed over the job of organising a diary or writing the Christmas cards when they had their stroke. On a more positive note, JP, DM and KR (those with more severe dysgraphia and the largest improvements to treated items) all reported that they noticed improvements when trying to complete everyday writing tasks, such as emailing or writing shopping lists and that they had been writing more often since therapy started. The fact that this was not supported by the frequency of writing data, suggests that this tool
may not have been a reliable method of measuring writing frequency due to participants forgetting to record activities.

Perceptions of writing also did not change significantly, apart from for KR whose rating became significantly more negative at follow up. This may be because she became more aware of her spelling difficulties throughout therapy. KR’s spelling score decreased significantly at 6 week follow up which she found very frustrating.

Total ratings on the CAT Disability Questionnaire only improved significantly directly after therapy for one participant, EB. There were significant changes to other participants’ ratings at follow up (in both directions); however, as there were six or twelve months between therapy and follow-up, these changes to perceptions of disability could be due to other events in the participants’ lives.

In this study the same therapies were given to each participant (so that patterns could be observed across participants) rather than therapies being tailored to each participant’s needs. The functional outcome measure chosen was email writing, which was an existing writing activity for five participants and a goal for six participants. JB and SR were not internet users and were not interested in using emails in the future. Furthermore, the therapies trained single word writing rather than functional writing activities, and therefore focused on the level of impairment (language function) rather than the level activity (WHO, 2015). It seems that to bring about changes to a participant’s everyday literacy skills and to their perceptions of their literacy skills, participants’ individual writing skills and activities need to be explored and their specific needs need to be addressed in therapy (Parr, 1995). Parr (1992; 1995; 1996) stressed the importance of functional and ecologically valid writing assessment and therapy for people with aphasia, which focuses on activities, strategies and adjustment.

In conclusion, this study has shown that a small amount of spelling practice can result in significant gains to spelling accuracy and that
generalisation can occur to untreated words and to different linguistic contexts. However, it has highlighted the need for additional training in more specific skills needed for transfer to functional writing activities such as email writing, and the need for further research investigating the range of skills required to support the transfer of gains from impairment-focused therapies into functional writing to improve levels of activity and participation.
Chapter 6. Promoting linguistic complexity, greater message length and ease of engagement in email writing in people with aphasia: Initial evidence from a study utilising assistive writing software


6.1 Abstract

Background: Improving email writing in people with aphasia could improve their ability to communicate, promote interaction and reduce isolation. Spelling therapies have been effective in improving single word writing. However, there has been limited evidence on how to achieve changes to everyday writing tasks such as email writing in people with aphasia. One potential area that has been largely unexplored in the literature is the potential use of assistive writing technologies, despite some initial evidence that training in assistive writing software can lead to qualitative and quantitative improvements to spontaneous writing.

Aims: This within-participants multiple case design study aimed to investigate the effects of training eight participants with dysgraphia related to aphasia to use assistive writing software to improve email writing.

Methods and Procedures: Eight participants worked through a hierarchy of writing tasks of increasing complexity within broad topic areas that incorporate the spheres of writing need of the participants: writing for domestic needs, writing for social needs and writing for business/ administrative needs. Through completing these tasks, participants learned to use the various functions of the software, such as predictive writing, word banks and text to speech. Therapy also included training and practice in basic computer and email skills to
encourage increased independence. Outcome measures included email skills, keyboard skills, email writing and written picture description tasks and a perception of disability assessment.

Outcomes & Results: Four of the eight participants showed statistically significant improvements to spelling accuracy within emails when using the software. On a group level there was a significant increase in word length with the software, while four participants showed noteworthy changes to the range of word classes used. Enhanced independence in email use and improvements in participants’ perceptions of their writing skills were also noted.

Conclusions & Implications: This study provided some initial evidence that assistive writing technologies can support people with aphasia in email writing across a range of important performance parameters. However, more research is needed to measure the effects of these technologies on the writing of people with aphasia, and to determine the optimal compensatory mechanisms for specific people given the linguistic-strategic resources they bring to the task of email writing.
6.2 Introduction

According to a review by the Equality and Human Rights Commission “Internet access and use are fast becoming essential components of everyday life” and are “a means of securing full and equal economic, social and political inclusion” (Jones, 2010, p.3 & 5). However, people with disabilities, including acquired cognitive and linguistic impairments caused by brain injury may be excluded from using the internet (Dietz, Ball & Griffith, 2011; Egan, Worrall & Oxenham, 2004, 2005; Elman, 2001; Jones, 2010) due to factors such as cognitive-linguistic, psychosocial, and training and support barriers (Egan et al., 2004, 2005). For many of these people, the internet will have been part of their lives prior to brain injury for educational, professional or social purposes. Access to the internet for people with acquired cognitive and linguistic impairments could provide better access to information and more opportunities to communicate (Elman, 2001; Sohlberg, Ehlhardt, Fickas & Sutcliffe, 2003), which for some, could significantly improve quality of life, considering that loneliness, social isolation and depression are issues that often affect individuals with brain injury (Egan et al., 2005).

Among the multiple disabilities that can result from brain injury, one that could significantly impede access to the internet is dysgraphia. Acquired dysgraphia refers to an acquired disorder of writing (Weekes, 2005) and 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 in incorporating linguistic, perceptual and spatial processes (Rapp, 2002). Dysgraphia can present in varying severities; however, in most cases people are considerably restricted in their use of writing.
In a survey with people with aphasia, Menger, Morris & Salis (2014) recently found that people with aphasia use the internet less than people with stroke and no aphasia and that aphasia was reported as their main barrier to using the internet.

In a comprehensive review of the writing therapy literature, Thiel, Sage & Conroy (2015a; Chapter 2) evaluated its usefulness for guiding clinicians in training writing, particularly for functional outcomes. The majority of studies evaluated impairment-based therapies targeting single words. However, fourteen studies were found that measured the effects of training people with aphasia to use assistive writing technologies (Beeson, Rewega, Vail, & Rapcsak, 2000; Beeson, Rising, Kim, & Rapcsak, 2008, 2010; Jackson-Waite, Robson, & Pring, 2003; Mortley et al., 2001; Murray & Karcher, 2000; 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). The technologies reviewed included electronic spelling aids, Lightwriter, voice recognition software (VRS), speech synthesiser software, C-Speak Aphasia, spell checker software and predictive writing software (see Thiel et al., 2015a, Chapter 2, for descriptions of these).

Predictive writing software typically provides ‘guesses’, based on initial letter selection, as to the intended word being typed, which narrows down as more letters are typed into the word processor. For example if the user intends to write the word ‘hello’ and types h, the words happy, hand, hold and he might appear, then as an e is added, only words beginning with he will remain (e.g. he, hello, hell and hen). The user can then select the required word from the list without having to type the entire word, which facilitates spelling and minimises the physical effort involved in writing (Dietz et al., 2011). Predictive writing software was originally designed to facilitate writing for people with physical disabilities as it limits the number of
keystrokes necessary for a word to be produced, but it has been used to support adults and children with language and learning disabilities with spelling (e.g. MacArthur, 1996).

There have been four published studies that have evaluated the use of predictive writing software for the rehabilitation of people with aphasia (Armstrong & MacDonald, 2000; Behrns, et al., 2009; Mortley et al., 2001; Murray & Karcher, 2000). Mortley et al. (2001) trained a participant with severe dysgraphia to use it as part of a combined approach to therapy, including impairment-based and compensatory approaches. They observed that although the participant had the required skills to use this software, he preferred to use a dictionary to find spellings than to use the predictive writing software. Murray & Karcher (2000) also used software to augment the effects of an impairment-based therapy, this time training written verbs and sentences. Their participant made gains following the verb and sentence therapy, but even more substantial improvements when using the software. Behrns et al. (2009) trained two participants to use predictive writing software to compensate for writing deficits. One of the participants (Bo) improved on number of words, proportion of correct words, words per minute and proportion of successful edits, though none of the changes were statistically significant. The other participant (Anders) produced more words, more correctly written words and made significantly more successful edits post-therapy. Finally, Armstrong & MacDonald (2000) trained a participant with Broca’s aphasia to use both a splint for his dominant hand and predictive writing software (with built in text to speech). His writing showed improvements such as increased text length, fewer spelling errors, more low frequency words and improved syntax.

There is clearly a need for further research investigating the effects of assistive writing technologies, which should include a wider range of participants with respect to dysgraphic symptoms and severity and include focus on natural writing activities such as email writing.
However, becoming independent at communicating via the internet, e.g. sending emails, requires a range of skills not just in writing, but in using a computer, the internet and a keyboard. Computer and email skills training for people with aphasia has been found to be successful in previous studies (Egan et al., 2004; 2005). Using a computer and the internet requires the integration of a complex set of cognitive, physical, language and visual skills that may be impaired, selectively or in parallel, in many individuals following a stroke (van der Sandt-Koenderman, 2004). Also, writing with a keyboard entails different peripheral writing skills to handwriting. Handwriting requires knowledge of letter shapes and the grapho-motor skills to produce letters, whereas to select letters on a keyboard, visual recognition skills and spatio-motor are important (Beeson et al., 2013).

For people with aphasia to start writing again after a stroke, one factor that might be important is the perception they have of their writing skills, i.e. whether, for example, they think their writing skills are good enough to write a email. This is an area that has been largely unexplored within the writing therapy literature. Some studies, however, have measured changes to the impact of the participant’s communication disability following writing therapies. For example, Estes & Bloom (2011) used the American Speech and Hearing Association’s (ASHA) Quality of Communication Life Scale (QCL) (Frattali, Thompson, Holland, Wohl & Ferketic, 1995) to assess the impact of the participant’s aphasia on her relationships, communication, interactions, participation in social, leisure, work and education activities, and overall quality of life. They found that, following training in voice recognition software, there was positive change to one item on the assessment: “I meet the communicative needs of my job [or school]”. The participant reported that she felt that she was more productive and useful at work. Similarly, Murray & Karcher (2000) asked their participant and his wife to complete the Communicative Effectiveness Index (CETI) (Lomas, Pickard, Bester, Elbard, Finlayson & Zoghaib, 1989) to determine whether any
changes in his daily communication had occurred following a
treatment targeting written verb and sentence production. The
average ratings of both the participant and his wife increased after
therapy, including the item concerning daily writing tasks, suggesting
that they both perceived his level of disability in daily communication
and activities to have decreased. These issues will also be
addressed in the current study.

The aims of this study were to answer the following questions

1. Can people with aphasia show improvements to internet and
   keyboard skills with relatively time limited internet and
   keyboard skills training?
2. Can assistive writing software improve accuracy and
   psycholinguistic quality within emails?
3. Does training in assistive writing software lead to any
generalised effects to accuracy in unsupported email writing or
   written picture description?
4. Does the training lead to any changes in perception of writing
difficulties?
6.3 Methods

Eight participants with acquired dysgraphia following a stroke were recruited to this study. Inclusion criteria were that participants had to: be at the chronic stage of their brain injury (i.e. post six months); and, have sufficient visual acuity and motor ability for writing on a computer; and finally, be monolingual speakers of English. They were screened using writing subtests from the Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004).

6.3.1 Background Assessments

The participants completed a battery of cognitive, linguistic and writing assessments. Tables 23, 24, 25 and 26 display participants’ demographic information, screen scores, spelling and language assessment results, writing characteristics, activities and goals. Participants have been ordered according to total baseline spelling scores on the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 1992) word spelling subtests (hand-written), with the most impaired to the left and the least impaired to the right. These tables are followed by a description of each participant’s language and writing skills.
<table>
<thead>
<tr>
<th>Participants:</th>
<th>LR</th>
<th>GP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
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<td>11</td>
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<td>10</td>
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<td>Building surveyor</td>
<td>Personal assistant</td>
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<td>Factory supervisor</td>
<td>Factory worker</td>
<td>Care manager</td>
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<td>6; 0</td>
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<td>3; 9</td>
<td>18; 7</td>
<td>3; 2</td>
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<td>8</td>
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</table>

CAT = Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004)
Table 24. BDAE and PPT Scores for 8 participants in technology training study

<table>
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<tr>
<th>Participants</th>
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<th>DM</th>
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<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
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<td>4</td>
<td>21</td>
<td>17</td>
<td>21</td>
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<td>6</td>
<td>3</td>
<td>5</td>
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<td>7</td>
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<td>20</td>
<td>21</td>
<td>30</td>
<td>27</td>
<td>24</td>
<td>30</td>
<td>32</td>
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<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>5</td>
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<td></td>
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<td>3</td>
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<tr>
<td>Reading</td>
<td>16</td>
<td>27</td>
<td>36</td>
<td>20</td>
<td>28</td>
<td>31</td>
<td>35</td>
<td>37</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>47</td>
<td>58</td>
<td>58</td>
<td>52</td>
<td>40</td>
<td>43</td>
<td>63</td>
<td>66</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>PPT</td>
<td>45</td>
<td>50</td>
<td>52</td>
<td>51</td>
<td>49</td>
<td>46</td>
<td>43</td>
<td>48</td>
<td>52</td>
<td>49/52</td>
</tr>
</tbody>
</table>

BDAE = Boston Diagnostic Aphasia Examination: short version (Goodglass, Kaplan & Barresi, 2001), PPT = Pyramids and Palm Trees Test (Howard & Patterson, 1992).
Table 25. PALPA spelling and self-correction of spelling assessment scores for 8 participants in technology training study

