Title: Using Voice Recognition Software to improve communicative writing and social participation in an individual with severe acquired dysgraphia: an experimental single case therapy study

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Abstract

Background

Two previous single-case studies have reported that voice recognition software (VRS) can be a powerful tool for circumventing impaired writing in aphasia (Bruce et al, 2003; Estes & Bloom, 2011). However, these studies report mixed results regarding transfer of skills to functional tasks, such as emailing.

Method

A single-case therapy study was conducted with "Stephen", a 63 -year old man with fluent aphasia and severe acquired dysgraphia and dyslexia limiting his social participation and ability to return to work. Treatment consisted of 16 one-hour sessions. Stephen was trained to use Dragon NaturallySpeaking[RTM] VRS to assist writing and Read+WriteGold[RTM] text-to-speech software to assist reading, and to develop computer skills required to use email. Outcome measures evaluated writing efficiency and communicative effectiveness, the functional impact of the intervention, and changes in participation.

Results

Training produced significant gains in the efficiency and communicative effectiveness of Stephen's writing, despite his underlying writing impairment remaining unchanged. Gains generalised to everyday functional communication, leading to increased social participation with Stephen undertaking a wider range of social activities and increasing his social network following treatment. Gains were maintained at follow-up assessment.

Discussion

Results indicate that a relatively short training period with assistive technologies achieved extensive generalisation to independent, functional communicative writing. Indeed, for this case, VRS training may have exceeded the degree of improvement in functional text writing that could have been achieved through impairment therapy, since gains were not limited to