<table>
<thead>
<tr>
<th>Participants</th>
<th>LR</th>
<th>GP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALPA 39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Letter</td>
<td>6/6</td>
<td>4/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
</tr>
<tr>
<td>4-Letter</td>
<td>4/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>5/6</td>
<td>6/6</td>
<td>4/6</td>
<td>6/6</td>
</tr>
<tr>
<td>5-Letter</td>
<td>1/6</td>
<td>3/6</td>
<td>5/6</td>
<td>4/6</td>
<td>4/6</td>
<td>6/6</td>
<td>5/6</td>
<td>5/6</td>
</tr>
<tr>
<td>6-Letter</td>
<td>1/6</td>
<td>2/6</td>
<td>3/6</td>
<td>2/6</td>
<td>3/6</td>
<td>4/6</td>
<td>3/6</td>
<td>5/6</td>
</tr>
<tr>
<td>PALPA 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Imageability, High Frequency</td>
<td>1/10</td>
<td>4/10</td>
<td>6/10</td>
<td>7/10</td>
<td>5/10</td>
<td>6/10</td>
<td>7/10</td>
<td>9/10</td>
</tr>
<tr>
<td>High Imageability, Low Frequency</td>
<td>1/10</td>
<td>2/10</td>
<td>2/10</td>
<td>6/10</td>
<td>4/10</td>
<td>6/10</td>
<td>6/10</td>
<td>7/10</td>
</tr>
<tr>
<td>Low Imageability, High Frequency</td>
<td>1/10</td>
<td>0/10</td>
<td>1/10</td>
<td>1/10</td>
<td>3/10</td>
<td>3/10</td>
<td>5/10</td>
<td>5/10</td>
</tr>
<tr>
<td>Low Imageability, Low Frequency</td>
<td>0/10</td>
<td>0/10</td>
<td>1/10</td>
<td>1/10</td>
<td>5/10</td>
<td>3/10</td>
<td>5/10</td>
<td>4/10</td>
</tr>
<tr>
<td>PALPA 44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular Words</td>
<td>7/20</td>
<td>6/20</td>
<td>12/20</td>
<td>13/20</td>
<td>13/20</td>
<td>15/20</td>
<td>18/20</td>
<td>13/20</td>
</tr>
<tr>
<td>PALPA 45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-word Spelling</td>
<td>1/20</td>
<td>0/20</td>
<td>0/24</td>
<td>0/20</td>
<td>10/24</td>
<td>2/24</td>
<td>19/24</td>
<td>4/24</td>
</tr>
<tr>
<td>Self-correction Assessment*</td>
<td>29/30</td>
<td>28/30</td>
<td>29/30</td>
<td>25/30</td>
<td>23/30</td>
<td>27/30</td>
<td>23/30</td>
<td>30/30</td>
</tr>
</tbody>
</table>

PALPA = Psycholinguistic Assessments of Language Processing in Aphasia (Kay, Lesser, & Coltheart, 1992), PALPA 39 = Letter Length Spelling, PALPA 40 = Imageability and Frequency Spelling, PALPA = Regularity and Spelling; *Self-correction of spelling assessment (handwriting): developed for the purpose of this study (Appendix 4).
Table 26. Writing characteristics, activities and goals of 8 participants in technology training study

<table>
<thead>
<tr>
<th>Assessment</th>
<th>LR</th>
<th>GP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects</td>
<td>Length; lexicality</td>
<td>Imageability</td>
<td>Imageability</td>
<td>Imageability length</td>
<td>None</td>
<td>None</td>
<td>Regularity; lexicality</td>
<td>Imageability</td>
</tr>
<tr>
<td>Error types</td>
<td>Substitution; omission; &lt;50% of target; morph</td>
<td>Omission; substitution, &lt;50% of target; semantic (occasional)</td>
<td>Omission, substitution, &lt;50% of target; semantic (occasional)</td>
<td>Addition, omission, substitution; &lt;50% of target; morph.</td>
<td>Addition; Substitution; addition, omission, transposition, phonological</td>
<td>Addition; omission; substitution; morphological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dysgraphia type</td>
<td>Phonological; GBD</td>
<td>Phonological Deep</td>
<td>Deep</td>
<td>GBD</td>
<td>Phonological Surface</td>
<td>Phonological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current writing activities</td>
<td>Email</td>
<td>Text messages; supporting conversation; emails; shopping lists</td>
<td>Supporting conversation; emails</td>
<td>Emails with support</td>
<td>No frequent activities</td>
<td>Occasional text messages</td>
<td>Email; Facebook</td>
<td></td>
</tr>
<tr>
<td>Writing goals</td>
<td>Improved spelling for email writing</td>
<td>Improved spelling for email writing</td>
<td>Improved spelling for email writing</td>
<td>More independent email use</td>
<td>Greetings cards; letters</td>
<td>Improved accuracy of text messages</td>
<td>More elaborate messages</td>
<td></td>
</tr>
</tbody>
</table>

Phonological = Affected by the sound of the target word: includes phonologically similar words and phonologically plausible non-words. Letter additions, substitutions, transposition (movement) and omission errors only include responses with at least 50% letters of target word. <50% of target letters = Errors with less than 50% of letter in target word; does not include responses that are phonologically or semantically related to target; semantic = responses with an associated meaning to the target word. Morph = morphological error, i.e. a response with an additional morpheme added (e.g. plural s).
6.3.2 Description of participants’ linguistic and writing skills

LR was 18 years post stroke and presented with fluent speech and occasional word-finding difficulties. She had a severe writing impairment characterised by a significant length effect on PALPA 39 \( (p < .01, \text{ Fisher's exact test}) \) and the lowest scores relative to the other participants on PALPA writing to dictation subtests. In most cases she only wrote the initial one or two letters of the word or did not give a response. However, she also made substitution, omission and morphological errors. She did not write any non-words correctly and often demonstrated lexicality effects for example, ‘fun’ for \text{fon} and ‘sofa’ for \text{soaf}, demonstrating impaired phonological processing. She therefore demonstrated symptoms of both phonological dysgraphia and graphemic buffer disorder (GBD). Despite her spelling difficulties, LR sometimes attempted to write emails to friends (she started using the internet since her stroke). However, she had extreme difficulty with this and it took her a long time to complete a message. She therefore chose to participate in the study with the hope of improving her email writing skills.

GP also had fluent speech but with more severe word finding difficulties. Background spelling assessments showed that his writing was severely impaired. Similar to LR, he could usually only write the initial letters of most words. Most of his other inaccurate responses were due to omitting letters. He showed an imageability effect on the PALPA 40 \( (p = .01, \text{ Fisher's exact test}) \) and was unable to write any non-words to dictation. He often lexicalised non-words (e.g. ‘ghost’ for \text{grest} and ‘cheese’ for \text{thease}). Therefore, his writing was characteristic of phonological dysgraphia. GP’s most frequent writing activity was sending text messages. He also copied words and phrases from the dictionary into his note book to either use for communication or to practise writing. His aim was to improve his email writing so that he could keep in touch with friends and use this as a way of completing administrative tasks such as writing to the
bank. He had used computers and the internet frequently before his stroke, predominantly for work.

DM had non-fluent aphasia following a stroke in 2007. He communicated effectively with spoken language, however, predominantly with nouns due to agrammatism. He showed a significant imageability effect on the PALPA 40 (Kay, Lesser & Coltheart, 1992) \((p = .03, \text{ Fisher's exact test})\), was unable to write any non-words to dictation and made occasional semantic errors (e.g. ‘dish’ for spoon and ‘post’ for letter) as well as letter omission and substitution errors. Some of his responses were unrelated to the target with less than 50% letters correct, e.g. ‘hidder’ for think. He had more difficulty writing verbs than nouns, and in many cases could not retrieve any of the word. His writing impairment could best be described as deep dysgraphia due to his inability to write non-words, his semantic errors and his imageability effect. DM had frequently used computers and the internet at work and home before his stroke and had trained himself to use them again since his stroke, but found the main barrier to be his aphasia. He was motivated to improve his writing for supporting spoken conversations and writing emails.

KR presented with severe non-fluent aphasia caused by a stroke in 2008. She communicated by producing a few single spoken words, writing single words and short sentences, and drawing. On the PALPA 40 (Imageability and Frequency Spelling) she scored significantly lower on low imageability words than high imageability words \((p < .001, \text{ Fisher's exact test})\) and on the PALPA 39 she showed a length effect \((p = .03, \text{ Fisher’s exact test})\). KR’s errors on these assessments included transposition, addition, omission and occasional semantic errors (e.g. ‘hand’ for glove). Many of her responses consisted of less than 50% of the letters in the target
She did not write any non-words correctly on the PALPA 45. Based on her difficulty in spelling non-words, her imageability effects and her errors, KR has been classified as having deep dysgraphia. Furthermore her length effect and errors are characteristic of graphemic buffer disorder. KR's dominant modality for communication was writing; therefore she wanted to improve her spelling to aid face to face conversations and email and Facebook use. She was independent at using her computer and the internet and had used them before and since her stroke.

AD had severely impaired expressive language following a stroke in 2009. Her speech was fluent but with frequent phonological errors. Her errors on word and non-word spelling assessments included letter additions, omissions, substitutions and morphological errors. Some of her responses contained less than 50% of the target letters. She correctly spelled 10 non-words to dictation, indicating that she had some ability to convert phonemes to graphemes. Her symptoms do not point clearly towards any one dysgraphic syndrome. However, her errors and the fact that her words and non-words were similarly affected (41.7% correct non-words; 53.8% correct words) suggest that she may have had a graphemic buffer disorder (Rapp, 2005; Sage & Ellis, 2006), although she did not show an effect of length. Before the start of the study, AD enjoyed searching the internet and sending emails but needed full support from her husband with these tasks. Her goal was to become more independent at communicating via the internet.

Since suffering a stroke in 1995, JB presented with aphasia, but also severe dysarthria. Her writing, which she had learnt to do with her non-dominant left hand, was very slow, effortful and often quite unintelligible. She only managed to write two non-words to dictation and sometimes lexicalised them (e.g. ‘fond’ for fon and ‘pearl’ for birl). Her incorrect responses were either included less than 50% of
the letters in the target word, or were letter substitution, addition or omission errors. Her impaired non-word writing and her unrelated responses were characteristic of phonological dysgraphia. JB wanted to improve her writing so that she could write greetings cards and letters to friends. At the beginning of this study she had never used the internet, but did play games on her computer. She had used a typewriter before her stroke.

SR had a stroke in 2007 and then another in 2010. His language skills appeared to be intact within conversations; however background language assessments revealed impaired naming, auditory comprehension and semantic access. He also had residual writing difficulties. He had more difficulty with spelling exception words than regular words on the PALPA 44 \((p < .001, \text{Fisher's exact test})\). Furthermore, he was able to spell 19/24 non-words correctly. The majority of his errors were either letter substitution, addition, omission or transposition errors or were regularisations of low frequency exception words (e.g. ‘sigaret’ for cigarette, ‘nefew’ for nephew). Based on these assessment results, SR’s spelling impairment can be described as surface dysgraphia. SR occasionally wrote text messages but he wanted to improve his writing so that he could write more accurate text messages to friends and family members. SR had used the internet before his stroke but said he had not used it since due to a lack of interest.

Following a stroke in 2010, EB had fluent speech with occasional phonological errors and word finding difficulties. She showed an imageability effect on the PALPA 40 \( (p = .02, \text{Fisher's exact test}) \) and only wrote four non-words correctly to dictation, indicating a more severe impairment spelling non-words compared to words. Her responses often consisted of correct initial and final spellings with the middle of the word being incorrect. This was especially true for longer words that could be segmented into morphemes (e.g. ‘accondation’ for accommodation). Many of her incorrect responses were letter omission, addition or substitution errors; however, she also frequently
added grammatical morphemes onto dictated words. The difficulties with converting phonemes to graphemes within non-words and the imageability effect suggest that EB had phonological dysgraphia. EB already used the internet (Facebook and email) to keep in touch with friends and family members since her stroke (before her stroke she used it for work purposes), but wanted to improve her spelling so that she could write longer and more elaborate messages.

In summary the participants presented with a range of dysgraphia types and severities. Participants all varied in their pre-morbid and post stroke writing activities and abilities and their motivations for improving writing. Email writing was a pre-morbid activity for GP, DM, KR, AD, SR and EB. Five participants (LR, DM, KR, AD and EB) wrote emails since their stroke, and six participants (LR, GP, DM, KR, AD and EB) were motivated to improve their writing so that they could write emails. SR and JB wanted to improve their writing skills but not necessarily for email writing.

On cognitive assessments most participants had low scores relative to the normal population on at least one test, indicating that they had difficulties in skills such as visuo-construction, planning, visual-memory, attention, and task switching (Table 27). Although different participants showed strengths in different areas, DM, GP, EB and KR generally had higher scores relative to the group, and LR, AD, JB and SR had scores that were in the lower percentiles. All participants had low scores on the Trail-making Test, which measured attention and task switching ability.
Table 27. Scores on cognitive assessments for 8 participants in technology training study

<table>
<thead>
<tr>
<th>Participants</th>
<th>LR</th>
<th>GP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
<th>Control Mean (SD)</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rey Complex Figure Test (percentiles)</td>
<td>Copy</td>
<td>14.5 (&lt;1)</td>
<td>35 (&gt;16)</td>
<td>36 (&gt;16)</td>
<td>30.5 (6-10)</td>
<td>13.5 (&lt;1)</td>
<td>28.5 (&gt;16)</td>
<td>20 (&lt;1)</td>
<td>34 (&gt;16)</td>
<td>34.29 (2.75)</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>5 (1)</td>
<td>21.5 (76)</td>
<td>22 (73)</td>
<td>23 (86)</td>
<td>2 (&lt;1)</td>
<td>5 (18)</td>
<td>0 (&lt;1)</td>
<td>11 (4)</td>
<td>19.9 (6.2)</td>
<td>36</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>5 (1)</td>
<td>21.5 (79)</td>
<td>22 (73)</td>
<td>22.5 (82)</td>
<td>2 (&lt;1)</td>
<td>1.5 (2)</td>
<td>1 (&lt;1)</td>
<td>14 (12)</td>
<td>19.85 (6.28)</td>
<td>36</td>
</tr>
<tr>
<td>Camden Memory Tests (percentiles)</td>
<td>Pictorial recognition memory test</td>
<td>28 (&gt;10)</td>
<td>30 (&gt;10)</td>
<td>30 (&gt;10)</td>
<td>30 (&gt;10)</td>
<td>26 (10)</td>
<td>22 (1-10)</td>
<td>23 (&lt;1)</td>
<td>29 (&gt;10)</td>
<td>30</td>
</tr>
<tr>
<td>Short recognition memory test for words</td>
<td>21 (10)</td>
<td>21 (10)</td>
<td>25 (&gt;90)</td>
<td>25 (&gt;90)</td>
<td>19 (10)</td>
<td>20 (10-25)</td>
<td>15 (&lt;5)</td>
<td>25 (&gt;90)</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Corsi Blocks</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6.2 (1.3)</td>
<td>9</td>
</tr>
<tr>
<td>Trail-making Test: Seconds (percentiles); 0=fail if over 3 minutes or &gt;1 errors</td>
<td>a</td>
<td>0</td>
<td>40 (10-50)</td>
<td>60 (&lt;10)</td>
<td>0</td>
<td>98 (&lt;10)</td>
<td>69 (&lt;10)</td>
<td>65 (&lt;1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>0</td>
<td>0</td>
<td>160 (&lt;10)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>158 (&lt;1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rey Complex Figure Test (Meyers & Meyers, 1995; a test of visuo-construction, memory and planning), the Camden Memory Test (Warrington, 1996; picture and word recognition tests), the Corsi Block-tapping Task (Kessels, van Zandvoort, Postma, Kappema, & de Haan, 2000; a test of visuo-spatial short term memory) and the Trail-making Test (Reitan, 1992; a test of visual attention and task-switching).
6.3.3 Software

Participants were trained to use Co:Writer 6 software (Don Johnston Assistive Technology). Co:Writer is a word prediction programme that was developed to support writing in children with physical or spelling difficulties. This software was chosen after reviewing several assistive writing programmes. It was selected based on a variety of factors including its sensitivity to spelling errors; its inclusion of word and grammar prediction, word banks, text to speech and spell check; its availability as an app (for participants who also wanted to use it on an iPad); the fact that it could be used online; and its relatively simple display. It had also previously been used successfully in other aphasia therapy studies (Armstrong & MacDonald, 2000; Murray & Karcher, 2000). Within this study participants were trained to use word prediction, word banks, text to speech and spell check.

6.3.4 Therapy sessions

Participants were given ten sessions of training over five weeks, with two sessions each week. Each therapy session included the following two components:

• Technology access training: First 0-15 minutes
• Writing with technology: Remaining 45-60 minutes

6.3.4.1 Technology Access Training

Participants completed a list of tasks related to sending emails, for example, turn on the computer, enter an email address, and send an email with an attachment. They completed each task once per session. If they needed help or responded incorrectly, then the therapist gave instructions or demonstrations. An additional element of technology access training was keyboard practice, which involved
copying out short texts into a word processing document. The therapist noted in each session whether activities were completed alone, with minimum support, with maximum support or not at all. When each activity had been completed three times independently (over three sessions), the technology access training stopped and participants spent the whole session on writing with technology.

6.3.4.2 Writing with technology

This involved using Co:Writer to complete a hierarchy of writing tasks (see Table 28). In the *Introduction and Orientation* session participants were introduced to the software. The therapist modelled each function and then asked participants to do the same with example words. At this stage the number of words on display, the text size and the speed of speech output were adapted for each person’s needs, i.e. they selected their preferred options. The next nine sessions were divided into three levels. The first three sessions (2-4) consisted of *simple tasks*. The next three sessions (5-7) comprised *medium complexity* tasks. The final three sessions (8-10) consisted of *high complexity* tasks. There were also three broad topic areas aimed to incorporate the spheres of writing need of the participants: *writing for domestic needs, writing for social needs and writing for business/ administrative needs*. Each topic area was covered at simple, medium and high complexity levels; therefore, there were three sessions on each topic over the course of therapy. The levels of complexity were based on estimated number of likely words, likely syntactic complexity, and relative vocabulary complexity. Model responses were constructed to determine the estimated levels of syntactic and vocabulary complexity as well as number of words needed for these tasks.
Table 28. Technology training therapy sessions

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
<th>Level</th>
<th>Example of task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction &amp; orientation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Writing for domestic needs</td>
<td>Simple tasks</td>
<td>Shopping list</td>
</tr>
<tr>
<td>3</td>
<td>Writing for social needs</td>
<td>Simple tasks</td>
<td>Birthday card</td>
</tr>
<tr>
<td>4</td>
<td>Writing for business/ administrative needs</td>
<td>Simple tasks</td>
<td>List of calendar entries</td>
</tr>
<tr>
<td>5</td>
<td>Writing for domestic needs</td>
<td>Medium complexity</td>
<td>Instructions to a neighbour</td>
</tr>
<tr>
<td>6</td>
<td>Writing for social needs</td>
<td>Medium complexity</td>
<td>Book a table/hotel room</td>
</tr>
<tr>
<td>7</td>
<td>Writing for business/ administrative needs</td>
<td>Medium complexity</td>
<td>Apology to GP for missing appointment</td>
</tr>
<tr>
<td>8</td>
<td>Writing for domestic needs</td>
<td>High complexity</td>
<td>Complaint to phone company</td>
</tr>
<tr>
<td>9</td>
<td>Writing for social needs</td>
<td>High complexity</td>
<td>Recommend a book, film or restaurant</td>
</tr>
<tr>
<td>10</td>
<td>Writing for business/administrative needs</td>
<td>High complexity</td>
<td>Apply for a job/course/voluntary job</td>
</tr>
</tbody>
</table>

Each session consisted of three tasks which participants were able to work through at their own pace. Regardless of how many tasks participants completed, they progressed to the next topic and difficulty level in the next session. At the beginning of each task, the participant and therapist collaboratively entered words and phrases that might be useful for the task into word banks. There was no limit on number of words or phrases or length of phrase. Therefore, a 'formal email' word bank might have consisted of items such as *dear,*
manager, yours sincerely, I would like to arrange an appointment.

Participants had the word bank open as well as the prediction box. They were encouraged to complete tasks as independently as possible (i.e. without the help of the therapist). However, the therapist provided support, including instructions or modelling whenever it was needed. Participants were encouraged to use the word bank, prediction, text to speech and spell check functions to complete tasks.

6.3.5 Outcome measures

The following assessment tasks were used to measure outcomes following therapy. They were all completed directly before and directly after therapy.

6.3.5.1 Email Skills Assessment

A rating scale developed specifically for this study but adapted from one by Egan et al. (2005), was used to assess competency in the computer and email skills required for emailing (e.g. enter an email address; click send; see Appendix 5). The scale consisted of the same activities that were treated within therapy. A rating of 1 was given if the participant completed the activity independently and 0 if they did not complete it independently. The total score was 15.

6.3.5.2 Keyboard Skills Assessment

This assessment consisted of copying tasks, for example of sentences containing punctuation marks (see Appendix 6). Participants obtained a mark for each correctly written word or sentence (out of a possible 20), and the response for each section was timed.
6.3.5.3 Email writing

Participants wrote three emails, each within 3 minutes:

1. Write an email arranging to meet a friend at a certain time, place and date.

2. Write an email to a friend telling them about a recent holiday.

3. Write an email to your MP about an issue of concern to you at the present time, e.g., a stroke club closing, library closure, unemployment, the environment etc.

As well as completing this task pre and post therapy with and without Co:Writer, participants completed it before and after an “effort phase” at the beginning of the study, in which they were asked to practise writing (preferably email writing if they were able to do this) in their own time over the course of a month without any training. The aim was to establish whether there were any improvements to email writing due to effort alone.

Emails were analysed using the following measures:

- **Number of correct units**: This included all words that were spelt correctly. Words that were not used in a grammatically correct manner and words that had not been used appropriately/ were not informative were included in this count.

- **Number of correct, relevant and informative units**: This was a count of all correctly spelt open class words (including personal and possessive pronouns) that were relevant and informative to the email. Words did not need to be used in a grammatically correct manner (e.g. ‘wish’ in ‘best wish’).

- **Psycholinguistic characteristics of words within emails**: Four psycholinguistic variables were investigated: frequency, imageability, length (in letters) and word class. All correctly spelt words were included in the analysis. Imageability,
frequency and word length ratings were calculated using N Watch (Davis, 2005) and the mean of each of these was then calculated. The word class analysis was conducted by the author. These analyses were carried out on emails written directly before therapy and directly after therapy.

For all of these measures, scores across the three email tasks (within nine minutes) were collapsed into one total score and scores were compared across two conditions: pre therapy without support and post therapy with Co:Writer. For counts of correct and correct and informative units the mean scores of forty two healthy control participants, who were asked to complete the same task (see Thiel, Sage & Conroy, 2015c; Chapter 3), were used as cut offs (i.e. the highest possible score) so that Chi Square analyses could be conducted to compare individual scores across conditions. The mean number of correct units from the control group was 201.45 and the mean number of correct and informative units was 122.40.

Finally, videos of post therapy emails written with Co:Writer were viewed by the first author and each correct word produced was categorised according to how it was produced: alone, with prediction or with a word bank.

**6.3.5.4 Written picture description**

The participants were asked to write a description of the Cookie theft picture (Goodglass, Kaplan & Barresi, 2001) with pen and paper within three minutes. As above, the number of correct units and the number of correct and informative units were counted and compared across time.
6.3.5.5 Perception of Writing

Participants were asked to complete the Comprehensive Aphasia Test Disability Questionnaire (Swinburn, Porter & Howard, 2004) and ratings on the writing subtest were compared across time.

6.4 Results

6.4.1 Can people with aphasia show improvements to internet and keyboard skills with relatively time limited internet and keyboard skills training?

6.4.1.1 Email skills assessment

Figure 33 shows participants’ scores out of a possible 15 on the Email Skills Assessment. All participants completed more tasks independently following therapy and on a group level this difference was significant (Ws+ 0.0, 1-tailed, p = .01). On an individual level only SR’s improvements were significant ($X^2= 5.52, 1$-tailed, $df= 1, p < .02$).
6.4.1.2 Keyboard Skills Assessment

Figure 34 displays the number of tasks completed independently by each participant out of a possible 20 on the Keyboard Skills Assessment. There was a positive trend following therapy; however, the improvements were not significant at group level ($W_+ = 7.5$, 1-tailed, $p = .15$) nor for the individual participants except SR ($X^2 = 12.29$, 1-tailed, $df = 1$, $p < .01$). This may reflect the fact that most participants were close to ceiling before therapy. Figure 35 shows the total amount of time taken to complete the assessment (only including typing time, with breaks between tasks omitted). Although most participants became faster at typing after therapy, the changes were not significant at group level ($W_+ = 29.0$, 1-tailed, $p = .07$).
6.4.2 Can assistive writing software improve accuracy and psycholinguistic quality within emails?

6.4.2.1 Pre and post effort phase: accuracy

In order to determine whether there are changes to email writing performance due to effort alone, the pre and post effort phase results were compared. There were no significant differences to the number of correct units (Pre: Mean = 28.38, SD = 16.76; Post: Mean = 30.13 SD = 16.90) or correct and informative units (Pre: Mean = 18.00 SD = 10.34; Post: Mean = 18.38, SD = 12.33) within emails for the group as a whole (correct units: Ws+ 12.0, 1-tailed, $p = .40$; correct and informative units: Ws+ 16.5, 1-tailed, $p = .44$) or for individual participants.
6.4.2.2 Pre therapy without support compared to post therapy with software: accuracy

To establish whether the training and software resulted in improvements to spelling accuracy, the number of correct units before therapy without the use of Co:Writer were compared to after therapy with the use of Co:Writer (Figure 36). A group comparison showed a significant increase when using Co:Writer ($W_s + 0.0$, 1-tailed, $p = .01$). On an individual level, there were significant improvements for participants SR ($X^2 = 4.39$, 1-tailed, $df = 1$, $p = .04$) and JB ($X^2 = 5.14$, 1-tailed, $df = 1$, $p = .02$). When the number of correct and informative units before and after therapy were compared (Figure 37), there was a significant improvement for the group ($W_s + 3.5$, 1-tailed, $p = .02$), for LR ($X^2 = 7.64$, 1-tailed, $df = 1$, $p = .01$) and for AD ($X^2 = 6.39$, 1-tailed, $df = 1$, $p = .01$).

Figure 36. Number of correct units pre therapy without Co:writer compared to post therapy with Co:Writer

![Figure 36. Number of correct units pre therapy without Co:writer compared to post therapy with Co:writer](image-url)
6.4.2.3 Psycholinguistic quality of emails

Mean imageability and frequency ratings and number of letters in correctly spelt words within emails pre therapy without Co:Writer were compared to post therapy with Co:Writer. No significant differences were found between the mean imageability and frequency ratings between the two conditions. However, the mean length of words used within emails (Figure 38) did increase significantly for the group (Ws+ 2.0, 1-tailed, p = .03).

Figure 37. Number of correct and informative units pre therapy without Co:Writer compared to post therapy with Co:Writer

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Words within emails were categorised according to word class. The categories included noun, verb, adjective, adverb, exclamation (e.g. hi), number (e.g. 12pm; 17th) and a general function word category, which included pronouns, prepositions, determiners and auxiliary verbs. The proportion of each word class per email for each participant is displayed in Table 29. For some participants (GP, KR, SR and EB) there was little or no noticeable change following therapy. However, others showed some substantial changes. LR, who had anomic aphasia increased her use of all open class words and showed a decrease in her proportion of function words. Similarly, AD who showed characteristics of conduction aphasia and used a high proportion of function words within emails before therapy demonstrated a decrease in these following therapy and an increase in verbs and adverbs. In contrast, DM, who had non-fluent agrammatic aphasia, showed a decrease in proportion of nouns, an increase in his proportion of verbs and a broader range of word classes including function words following therapy. JB, who also had non-fluent aphasia, produced a lower proportion of nouns and a higher proportion of function words after therapy.
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<td>-</td>
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</tbody>
</table>

6.4.2.4 Frequency of technologies used within assessments

Videos of assessments were observed to determine the percentage of correctly spelt words that were produced alone by the participant, with word prediction and with word banks. This data is presented in Table 30. On average, participants wrote 51.9% of words alone, 12.8% with prediction and 35.3% with word banks.
<table>
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<th>Participant</th>
<th>Alone (%)</th>
<th>Prediction (%)</th>
<th>Word bank (%)</th>
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</tr>
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<tr>
<td>Mean (SD)</td>
<td>51.9 (29)</td>
<td>12.8 (9.3)</td>
<td>35.3 (27.5)</td>
</tr>
</tbody>
</table>

6.4.3 Does training in assistive writing software lead to any generalised effects to accuracy in unsupported email writing or written picture description?

6.4.3.1 Emails

To measure any changes to unsupported email writing resulting from the therapy, emails written pre and post therapy without the use of Co:Writer were compared. There were no significant changes to the number of correct units or correct and informative units for the group (correct: Ws+ 14.0, 1-tailed, $p = .31$; correct and informative: Ws+ 11.0, 1-tailed, $p = .18$) or for individuals.
6.4.3.2 Written picture description

The number of correct units and the number of correct and informative units within hand-written picture descriptions pre and post therapy were compared. There were no significant changes to correct units (Ws+ 18.0, 1-tailed, $p = .47$) or correct and informative units (Ws+ 15.0, 1-tailed, $p = .47$) for the group following therapy.

6.4.4 Does the training lead to any changes in perception of writing difficulties?

On the writing subtest of the CAT Disability Questionnaire (Swinburn et al., 2004) (Figure 39) ratings became significantly more positive for the group following therapy (Ws+ 25.0, 1-tailed, $p = .04$) but not for individuals despite a positive trend for five participants.

Figure 39. CAT Disability Questionnaire: Ratings on writing subtest before and after technology training

* $p < .05$
6.5 Discussion

The aim of this study was to establish whether training eight participants with aphasia to use assistive writing software would improve their ability to write emails. It was found that spelling accuracy within emails improved both on a group level and for SR and JB when using the software, when mean scores from healthy control participants were used as the ceiling. When only correct and informative open class words were counted, there was significant improvement both on a group level and for LR and AD (again when compared using control scores as the ceiling), indicating that the software enabled these two participants, who both had fluent aphasia and severe writing difficulties, to write more meaningful messages.

Some of the participants commented that they felt supported by Co:Writer and noticed that they could now use more difficult words. Therefore, a more in-depth analysis of the psycholinguistic properties of words produced with and without support was conducted and it was found that the participants wrote significantly longer words with Co:Writer. Furthermore, two participants with fluent aphasia, AD and LR, used a higher proportion of open class words and two participants with non-fluent aphasia wrote a higher proportion of either verbs (DM) or function words (JB).

These findings were consistent with those of previous studies which found some positive outcomes in training participants to use similar technologies, although the present study did so across a larger number of participants. Participants in studies by Armstrong & MacDonald (2000), Behrns et al. (2009) and Murray & Karcher (2000) improved in accuracy when using predictive writing software. Moreover, one participant in the study by Behrns et al. (2009), who was described as having non-fluent agrammatic aphasia (similar to DM and JB), also wrote more verbs with the software. Murray & Karcher's participant wrote longer words. Armstrong & MacDonald (2000) found changes to their participant’s texts such as lower
frequency words and more grammatical sentences. Therefore, it seems that assistive writing technologies can support people with aphasia in producing words they would not usually be able to write. EB commented that although she finds writing with Co:Writer slower, she no longer feels “embarrassed or stupid about using simple words” when writing to friends.

A further interesting finding was that not all participants used the software to the same extent. KR and SR did not use it frequently within the post therapy assessment despite being able to use it. KR found in therapy that Co:Writer slowed her down (in comparison to typing without) and that speed was more important to her than spelling accuracy. SR was able to write most of the words that he wanted to write without the software, and was content with writing short messages with familiar words and phrases. The participants who used word banks to write most of their words, LR, AD and JB, were the ones who showed the greatest improvements post therapy (along with SR), probably because clicking on a phrase within a word bank can produce multiple correct words. These participants did not use prediction to a great extent as they found it difficult to do so.

GP, DM and EB wrote some words independently while making use of prediction and word banks for others. It was actually these participants who were most enthusiastic about the software. They reported using it outside of therapy and commented that they had been writing more frequently since they started using it. An advantage of prediction (for people who do not have difficulties using it) is that it does not necessarily require any support from others. To use word banks, words and phrases first need to be entered by somebody who can spell them. Although the participants were given Co:Writer at the end of therapy along with the word banks that they had created within therapy, these might not have necessarily been useful in every possible writing situation, in contrast to word prediction. This may be a reason for the more positive reports after therapy from participants who could also use word prediction.
Despite the positive comments regarding writing with Co:Writer, DM, EB and GP did not show significant changes to the number of correct words produced within emails. This may be due to the fact that prediction slowed them down, which was a comment that they all made and was also observed within therapy. In order to find the correct word, the participant often has to scroll then to add or delete letters and to read or listen to words as they appear, which can be time consuming. Similarly, Behrns et al. (2009) proposed that a participant in their study whose production rate decreased was slowed down by having to read and then select words from the prediction list. A further reason for not having significant gains might be that these participants all chose to write a large proportion of words alone, which indicates that they were managing without Co:Writer much of the time. This may account for the smaller difference between the two conditions compared to other participants. The participants who struggled to write any words alone without Co:Writer (AD, JB and LR) were the ones who showed more substantial gains, probably because there was more room for improvement.

Cognitive skills are often impaired following a stroke and all participants in this study showed a deficit in at least one of the skills tested. The participants who tended to be at the lower end of the range on these assessments, AD, SR, LR and JB, were the ones who showed significant improvements to email accuracy. Three of these participants (AD, LR and JB) found predictive writing difficult and chose to use word banks. Predictive writing requires the use of skills such as task switching, i.e. between the target word and the prediction box, visual memory, for example of which key to press to scroll for more words, and selective and divided attention, in concentrating on the target word while ignoring distractions and in dividing attention between the text and the predicted words. These were the skills that were impaired in AD, LR, JB, and SR when tested on the Rey Complex Figure Test (Meyers & Meyers, 1995; a test of
visuo-construction, memory and planning), the Camden Memory test (Warrington, 1996; picture and word recognition tests), the Corsi Block-tapping task (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000; a test of visuo-spatial short term memory) and the Trail-making Test (Reitan, 1992; a test of visual attention and task-switching).

Another factor that may contribute to success on writing with predictive writing software is spelling ability. To use prediction, the user needs to be able to write the first letter(s) of a word correctly. The closer the user gets to the target, the narrower the range of plausible options for the software, and the more chance there is of the correct word appearing. There were no observable patterns regarding therapy success and type of dysgraphia. With the exception of SR, those who improved and those who did not improve showed similar symptoms of phonological dysgraphia and/or graphemic buffer disorder. However, the participants with the lowest accuracy scores on emails at baseline were AD, LR and JB. They were not the participants with the most severe dysgraphia (apart from LR) when assessed on spelling to dictation assessments, which suggests that they had particular difficulty with skills specific to the email task, such as writing with a keyboard, and message generation. All three participants had difficulty with deciding what to say and generating the vocabulary they needed, which may suggest difficulties with thinking for speaking (or here, writing) (Marshall & Cairns, 2005). AD and JB spent a long time looking for the letter keys while typing words (for JB this was to do with lack of familiarity with the keyboard). In this time, they then often forgot what they wanted to write. AD and JB also both had a hemiplegia and were required to type with their non-dominant hand, which for both was a slow, arduous process. Therefore, it seemed that word prediction was extremely difficult for LR, AD and JB to use because of an interaction between their cognitive, language, spelling and motor difficulties. This may explain why they chose to use word and phrase banks,
which significantly improved their email writing accuracy through compensating for these impairments. In fact, LR and AD commented that having words and phrases related to the topic in front of them helped them to stay on track and to remember what they wanted to write. Furthermore, word and phrase banks did not require any spelling ability, just skills in either reading or auditory comprehension.

Opinions of Co:Writer varied with some participants finding it extremely frustrating and difficult or too slow to use (LR, AD, JB, KR) and some finding it supportive and useful for writing more difficult words (DM, GP, EB, AD). AD found it difficult to use but wanted to continue using it anyway as she noticed a difference to her writing. Most participants agreed that Co:Writer was not particularly user-friendly or aphasia-friendly. For example, they had difficulties with buttons with similar icons (e.g. one arrow to press for listening to words, a different arrow for accessing settings, and the right arrow key on the keyboard for scrolling), having too many boxes that needed moving around while writing, and generally having to switch from keyboard to mouse and from text to prediction box and word bank, which was cognitively demanding and required good motor skills.

To control for improvements not associated with therapy or technology use, an effort phase was incorporated within this study, in which participants were asked to do some writing in their own time. They were assessed at the beginning and at the end of this phase and no significant changes were found to their writing accuracy within emails, indicating a stable baseline. There were also no significant improvements to either email writing or written picture description (using pen and paper) without support following therapy; therefore the ten sessions of therapy, in which participants practised writing within a range of functional tasks, did not have any generalised effects on the participants’ writing. This suggests that improvements in the ‘with Co:Writer’ condition can be attributed to the participants’
successful use of the programme rather than to improvements to language as a result of writing practice.

It is important to note that despite the positive findings at the whole group level, for each accuracy measure only two participants improved significantly and the gains were therefore relatively small. This could be related to the difficulty using the programme discussed above. However, it could also relate to the fact that therapy and assessment tasks were not tailored to individuals’ needs and interests. Parr (1992, 1995) demonstrated the large variation of everyday writing activities carried out by participants both before and after the onset of aphasia, and how these changed following the participant’s stroke. She stressed the importance of setting goals related to the participant’s abilities, roles and activities. This study aimed to improve functional writing by practising a range of everyday writing tasks; however, as these were pre-selected by author, they were not necessarily functional to every person. JB, GP and SR did not write emails before the study started and JB and SR were not interested in writing emails in the future. JB had never before written an email and her husband had taken on the role of completing domestic administration tasks. SR had used the internet before but his interests had changed since he had his stroke. Although these two participants did show changes to their email writing, neither reported writing more or using emails since therapy.

If the aim of therapy is to independently communicate via email, then general computer and internet skills are also necessary. Therefore, these were included into the therapy protocol. All participants improved on the Email Skills Assessment which was significant on a group level and for SR who had not used the internet since his stroke. All participants except JB commented that they found this training useful. Even the more experienced technology users were happy to learn additional skills, for example, how to attach pictures to email messages. As JB had never used the internet before, this small amount of training was not enough to support her to use it. Despite
this, she found the writing therapy useful and planned to print out messages that she had created to send as letters or in greetings cards. On the Keyboard Skills Assessment most participants did not achieve higher scores as most were almost at ceiling before therapy. SR, again, had a significantly higher score after therapy, which reflects the fact that he was not very familiar with the keyboard before therapy and benefitted from the practice. Most became faster at typing (although this change was not significant) and reported that they found the typing practice useful.

As a group the participants had significantly more positive perceptions of their own writing on the CAT Disability Questionnaire (Swinburn et al., 2004), which mirrors results from previous studies that have trained assistive writing technologies in people with aphasia (Estes & Bloom, 2011; Murray & Karcher, 2000). This is an extremely positive finding for participants in the current study, most of who were unhappy and embarrassed about their writing before therapy and avoided engaging in writing activities. It seems plausible that if people with aphasia view their writing skills as less impaired then they may be more likely to engage in writing activities.

This study has aimed to contribute to the writing therapy literature, which is currently dominated by single word impairment-based therapy studies (Thiel et al., 2015a) due to a focus on language function rather than activity and participation (WHO, 2015). All of the participants in this study had some level of spelling ability and they all wrote some words independently within assessments and used Co:Writer for words they could not write. The improvements in accuracy, informativeness, the characteristics of words used and perceptions of writing suggest that there should be an increasing role for assistive writing technologies in the rehabilitation of stroke aphasia to build on gains from impairment-based therapies and to augment or compensate for writing difficulties, depending on the severity of the dysgraphia.
More research is needed into the efficacy and the candidacy for these types of therapies and technologies. Specifically, this will require studies with a greater range and number of participants to allow for sufficient statistical power to analyse the relative contribution of factors such as dysgraphia and aphasia symptoms and severity of cognitive, motor and visual skills. There is also a case to be made for developing and evaluating bespoke software specifically designed towards functional ease of access together with visual and linguistic simplicity for people with aphasia and related motor-visual impairments following stroke. Qualitative feedback in this study indicated that even the most accessible of commercially available software was considered too ‘busy’ and multi-faceted. This bespoke model could allow for pre-selection of specific technological compensations, based on robust findings in relation to optimal cognitive-linguistic profiles. Finally, technology could also usefully support analysis of the role of time investment and effort in this type of rehabilitative work (a measurement of participant engagement with the intervention) such that, we could explain to participants the required ‘buy-in’ they would need to undertake in order to arrive at clinically positive outcomes. Whilst technology holds incredible therapeutic promise, effective treatment development will increasingly have to grapple with the candidacy issue: ‘who’, ‘what’ and ‘how’ from the increasingly rich and varied menu of technological solutions to everyday functioning.
Chapter 7. Discussion

In this concluding chapter, each of the research questions proposed in the Introduction to the thesis will be addressed and the results of each of the studies will be summarised. The contributions and limitations of the thesis will then be discussed and finally some clinical implications and future directions for further research will be outlined.

7.1 What is the range of performance of email writing accuracy in healthy control participants?

In Chapter 3, the emails of forty two healthy control participants were analysed with respect to three key measures: number of units (i.e. word-like sequences of letters), number of correct units (i.e. accurately spelt words) and number of correct and informative units (accurately spelt and semantically relevant). Firstly, it was established that when the numbers of units were calculated across the email tasks for each participant there was a very broad range of writing productivity (units: 22 to 580; correct units: 14 to 580; correct and informative units: 9 to 370). There was also variation across participants for individual tasks and between tasks, with Task 1 having substantially shorter responses than Tasks 2 and 3. Secondly, for a subset of ten participants, all three measures were stable across two trials, indicating that this measure was appropriate for measuring outcomes in the ten matched participants with aphasia in the therapy studies (Chapters 5 and 6). Thirdly there was a significant relationship between all three measures and age and education for Tasks 2 and 3, but not Task 1, which was predicted to be due to the fact that Task 1 was less challenging and therefore did not result in shorter or less accurate emails for older or less educated participants. However, for Tasks 2 and 3, participants who were younger and had more years of education wrote more correctly spelt words and more correctly spelt informative open class words. This reflected previous findings that there is an age-related decline in
spelling (Stuart-Hamilton & Rabbitt, 1997) and word-retrieval accuracy (Griffin & Spieler, 2006; Burke, MacKay, Worthley, & Wade, 1991) and speed (Spieler & Griffin, 2006) and may be related to findings of the Oxford Internet Surveys (OXIS, 2015) which showed that people who are younger and have higher levels of education use the internet more often. These results have important implications for assessing neurologically impaired individuals and suggest that, if this assessment were to be used as a measure, clinicians would need to use descriptive statistics for a given age and education range. Furthermore the variation between email tasks supports the idea of using a range of tasks with different genres, purposes and topics to assess the discourse skills of people with aphasia and analysing the responses from these tasks separately (Whitworth et al., 2015).

The data from this study have several potential applications. Firstly, the raw email data will be published and therefore made accessible for researchers and clinicians to use for their own purposes. Secondly, the descriptive statistics of measures that were found to be stable in Chapter 2 were used in Chapters 5 and 6 as a ceiling to measure activity-level outcomes of therapies for people with aphasia and acquired dysgraphia. Thirdly, future work could focus on collecting data from a larger number of participants (with and without brain injury), on a broader range of measures and tasks, and on further developing the assessment so that it could be used clinically to assess people with acquired dysgraphia, to contribute to a profile of a patient’s writing abilities, to plan intervention and to measure outcomes.
7.2 Comparing uni-modal and multi-modal impairment-based therapies for dysgraphia: is there a difference in the effects on spelling accuracy?

In Chapter 4 two impairment-based therapies were compared: a uni-modal lexical spelling therapy and a multi-modal lexical therapy that included selecting words from semantic, phonological and orthographic distractors and writing and saying the words. The study aimed to investigate whether a multi-modal therapy would be more successful in achieving improvements to treated words, untreated words and maintenance of learning than a uni-modal therapy. The study found no difference between the two therapies in terms of changes to treated or untreated words or maintenance, similar to other studies comparing uni- and multi-modal therapies in people with aphasia (Rose & Douglas, 2008; Rose et al., 2002; Rose et al., 2013).

From one perspective this may indicate that, at least for the participants in this study, a therapy with tasks in different modalities is no more effective than one with just spelling tasks, and that improvements were simply driven by the elements that were the same: the actual spelling practice, and/or the strengthening of orthographic representations, and/or the idiosyncratic learning styles such as strategy development and use. However, from a different perspective, the multi-modal therapy was as effective as the uni-modal treatment despite the participants having considerably less spelling practice for each word; they wrote multi-modal words half as many times as uni-modal words. In the same amount of time that participants were just practising spelling in uni-modal therapy, they were also practising saying (reading or repeating) and identifying the written word in the multi-modal therapy. Attard, Rose & Lanyon (2013) described their multi-modal therapy (M-MAT) as “a highly enriched learning paradigm, involving multiple associations” (phonological, orthographic, motor and visuospatial), which may have activated numerous neural networks in some participants. This may
explain any advantages to the multi-modal therapy in this study, i.e. the practice in different modalities may have strengthened connections between semantic, phonological and orthographic representations.

The multi-modal therapy may also have had benefits to other modalities. As the focus of this study was spelling, outcomes to other language modalities were not tested, but this would be an interesting question for future research studies. Similar to findings by Rose et al. (2013), all participants preferred multi-modal therapy as they perceived it to be useful to practise saying the words and found it more interesting and challenging. Therefore arguably this would be recommended to clinicians for participants with similar aphasia and dysgraphia profiles over standard copy and recall therapies.
7.3 Do impairment-based lexical spelling therapies lead to improvements in writing in people with acquired dysgraphia?

In Chapter 5, the data from the above comparison study were collapsed and the focus was on the effects of lexical spelling therapies on the accuracy of treated and untreated single words, written picture description and email writing. Therefore, in terms of the ICF (WHO, 2015) the study targeted both the levels of *function* (single word spelling) and *activity* (email writing), whereas in previous writing therapy studies the emphasis has largely been on improving language *function*. The study found significant gains for all participants to treated and untreated words as had been found in previous lexical spelling therapy studies (e.g. Rapp, 2005; Raymer et al., 2010; Thiel & Conroy, 2014), as well as significant improvements at the group level to written picture description. This is consistent with the limited evidence on gains to written picture description following spelling therapies (Pound, 1996; Raymer et al., 2003). Although spelling accuracy only improved in the emails of one participant (JP), the mean word length within emails did increase for the group, suggesting that the therapies enabled participants to write words that they were not writing before therapy.

One of the major disadvantages cited in the literature of lexical spelling therapies has been item-specific improvements (Beeson & Rapcsak, 2002) with some exceptions (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). Therefore, the results of this study can be seen as being extremely positive and may encourage clinicians to use such therapies. Written picture description is not a particularly ecologically valid task, in that in everyday writing tasks a picture is not usually available for support. As Lesser & Algar (1995) emphasised, the goal of aphasia therapy is not to improve descriptions of complex picture scenes, but to improve functional
communication. However, it is closer to most real life tasks than spelling dictation as word generation is somewhat unconstrained, and it allows for production of phrases and sentences. The fact that participants were able to spell words not trained in therapy within spelling to dictation and picture description tasks suggests that there were some generalised effects from the therapy to both different words and a different type of task.

On a less positive note, six to twelve months after therapy, only two participants’ scores were maintained, echoing the problem found in some previous writing therapy studies (e.g. Beeson et al., 2006). Also, spelling accuracy within emails did not improve in this study, which was perhaps unsurprising, given the complex set of linguistic, cognitive, visual and motor skills necessary to use a keyboard and to write an email (Todis, et al., 2005), and given the absence of specific training of these skills within this study. These findings suggest that more research is needed into therapies or strategies that lead to retention or facilitate writing in the long term and bridge the gap between improved language function (i.e. single word spelling) and more functional but complex writing tasks such as emailing and text messaging that can improve a person’s levels of activity and participation.
7.4 Do assistive writing technologies lead to improvements in writing in people with acquired dysgraphia?

In Chapter 6, it was found that training assistive writing software, specifically Co:Writer 6, can improve spelling accuracy and can alter the types of words used within emails for a group of individuals with a range of types and severities of aphasia and dysgraphia. This was consistent with findings from previous, smaller studies that had utilised similar technologies (Armstrong & MacDonald, 2000; Behrns et al., 2009; King & Hux, 1995; Murray & Karcher, 2000).

The participants who made significant improvements to spelling accuracy within emails (AD, LR, SR and JB) were dissimilar in terms of dysgraphia subtype and severity and did not all fall at the top or bottom of the range on language assessments. Three factors that may have linked them were their relatively low scores on cognitive assessments and their relatively low scores on baseline emails (AD, LR and JB had the lowest scores of the group).

The participants in this study did find Co:Writer difficult to use, which may have related to their cognitive impairments. However, they self-selected the elements which they could use and which helped them most, which in the cases of JB, LR and AD were word banks. These results indicate that assistive writing technologies are particularly useful for individuals with severe deficits. As Jacobs, Drew, Ogletree & Pierce (2004) put it, “there continues to be an intuitive fit between AAC [augmentative and alternative communication systems] and persons with severe aphasia.”

The other participants, KR, GP, DM, and EB, did not improve significantly on accuracy within email writing, which may have reflected higher level cognitive and email writing skills, and were able to use word prediction effectively. Prediction was more difficult to use, requiring spelling, motor and cognitive skills, and also slowed participants down as was found by Behrns et al. (2009). Although the participants who opted for this as a strategy did not make such
noticeable improvements, DM, EB and GP commented that they felt happier with their writing. They report that they have continued using Co:Writer and found it supportive and helpful for writing more difficult words, which was supported by the CAT Disability Questionnaire scores of these participants, which became more positive. With regard to the analysis of psycholinguistic variables of words, DM used a greater range of word classes and EB and GP wrote longer words with the software. Interestingly, KR, DM and EB were among the highest performing on spelling therapies and lowest on the assistive technology training. It might be argued that as they were writing more independently (as seen in Table 30, Chapter 6), they did not need as much support from word banks as JB, LR and AD and only needed subtle changes to feel happier and to write and communicate more often. AD, LR and JB, who were more impaired at baseline had more room for improvement and did improve, but changes had still not given them adequate skills to write outside of therapy independently.

The differences in the comments made by these two groups of participants may also reflect the fact that DM, EB and GP had been writing emails before their stroke and had been trying to continue to write emails since their stroke, suggesting that for them email writing was a functional activity. In contrast, LR and JB had not written emails pre-morbidly (as they had their strokes nearly 20 years previously), JB had never used a computer and LR and AD had attempted emailing but with a large amount of support from their partners. Parr (1992, 1995) stresses the importance of therapy and assessment tasks being functional for the individual. In this study, the fact that tasks were not tailored to participants’ everyday activities may be a factor in how they felt about their own writing after therapy. Additionally, this study aimed to train participants to write and send emails independently, whereas Parr (1995) argues that independence may not be as important as “minimising the manifestations of impairment” (p.234). Perhaps, at least for some
participants, less emphasis on independence and more on support, i.e. in training partners to support them in using the software may have been a more feasible option for facilitating writing in the long term.

One factor that may help to partly explain the pattern of performance across participants was age, and related to that, familiarity and experience with technology. Chapter 3 showed that there was a significant relationship between age and productivity and accuracy within email writing, which was supported by data on word retrieval accuracy and speed (Stuart-Hamilton & Rabbitt, 1997; Griffin & Spieler, 2006; Burke, MacKay, Worthley, & Wade, 1991; Borod, Goodglass, & Kaplan, 1987; Spieler & Griffin, 2006). AD, JB and LR were the oldest participants (ages 74, 80 and 66) and had either never engaged with computers (JB), or had only done so recently with support from a partner (AD and LR). These participants therefore had more difficulties with general internet and keyboard use (e.g. finding the correct letter keys) and with the more complicated elements of Co:Writer. This may explain why, firstly, they had lower baseline scores on the email task (they had the lowest scores of the group), hence more room for improvement and, secondly, why they opted for the easier to use, more supportive word banks. EB, DM, GP and KR were younger participants (50, 50, 58 and 58). They had all used computers and the internet as part of their work and home lives prior to having a stroke and had continued to use them to some degree after their stroke, which was apparent in their baseline email skills assessment scores (see Figure 33, Chapter 6). They all were able to use Co:Writer relatively quickly and without much apparent effort, which they continued to do after therapy. Their lack of noticeable gains may have been partly due to the fact that they were more experienced in writing messages and had a core set of words and phrases that they could already use alone, which meant that there were less measurable differences following therapy.
As email writing and use of assistive writing technology require a complex interaction of cognitive, linguistic, visual and motor skills, it was difficult within a small scale study with a heterogeneous group of participants to isolate the particular factors that led to their success or lack of success. However, to answer the research question, certainly for some participants with acquired dysgraphia, assistive technologies did lead to measurable improvements in writing.

7.5 Can a combined approach to writing therapy that includes both spelling practice and training in supportive computer technologies improve writing via the internet in participants with acquired dysgraphia?

Aphasia treatment has traditionally fallen into distinct camps (Herbert, Best, Hickin, Howard & Osbourne, 2003): impairment-based therapy studies, guided by neuropsychological models of language processing (e.g. Franklin, Buerk & Howard, 2002; Martin, Fink, Renvall & Laine, 2006; Sage & Ellis, 2006; Schmalzl & Nickels, 2006), which aim to “regain lost function, including understanding of language and ability to use expressive language” (RCSLT, 2009 p.8); and functional (activity-level) therapy studies (e.g. Carragher, Sage & Conroy, 2014; Cunningham & Ward, 2003; Worrall & Yui, 2000) aiming to maximise the individual’s communicative ability through encouraging use of residual skills and compensatory strategies or training communication partners (RCSLT, 2009). However, in recent years attempts have been made within aphasia and dysgraphia therapy studies to bridge the gap between impairment-focused and functional approaches (e.g. Herbert et al., 2003; Robson et al., 2001; Panton & Marshall, 2008). Moreover, the potential of assistive technologies has been explored and some studies have successfully combined training in compensatory software with impairment-based techniques (e.g. McCall, Virata, Linebarger & Berndt, 2009; Mortley et al., 2001; Murray & Karcher, 2000; Beeson et al., 2010).
Chapters 4, 5 and 6 demonstrated that both spelling practice and assistive writing technologies could support writing in people with acquired dysgraphia. The aim of the thesis was to evaluate a combined approach with the ethos of bringing together all available resources for writing rehabilitation and examining the relative contribution of each element. It was hypothesised that spelling therapies would improve spelling accuracy which may lead to small improvements in email writing. It was then predicted that assistive writing software would build on the gains from spelling therapies and would facilitate email writing through providing support with more difficult spellings (through prediction or word banks), grammar (through grammar prediction or phrases in word banks), editing (through spell check or text to speech) and self-monitoring (through text to speech). The following sections will summarise any findings of combined improvements to the following: spelling accuracy within emails, psycholinguistic properties within emails, and perception of writing. As two participants withdrew after the initial study and two new participants volunteered for the second study, only six participants took part in both lexical and compensatory therapies. These were KR, AD, EB, DM, SR and JB and in the following sections only their performance will be considered. A summary of their baseline spelling and language assessments as well as aphasia and dysgraphia profiles can be seen in Table 31.
Table 31. Summary of baseline aphasia and spelling profiles of participants who participated in both studies

<table>
<thead>
<tr>
<th>Assessment</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total BDAE score</td>
<td>80</td>
<td>35</td>
<td>76</td>
<td>69</td>
<td>97</td>
<td>99</td>
<td>115</td>
</tr>
<tr>
<td>Fluent/ Non-fluent</td>
<td>Non-fluent</td>
<td>Non-fluent</td>
<td>Fluent</td>
<td>Non-fluent</td>
<td>Fluent</td>
<td>Fluent</td>
<td></td>
</tr>
<tr>
<td>Total PALPA word spelling score</td>
<td>51</td>
<td>55</td>
<td>56</td>
<td>65</td>
<td>66</td>
<td>72</td>
<td>128</td>
</tr>
<tr>
<td>Non-words</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>2</td>
<td>19</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Effects</td>
<td>Imageability</td>
<td>Imageability; length</td>
<td>None</td>
<td>None</td>
<td>Regularity; lexicality</td>
<td>Imageability</td>
<td></td>
</tr>
<tr>
<td>Error types</td>
<td>Omission, substitution, &lt;50% of target; semantic (occasional)</td>
<td>Transposition, addition, omission, &lt;50% of target; semantic (occasional)</td>
<td>Addition, omission, substitution; &lt;50% of target morph.</td>
<td>Substitution; addition, omission; &lt;50% of target</td>
<td>Addition; omission; substitution; morphological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dysgraphia type</td>
<td>Deep</td>
<td>Deep</td>
<td>GBD</td>
<td>Phonological</td>
<td>Surface</td>
<td>Phonological</td>
<td></td>
</tr>
</tbody>
</table>
7.5.1 Spelling accuracy

The participants’ spelling accuracy scores (in spelling to dictation, written picture description and email writing assessments) across lexical therapy and technology training are presented in Table 32. All participants showed significant improvements to treated and untreated items following lexical therapies. However, there was a wide range of performance within the group. The participants with the highest scores on treated items (of the six who took part in both therapies) were DM and KR (see Table 32). As can be seen in Table 31, DM and KR were both non-fluent but were not similar in terms of aphasia severity. However, they did have similar dysgraphia profiles with symptoms of deep dysgraphia and both having the lowest PALPA scores of the group. As discussed above, this is likely to reflect the types of words (high frequency, high imageability, functional) targeted in therapy for these participants. AD and JB had the lowest lexical therapy scores, although in terms of aphasia and dysgraphia severity they fell in the middle of the group. Table 27 (Chapter 6) shows participants’ cognitive assessment scores. Interestingly, it was AD and JB who had the low scores relative to the group and DM and KR who had the highest scores, suggesting that cognitive ability, particularly visual memory skills (Rey Complex Figure Test; Camden Memory Test) are important for relearning the spellings of words. This is perhaps unsurprising considering that copy and recall tasks were used in lexical therapies. Similar results were found in the naming therapy literature, where performance on naming therapies was found to be related to executive functioning skills (Lambon Ralph, Snell, Fillingham, Conroy & Sage, 2010). Furthermore, Beeson et al. (2003) hypothesised that their participant’s low performance in spelling therapy was due to poor performance on visual problem solving abilities and visual span.
Written picture description performance was assessed before and after both lexical therapies and technology training. Although group changes were only significant after lexical therapies (and statistical significance of individual scores could not be tested), some participants showed improvements across both therapies. DM showed small improvements following both phases of therapy; however, following technology training this was only to correct units. KR only improved following lexical therapies, which is likely to reflect her significant gains on spelling to dictation at this stage of therapy in contrast to the technology training where no improvements were noted. AD did not improve on written picture description at any stage, probably because she had difficulties with message generation, word retrieval and spelling as well as the motor aspects of handwriting. JB only improved following lexical therapies. EB and SR showed large changes following both therapies. For EB the changes following lexical therapy were not maintained at the assessment point before technology training but her writing skills seem to have then been boosted again by the additional writing practice. SR made incremental gains across the two therapies with scores to correct units increasing from 9 at baseline to 35 post technology training (correct and informative units 7-18). This may reflect his significant improvements to other tasks following both types of therapy. In fact, improvements in technology training could not be attributed to word prediction or word banks as he did not use these to a great extent within therapy (see Table 30) and therefore seemed to be due to support in monitoring from text to speech and spell check (which he said that he found helpful). It could be the case that writing practice in both therapies led to generalised improvements to writing and/or editing.

Lexical spelling therapies did not result in significant improvements to spelling accuracy within email tasks for the group or for these six participants. Following the compensatory, assistive technology
training approach, there were significant gains to email writing both at the group level and individually for SR and JB (in terms of correct units) and AD (in terms of correct and informative units). Moreover, there was also a positive trend for DM, AD and EB for correct units and DM, JB, SR and EB for correct and informative units. Therefore, it seems that technology training and use was more effective in improving spelling accuracy within emails than lexical therapies. As discussed previously, this is unsurprising considering the differences between writing single words (predominantly nouns) with pen and paper and writing emails which requires keyboard and computer knowledge and skills, message generation ability and ability to retrieve and spell a wide range of words that may include low imageability, low frequency items and a range of word classes. The use of Co:Writer at least partly compensated for difficulties with message generation, written word retrieval and spelling impairments, and the keyboard and internet training provided support for the keyboard and internet skills specific to email writing.

The participants who demonstrated significant improvements had a range of language profiles (see Table 3). SR was among the participants with the highest scores on the BDAE (when total scores were calculated out of 115) while AD and JB had relatively lower scores. SR and AD had fluent aphasia and JB had non-fluent aphasia. In terms of reading and comprehension, these participants, again, did not all fall at the top or the bottom of the range. They had a range of dysgraphia profiles, with JB fitting the category of phonological dysgraphia, AD having symptoms of graphemic buffer disorder and SR presenting with surface dysgraphic symptoms. Also there was no observed relationship between email writing accuracy and total baseline PALPA scores and therapy outcomes.

However, some patterns were observed. As was the case in the lexical therapy study, with the exception of SR, it was those with the lowest performance at baseline who performed better. AD and JB had the lowest pre-therapy performance on email writing and both
showed significant improvements to email writing when using Co:Writer. Therefore, room for change seems to be an important factor in success. In lexical therapies this was related to the fact that the participants with the more severe dysgraphia were perhaps more motivated and were treated on easier and more functional words. In the technology training the participants with the most marked difficulties with email writing selected word banks, which proved to be a very helpful strategy (see Chapter 6 Discussion). There was also a pattern regarding cognitive skills, with the higher performing participants in the technology training study demonstrating the lowest scores on cognitive assessments (see Table 27, Chapter 6).

Although, cognitive impairments impeded lexical relearning for AD, SR and JB and also contributed to difficulties with using word prediction for AD and JB, this then led to the selection of word banks as a strategy which were highly effective in producing accurate written text quickly.

In summary, contrary to predictions, the contributions of both approaches to spelling accuracy were not seen within email writing which we had adjudged to be our ultimate functional writing task, but in separate and discreet outcome measures: lexical therapies resulted in significant improvements to single word and picture description tasks while Co:writer training and use led to improvements to accuracy within emails. Therefore, in terms of the ICF framework (WHO, 2015), it seems that impairment-based spelling therapies can improve a person’s language function (here spelling accuracy), whereas assistive writing technologies are a more feasible option for improving a person’s level of activity. According to the RCSLT, activity level aphasia therapy aims to “minimise communication disability by ensuring maximum use of current abilities [which] may include compensatory strategies and alternative means of communication (RCSLT, 2009, p.8).
There may have been unobserved contributions, for example, that generalised improvements to writing following the lexical spelling therapy facilitated use of the predictive writing software or spell check, which required a certain level of spelling to generate initial letters of a word. However, as software use was not tested before the lexical therapy, it was not possible to determine how well participants could use it beforehand and whether the lexical therapy supported this. In any case it seems that some participants, particularly those with higher level cognitive skills (i.e. DM and KR), respond better to lexical therapies, and for others who have lower level cognitive skills and difficulties relearning words (i.e. AD, JB and SR), a supportive compensatory approach is a more realistic and successful method of writing.
Table 32. Accuracy scores across therapies

<table>
<thead>
<tr>
<th>Assessment</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
<th>Ceiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score on treated words in lexical therapies</td>
<td>51*</td>
<td>48*</td>
<td>21*</td>
<td>16*</td>
<td>27*</td>
<td>35*</td>
<td>80</td>
</tr>
<tr>
<td>Total score on untreated words in lexical therapies</td>
<td>13*</td>
<td>9*</td>
<td>8*</td>
<td>5*</td>
<td>12*</td>
<td>8*</td>
<td>40</td>
</tr>
<tr>
<td>Written picture description: correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>5</td>
<td>16</td>
<td>6</td>
<td>2</td>
<td>9</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Post lexical</td>
<td>10</td>
<td>26</td>
<td>5</td>
<td>7</td>
<td>29</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Pre technology training</td>
<td>13</td>
<td>27</td>
<td>9</td>
<td>8</td>
<td>25</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Post technology training</td>
<td>16</td>
<td>24</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Written picture description: correct and informative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>5</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Post lexical</td>
<td>10</td>
<td>14</td>
<td>2</td>
<td>5</td>
<td>12</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Pre technology training</td>
<td>13</td>
<td>15</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Post technology training</td>
<td>12</td>
<td>14</td>
<td>4</td>
<td>3</td>
<td>18</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Email: correct units</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean baseline</td>
<td>18.5</td>
<td>37</td>
<td>18.5</td>
<td>11</td>
<td>33.5</td>
<td>63.5</td>
<td></td>
</tr>
<tr>
<td>Post lexical</td>
<td>18</td>
<td>31</td>
<td>20</td>
<td>7</td>
<td>35</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Pre technology training no Co:Writer</td>
<td>26</td>
<td>40</td>
<td>18</td>
<td>11</td>
<td>39</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Post technology training with Co:Writer</td>
<td>33</td>
<td>43</td>
<td>32</td>
<td>25*</td>
<td>58*</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Email: correct and informative words</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean baseline</td>
<td>15</td>
<td>23</td>
<td>8.5</td>
<td>5.5</td>
<td>21</td>
<td>43.5</td>
<td></td>
</tr>
<tr>
<td>Post lexical</td>
<td>14</td>
<td>22</td>
<td>6</td>
<td>5</td>
<td>23</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Pre technology training no Co:Writer</td>
<td>21</td>
<td>22</td>
<td>8</td>
<td>9</td>
<td>30</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Post technology training with Co:Writer</td>
<td>26</td>
<td>18</td>
<td>22*</td>
<td>17</td>
<td>40</td>
<td>39</td>
<td></td>
</tr>
</tbody>
</table>

*statistically significant improvement (p < .05).
7.5.2 Psycholinguistic properties of words within emails

Within dysgraphia therapy studies, there has been a focus on spelling accuracy. However, people with aphasia often have difficulty, not just with arranging letters correctly within a word, but in retrieving words with particular psycholinguistic properties (e.g. low imageability words for participants with phonological or deep dysgraphia). There was one measure that showed significant improvements on a group level following both phases of therapy: mean length of words within emails. Table 3 shows the participants’ mean word length within emails across therapies. Mean word length increased for JB, SR and KR (with minimal changes for DM and EB) following impairment-based therapies, and for AD, SR and EB (with minimal changes for JB) following assistive technology training. Armstrong & MacDonald (2000) also found that their participant was able to spell long words more accurately when using word prediction software. For all participants at least one of the therapies helped them with writing longer words, and one participant, SR, was able to use longer words as a response to both phases of therapy. His mean word length increased from 3.2 letters at baseline, to 3.7 letters post spelling therapies, then decreased to 3.4 at follow-up (baseline of technology training) and increased to 3.9 post technology training. This suggests that for him, the combined efforts of learning words and using assistive software had positive effects on the words used within emails, with impairment-based therapies taking him so far and then assistive software supplementing this. DM only showed improvement to word length following impairment-based therapies, which was consistent with the findings from accuracy data that impairment-based therapies were more successful for him. AD and EB only showed an increase in word length following technology training. For AD this reflected her more marked improvements to writing with software, whereas for EB, who did not show any other improvements with the software, it suggested that there were perhaps some subtle changes, which supported her perception that
her writing was better (i.e. more elaborate, less simple) when using the software.

Table 33. Mean letter length in emails across therapies

<table>
<thead>
<tr>
<th></th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre lexical therapy</td>
<td>4</td>
<td>3.9</td>
<td>3.1</td>
<td>4</td>
<td>3.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Post lexical therapy</td>
<td>3.9</td>
<td>4.2</td>
<td>2.9</td>
<td>4.6</td>
<td>3.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Pre technology training</td>
<td>4.8</td>
<td>4</td>
<td>2.6</td>
<td>4.5</td>
<td>3.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Post technology training with Co:Writer</td>
<td>4.8</td>
<td>3.9</td>
<td>3.9</td>
<td>4.6</td>
<td>3.9</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Another psycholinguistic measure that showed positive changes was word class. These were predominantly associated with technology training, with DM, JB and AD showing differences to the types of words they were using. However, DM produced a greater range of word classes following both types of therapy, which was an important change for him due to his agrammatism and difficulties with producing verbs and function words in speech and writing. Both therapies resulted in a lower percentage of nouns and a higher percentage of verbs and function words. A similar finding emerged in the Behrns et al. (2009) study where one participant with non-fluent, agrammatic speech, managed to produce verbs with predictive writing software.

These types of findings emphasise the importance of conducting more fine-grained analyses of written language to measure the outcomes of such complex therapies. The increase in length following impairment-based therapies also indicated that impairment-based therapies may result in at least subtle changes to functional writing within unconstrained tasks, which is a novel finding, as until now the focus of spelling therapy studies has been measuring changes to accuracy, which may not be sensitive enough for functional writing tasks such as email writing.
7.5.3 Perception of writing

The ultimate goal of aphasia therapies is to affect change in functioning in everyday life (Carragher, Conroy, Sage & Wilkinson, 2012). Following both therapy phases, participants reported that they noticed general improvements to their everyday writing skills. DM, JP and KR commented that they had noticed improvements in everyday writing tasks, such as emailing or writing shopping lists, following lexical therapies, and that they had engaged in writing more frequently since therapy. DM and EB mentioned that they had been writing more frequently since they started using Co:Writer. However, when the CAT Disability Questionnaire was used individual participants did not rate their writing significantly more positively after either therapy, despite improvements occurring on a group level following assistive writing technology training, due to the positive trend for participants DM, GP, KR, SR and EB (see Table 34 for the CAT Disability Questionnaire writing subtest scores across therapies). The participants who made significant gains on the assistive technology training (AD, SR & JB) did not find that they were writing more often, nor did they think that their writing had improved. Unfortunately, they were unable to use the software independently, which suggested that for some participants with marked cognitive and linguistic impairments, more training and/or support after therapy is necessary (van der Sandt-Koenderman, 2011; van de Sandt-Koenderman, Wiegers, Wielaert, Duivenvoorden & Ribbers, 2007). In the case of AD, LR and JB, training their husbands to use the software would have meant that they would have had support whenever they needed it. The fact that therapies were not tailored to participants’ individual needs and interests and that all had the same therapy targets and outcome measures regardless of premorbid and post-stroke writing experience, types of activities and levels of motivation may have been a contributing factor to the lack of change to perception of writing (Parr, 1995).
Table 34. CAT Disability Questionnaire writing subtest scores across therapies

<table>
<thead>
<tr>
<th></th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre lexical therapy</td>
<td>12</td>
<td>4</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Post lexical therapy</td>
<td>8</td>
<td>6</td>
<td>11</td>
<td>5</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Pre technology training</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Post technology training</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

7.5.4 Summary

If all outcome measures are considered, all participants except KR showed some degree of benefit from both approaches, suggesting that they both contributed to improved writing performance, with impairment-based therapies contributing more to improvements to the language function level and technologies targeting the activity level. Following lexical therapies, all participants improved significantly on single word spelling accuracy with some also showing gains to written picture description, and DM, KR, JB, SR and EB writing longer words after therapy. Following assistive technology training SR, AD and JB improved significantly on spelling accuracy within emails and all except KR showed changes to the types of words they were using. Previous studies which combined impairment-based therapies with assistive writing technologies found similar results, i.e. that the impairment-based therapy had improved accuracy and that the technology (e.g. electronic spelling aid or
predictive writing software) had then further increased accuracy to either single words or narrative or procedural discourse (Beeson et al., 2010; Murray & Karcher, 2000). In the present study only the assistive writing training resulted in improved perceptions of writing. Again, previous writing therapy studies found changes to perception of disability having training the participant to use an assistive writing technology (Estes & Bloom, 2011; Murray & Karcher, 2000).
7.6 Does this work make a novel contribution to the dysgraphia literature?

This thesis aimed to make a novel contribution to the aphasia and dysgraphia literature. It has involved measuring the effects of a complex intervention which combined two types of therapy. Other therapy studies which included both impairment-based and compensatory elements (e.g. Murray & Karcher; Beeson et al., 2010; Mortley et al., 2001) made positive contributions to the aphasia and dysgraphia literature in that, for example, they showed that combined interventions could be successful for improving the writing of individual participants. However, they did not describe the relative contributions of each element separately. Recently, the British Medical Journal published ‘The Template for Intervention Description and Replication’ (TIDieR, Hoffman, Glasziou, Boutron, Milne, Perera, Moher, Altman, Barbour, Macdonald, Johnston, Lamb, Dixon-Woods, McCulloch, Wyatt, Phelan & Michie, 2014), a checklist and guide for better reporting of interventions. According to the Hoffmann et al. (2014) descriptions of interventions often omit information such as duration, dose, intensity and mode of delivery, meaning that findings cannot be replicated by researchers and that treatments cannot be implemented by clinicians. They stress that this information should be reported for each element of the intervention. This study has measured the effects of both phases of a combined intervention and each element has been described in detail so that it can be replicated.

As stated in the Introduction, seventy nine percent of dysgraphia therapy studies have had a sample size of between 1 and 4 and most have included participants with similar types or severities of dysgraphia. With ten participants (eight in each study), the studies reported in this thesis form a series of relatively large dysgraphia therapy studies. Participants with a range of types and severities of dysgraphia were selected, firstly, so that patterns could be found,
and secondly, to reflect the range of needs typically found within clinical practice.

A further discrepancy in the dysgraphia literature, which emerged in Chapter 2, was the lack of functional outcomes for dysgraphia, both for use by clinicians and to measure the outcomes within studies. This study has been novel in the fact that an ecologically valid outcome measure was developed, normed on healthy control participants and then used to measure therapy outcomes. This is going to be developed further and published so that it can be made available to clinicians.

7.7 Limitations of the thesis

This study attempted to evaluate complex interventions, which can be subject to a large amount of variation (Campbell, Fitzpatrick, Haines, Kinmonth, Sandercock, Spiegelhalter & Tyrer, 2000). Writing therapy studies in general and particularly those evaluating assistive writing technologies are still in their infancy and require preliminary work to determine their important components (Campbell et al., 2000). Therefore, this was a Phase 1 study, designed to investigate the efficacy of different therapies and to identify which aspects of writing therapies are required for writing to be improved, so that this information can be used to design clinical trials in the future (Campbell et al., 2000; Robey & Schultz, 1998). This has been one of the first studies to evaluate assistive writing technologies; therefore the most appropriate type of design was a multiple case study, as it allowed for time consuming assessments and interventions to be carried out on a small number of participants so that a thorough profile could be made for each participant's aphasia, dysgraphia and stroke symptoms, while having a large enough number to find some patterns in individual characteristics. One limitation of single and multiple case studies is that the findings cannot be generalised across a wider population of people with
aphasia, especially because aphasia is an extremely heterogeneous condition, with each individual presenting with different symptoms and levels of severity of impairment regarding expressive and receptive language (Brady, Kelly, Godwin & Enderby, 2012). Furthermore, as computer and internet skills as well as technologies were trained across the studies, other cognitive, motor and visual skills that can be impaired by stroke may have been required. Therefore, although therapists may decide to use these findings to guide them in therapy with patients with similar symptoms, it is likely that they will respond differently due to other factors (e.g. cognition, motivation, experience, age, level of support).

In hindsight the results may have been clearer if there had been more exclusion criteria. For example potential participants could have been excluded if they did not already have experience with using the internet or if they had a certain level of cognitive impairment. Control participants could have had stricter criteria too so that the number of possible factors affecting productivity could have been reduced (e.g. prior computer experience). However, JB would then have been excluded (due to lack of experience and cognitive impairment) and in fact she made improvements on both types of therapies despite these barriers. This study has attempted to reflect the heterogeneity in patients in real-life clinical practice. One difficulty with interpreting results from the aphasia literature has been that there is a bias towards recruiting participants with mild to moderate aphasia or dysgraphia, whereas the current study has added to the evidence that people with severe cognitive, linguistic or spelling deficits can make significant gains following therapy (Ball et al., 2011; Beeson et al., 2013; Mortley et al., 2001). A further disadvantage of the small sample size was that it was not possible to use statistical methods, e.g. multiple regression analyses, to examine the relationships between cognitive, linguistic and spelling skills and therapy outcomes.
The email writing task had two assessment periods around an “effort phase” to control for changes in writing due to effort alone. Also, the two measures that were used (correct unit and correct and informative units) were found to be stable for the ten matched controls who were tested twice. However, the rigour of this study could still have been strengthened through achieving a more stable baseline for each of the outcome measures, especially because writing is a skill that seems to be highly variable. There was only one baseline assessment point for written picture description; therefore improvements on this assessment following impairment-based therapies may have to be interpreted with caution. On the other hand, participants took part in this study for two years which included twenty sessions of therapy and many more sessions of assessments. From an ethical point of view, there needs to be a consideration of how much we are overburdening participants in these studies. Participants consented to this number of sessions and were always happy to continue, but most conceded at the end that they were glad that it was finished because it was tiring. Therefore, there has to be a limit on the number of assessments conducted.

The primary outcome measures for email writing were number of correct units and number of correct and informative units. On reflection, measures of productivity such as these might not have been the most appropriate to evaluate technologies that slow writing down, i.e. word prediction. Time was not necessarily important to all of the participants. For example, DM was prepared to spend an hour on an email to make it as accurate and meaningful as possible. Comparing emails before therapy without Co:Writer to after therapy with Co:Writer was probably always going to show Co:Writer as being at a disadvantage if prediction was used as there were likely to be less words produced, even if emails were generally more accurate. For this reason, percentages were calculated too but were all too high to show any statistical differences. Based on participants’ positive comments about the more difficult words they were able to
write after therapy (that were not showing up in these measures), more fine grained analyses of types of words were conducted. As expected these did show some improvements.

The rigour of this study may also have been strengthened if an independent assessor had been used to administer assessments before and after each therapy. Using the same person to provide assessment and therapy introduces observer bias into the study which is a common problem in single subject design studies (Tate, McDonald, Perdices Togher, Schultz & Savage, 2008).

When conducting statistical analyses (Wicoxon Matched Pairs Test, Chi Square Test and McNemar Test) for pre and post therapy comparisons of outcome measures and across therapy comparisons, the one-tailed version of the test was chosen rather than the two-tailed equivalent, which in some cases would have led to non-significant results which differed from the significant ones provided by 1 tailed tests. The one-tailed test is the most appropriate test to choose if a directional hypothesis is being tested (Field, 2009). In the case of these comparisons the hypothesis was that scores on a certain measure would improve with therapy or that one therapy would be more effective than another. Although one-tailed tests have the advantage of being more powerful for detecting a false null-hypothesis, the disadvantages of using one-tailed tests are that they do not look at effects in the other direction (the opposite of what is being predicted); in this case, whether participants became significantly worse after therapy, and it is therefore difficult to interpret a non-significant result (Ruxton & Neuhaeser, 2010).

According to Parr (1992; 1995; 1996), therapy targeting reading and writing skills need to be designed collaboratively with the patient through thorough assessment and interview. Pre-morbid and post-stroke activities, roles and activities need to be taken into account. Parr (1995) recommends that therapy should target reading and
writing activities but also supportive strategies and adjustment. In this study an attempt was made to measure the effect of therapies on a functional activity, email writing (within Chapters 5 and 6), and to train email writing (in Chapter 6). Furthermore, in Chapter 6 a more social-model approach (Parr, 1995) to therapy was used with participants’ being trained to write with supportive assistive technologies. The emphasis was on minimising disability rather than retraining language and therefore was focused on the activity level of the ICF (WHO, 2015), rather than the language function level. In both Chapters 5 and 6 participants’ perceptions of their disability were evaluated. Moreover, a thorough case history for each participant was conducted and therapy tasks were selected with participants’ interests in mind (e.g. writing a birthday card was included with consideration of JB). However, this was a case series study and it was therefore important to keep as many variables as possible constant so that patterns across participants could be explored; therefore, the same assessment and therapy tasks were given to all participants. This may be a factor in the minimal changes following therapy as therapies were not tailored to participants’ needs or interests which may have led to a lack of motivation or ability to complete the tasks. A further related limitation was the fact that data from all email assessment tasks were combined within the clinical studies, despite differences in outcomes of discourse measures being found across tasks in Chapter 3. As Whitworth et al. (2015) point out, different genres have different common structures (e.g. for cohesion and coherence) and can be used to elicit different grammatical forms (Coelho, 2002). The responses to these different tasks were not analysed separately in Chapters 5 and 6 due to practical constraints such as word counts within journal articles (these papers were submitted to peer review journals). However, there is scope for these data to be analysed further in future studies to explore the differences across genres.
Finally, since this study was designed four years ago, there have been rapid and exciting developments in the technologies that have become available. Now on tablets, mobile phones and laptops, technologies that can support writing are already included (e.g. prediction on the iPad’s email programme) or available through apps (e.g. Co:Writer or Read&Write). In reality, people with aphasia might prefer to use these instead of investing in expensive computer software (Co:Writer = £179 per license). Although the software in this study may have similar elements to more newly available technologies, there is a need for research to keep up to date and to reflect the real-life support or barriers that people with aphasia are experiencing.

7.8 Clinical implications and future directions

Firstly, the research reported in this thesis has shown that multi-modal lexical therapies that target individual words with different language tasks (repetition, reading, spelling, and spoken word to written word matching) may be advantageous to uni-modal spelling therapies, as they are equally successful in improving spelling while also providing the opportunity to target the word in other modalities. Multi-modal therapy was also preferred by participants (as was found by Rose et al., 2013).

Secondly, lexical impairment-based spelling therapies (with copy and recall tasks) seem to be worth the time investment as they improve spelling accuracy of treated and, to some extent, untreated words and can lead to generalised gains to different linguistic contexts. However, due to the poor maintenance in this study it is advisable that patients continue to practise words outside of therapy. Participants can train themselves with copy and recall therapies (Beeson, 1999). Furthermore, for functional writing tasks it seems that more specific training needs to be provided (e.g. Beeson et al., 2013; Greenwald, 2004).
Thirdly, the evidence on assistive writing technologies is still in its infancy and it is not yet known which types of technologies work for which individuals. Based on this study it seems that participants with more severe cognitive, spelling, motor and linguistic deficits benefit most from word and phrase banks and that to use predictive writing software, higher level cognitive and spelling skills are necessary.

Although there is a relatively large body of research on how to improve single word spelling accuracy, there is clearly a need for more research on therapies and strategies that aim to achieve gains in functional writing, especially tasks that will provide more opportunities to communicate such as email writing and text messaging. As therapists are likely to use all available resources to facilitate writing in their patients with aphasia, further research could further explore the idea of combining both impairment-based and compensatory techniques, especially as more and more freely-available writing technologies are being developed and sold at more affordable prices. A larger study is needed to investigate the predictive value of cognitive, linguistic, reading, spelling and motor skills as well as experience of technology use on success in therapies and with technologies. Building on some initial healthy control data collected in this study, an email writing assessment needs to be developed so that clinicians have an ecologically valid tool that can be used. Finally, this study has shown that a relatively user-friendly programme that was developed for people with spelling and motor impairments was not easy to use for people with aphasia following stroke who had a combination of deficits in cognitive, linguistic and motor skills. There is scope for an aphasia-friendly programme or app to be developed in conjunction with people with aphasia so that their specific writing needs can be met.
7.9 Conclusion

In conclusion, the studies in this thesis have suggested that impairment-based and compensatory technologies have their own unique roles within aphasia rehabilitation, but can also be either combined or discreetly applied to facilitate writing. Both approaches can support people with a range of types and severities of dysgraphia but both require a great deal of motivation and time investment. Finally, an important finding that emerged throughout the entire study was that within therapies, participants actively selected and developed their own coping and learning strategies for negotiating the complex range of tasks within writing. This implies that, as a clinician, it is important to remain flexible and take into account individual learning styles and preferences.
References


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Appendices

Appendix 1. Figure 40. Time course of therapy

Baseline and background assessment: 1-2 month

Lexical therapy 1 and post therapy assessment: 3 weeks

2 week break

Lexical therapy 2 and post therapy assessment: 3 weeks

6 week break

Follow-up assessment: 1 week

12 month break for Group 1; 6 month break for Group 2

Follow-up assessment: 1 week

4 month break for planning of technology study

Baseline assessment: 2 weeks

Technology training: 5 weeks

Assessment: 2 weeks
Appendix 2. Emails written by a healthy control participant (Participant 9)

1.
Hello, hope you’re ok. Please come to mine for about half seven on Saturday and then we will get the train into Manchester at around 8. Should be home for around 10ish? See you then. Sally

2.
Hello, recently I have been on holiday to Transylvania. I did this as part of a biology expedition with college, for two weeks. We stayed mostly in tents, but spent a few nights in guest houses. These were still only basic and I was much looking forward to sleeping in my own bed! We got to see loads of animals and even a bear, which was really cool. Hope to see you soon. Sally

3.
Dear Nigel Evans,
Following Barack Obama’s recent speech regarding a decrease in the possession of nuclear weapons, I think now would be an appropriate time to consider the future of project Trident.

Projects such as this are unnecessary and are in no way helpful in decreasing nuclear warfare across the world. Surely it is hypocritical for us to be again the behaviour of South Korea, for example, yet be hiding a similar potential scheme ourselves?

In a time where money is scarce and all sectors face severe cuts
Appendix 3. Sample spelling errors of participants with aphasia

Table 35. Responses to first 10 words from PALPA 44 (Regularity and Spelling) for LR, GP, JP, DM and KR

<table>
<thead>
<tr>
<th>Target</th>
<th>LR</th>
<th>Error types</th>
<th>GP</th>
<th>Error types</th>
<th>JP</th>
<th>Error types</th>
<th>DM</th>
<th>Error types</th>
<th>KR</th>
<th>Error types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant</td>
<td>Elap</td>
<td>&lt;50% of target letters</td>
<td>empin</td>
<td>&lt;50% of target letters</td>
<td>elephant</td>
<td>Correct</td>
<td>elephant</td>
<td>Correct</td>
<td>elephant</td>
<td>Correct</td>
</tr>
<tr>
<td>Aunt</td>
<td>Auat</td>
<td>Substitution</td>
<td>aum</td>
<td>Substitution/ omission</td>
<td>Ant</td>
<td>Omission</td>
<td>aum</td>
<td>Substitution</td>
<td>aunt</td>
<td>Correct</td>
</tr>
<tr>
<td>Egg</td>
<td>Egg</td>
<td>Correct</td>
<td>egg</td>
<td>Correct</td>
<td>Egg</td>
<td>Correct</td>
<td>egg</td>
<td>Correct</td>
<td>egg</td>
<td>Correct</td>
</tr>
<tr>
<td>Squirrel</td>
<td>S</td>
<td>&lt;50% of target letters</td>
<td>squi</td>
<td>Omission</td>
<td>squill</td>
<td>Substitution/ addition/ transposition</td>
<td>squir</td>
<td>Omission</td>
<td>squirle</td>
<td>Transposition</td>
</tr>
<tr>
<td>Bump</td>
<td>bumy</td>
<td>Substitution</td>
<td>mi</td>
<td>&lt;50% of target letters</td>
<td>Bume</td>
<td>Substitution</td>
<td>hump</td>
<td>Substitution/ semantic/ phonological</td>
<td>bump</td>
<td>Correct</td>
</tr>
<tr>
<td>Sword</td>
<td>Su</td>
<td>&lt;50% of target letters</td>
<td>sh</td>
<td>&lt;50% of target letters</td>
<td>Sord</td>
<td>Omission/ Phonological</td>
<td>sword</td>
<td>Correct</td>
<td>sword</td>
<td>Correct</td>
</tr>
<tr>
<td>Hold</td>
<td>HOLy</td>
<td>Substitution</td>
<td>owes</td>
<td>&lt;50% of target letters</td>
<td>Hold</td>
<td>Correct</td>
<td>hold</td>
<td>Correct</td>
<td>baggane</td>
<td>&lt;50% of target letters</td>
</tr>
<tr>
<td>Bird</td>
<td>Brin</td>
<td>Substitution/ transposition</td>
<td>bird</td>
<td>Correct</td>
<td>Brid</td>
<td>Transposition</td>
<td>bird</td>
<td>Correct</td>
<td>bird</td>
<td>Correct</td>
</tr>
<tr>
<td>Giraffe</td>
<td>-</td>
<td>No response</td>
<td>ga</td>
<td>&lt;50% of target letters</td>
<td>Giraff</td>
<td>Omission</td>
<td>givffe</td>
<td>Omission/ substitution</td>
<td>giraffe</td>
<td>Addition/ omission</td>
</tr>
<tr>
<td>Spring</td>
<td>Spi</td>
<td>Omission</td>
<td>sin</td>
<td>Omission</td>
<td>Sping</td>
<td>Omission</td>
<td>sping</td>
<td>Omission</td>
<td>spring</td>
<td>Correct</td>
</tr>
</tbody>
</table>

Phonological = Affected by the sound of the target word: includes phonologically similar words and phonologically plausible non-words. Additions, substitutions, transposition and omission errors only include responses with at least 50% letters of target word. <50% of target letters = Errors with less than 50% of letter in target word; does not include responses that are phonologically or semantically related to target; semantic = responses with an associated meaning to the target word.
Table 36. Responses to first 10 words from PALPA 44 (Regularity and Spelling) for AD, JB, SR, MB and EB

<table>
<thead>
<tr>
<th>Target</th>
<th>AD</th>
<th>Error types</th>
<th>JB</th>
<th>Error types</th>
<th>SR</th>
<th>Error types</th>
<th>MB</th>
<th>Error types</th>
<th>EB</th>
<th>Error types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant</td>
<td>ELOPHNT</td>
<td>Substitution/omission</td>
<td>Eleputp</td>
<td>Substitution/omission/addition</td>
<td>ELEPHANT</td>
<td>Correct</td>
<td>ELEPHANT</td>
<td>Correct</td>
<td>elephant</td>
<td>Correct</td>
</tr>
<tr>
<td>Aunt</td>
<td>AUNT</td>
<td>Correct</td>
<td>aunt</td>
<td>Correct</td>
<td>HANT</td>
<td>Addition/omission</td>
<td>AUNT</td>
<td>Correct</td>
<td>aunt</td>
<td>Correct</td>
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<tr>
<td>Egg</td>
<td>EGG</td>
<td>Correct</td>
<td>Egg</td>
<td>Correct</td>
<td>EGG</td>
<td>Correct</td>
<td>EGG</td>
<td>Correct</td>
<td>egg</td>
<td>Correct</td>
</tr>
<tr>
<td>Squirrel</td>
<td>SQUIHCHL</td>
<td>Substitution</td>
<td>Sq</td>
<td>&lt;50% of target letters</td>
<td>SQUIRAL</td>
<td>Omission/substitution</td>
<td>SQUIRELL</td>
<td>Addition/omission</td>
<td>skquer</td>
<td>Addition/substitution/omission</td>
</tr>
<tr>
<td>Bump</td>
<td>BUMP</td>
<td>Correct</td>
<td>Bump</td>
<td>Correct</td>
<td>BUBPE</td>
<td>Substitution/addition</td>
<td>BUMP</td>
<td>Correct</td>
<td>bump</td>
<td>Correct</td>
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<tr>
<td>Sword</td>
<td>SCORD</td>
<td>Substitution</td>
<td>Sword</td>
<td>Correct</td>
<td>SWORD</td>
<td>Correct</td>
<td>SWORD</td>
<td>Correct</td>
<td>swored</td>
<td>Addition</td>
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<tr>
<td>Hold</td>
<td>HOLD</td>
<td>Correct</td>
<td>Holt</td>
<td>Substitution</td>
<td>HOLD</td>
<td>Correct</td>
<td>HOLD</td>
<td>Correct</td>
<td>hold</td>
<td>Correct</td>
</tr>
<tr>
<td>Bird</td>
<td>BIRDS</td>
<td>Morph.</td>
<td>Bird</td>
<td>Correct</td>
<td>BIRD</td>
<td>Correct</td>
<td>BIRD</td>
<td>Correct</td>
<td>bird</td>
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<tr>
<td>Giraffe</td>
<td>JAPIS</td>
<td>50% of target letters</td>
<td>Griffen</td>
<td>Transposition/omission/addition</td>
<td>GERAFFE</td>
<td>Substitution</td>
<td>GIRIAFFE</td>
<td>Addition</td>
<td>affle</td>
<td>Substitution/omission/addition</td>
</tr>
<tr>
<td>Spring</td>
<td>SRRINS</td>
<td>Substitution</td>
<td>Spring</td>
<td>Correct</td>
<td>SPRING</td>
<td>Correct</td>
<td>SPRING</td>
<td>Correct</td>
<td>scringe</td>
<td>Substitution/addition</td>
</tr>
</tbody>
</table>

Additions, substitutions, transposition and omission errors only include responses with at least 50% letters of target word. <50% of target letters = Errors with less than 50% of letter in target word; does not include responses that are phonologically or semantically related to target. Morph = morphological error, i.e. a response with an additional morpheme added (e.g. plural s).
Table 37. Number of types of responses and spelling errors in first 10 words of PALPA 44

<table>
<thead>
<tr>
<th>Error type</th>
<th>LR</th>
<th>GP</th>
<th>JP</th>
<th>DM</th>
<th>KR</th>
<th>AD</th>
<th>JB</th>
<th>SR</th>
<th>MB</th>
<th>EB</th>
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<tbody>
<tr>
<td>Correct</td>
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<td>2</td>
<td>3</td>
<td>5</td>
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<td>3</td>
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<tr>
<td>&lt;50% of target letters</td>
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</tr>
</tbody>
</table>
Appendix 4. Self-correction Assessment

a. The therapist dictates each word.

b. The participant writes each word (on paper) as it is dictated.

c. The therapist asks the participant whether it has been written correctly and notes down the response (yes or no)

d. The participant scores 1 if they have correctly identified that the word is correct or incorrect and 0 if they have falsely stated that it is correct or incorrect. No score is given for correctly written words.

<table>
<thead>
<tr>
<th>Target</th>
<th>Response</th>
<th>Yes/ no</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair</td>
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<td></td>
<td></td>
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<tr>
<td>Scissors</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bottle</td>
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<td></td>
<td></td>
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<tr>
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<td>Certain</td>
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<td>Receive</td>
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<td>Actually</td>
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<tr>
<td>Giraffe</td>
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<td>Computer</td>
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<td></td>
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<tr>
<td>Gone</td>
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<tr>
<td>Because</td>
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<td></td>
<td></td>
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<tr>
<td>Belief</td>
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<tr>
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<tr>
<td>Chicken</td>
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<td>Appointment</td>
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<td>Time</td>
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<tr>
<td>Vehicle</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Understand</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5. Email Skills Assessment

Scoring:

1: Can do independently
0: Can’t do independently

1. Turn on computer
2. Click onto internet icon
3. Access e-mail account (type e-mail website into browser and click on link)
4. Log into email account
5. Go to new message
6. Enter e-mail address
7. Enter subject
8. Attach a document/ picture to the message
9. Click send
10. Go to inbox
11. Reply to message (the message should not be written)
12. Forward a message
13. Copy somebody into a message (cc)
14. Close email window
15. Shut down computer

/15
Appendix 6. Keyboard Skills Assessment

Scores:

0 – can’t do without support
1 - can do independently

Words

*Type the following words:*

door
octopus
envelope

/3 (1 point for each correctly written word)

Capitals

*Type the following words with capital letters in the correct places:*

Sarah
December
Chester

/3 (1 point for each correctly written word)
**Space**

Write the following sentence with spaces between the words:

the sun is shining

/3 (1 point for each correctly inserted space)

**Enter**

Write the following list of words with each starting on the next line:

peas

 carrots

broccoli

onions

/3 (1 point for each word that starts on the next line to the previous word. Curser can be used)
Delete

Write the following words then delete them:

spring
summer
autumn

/3 (1 point for each deleted word)

Punctuation

Copy the following, using the correct punctuation marks:

let’s meet
how are you?
brilliant!
see you soon.
it was nice, but it rained a lot

/5 (1 point for each correctly written sentence)

Total score /20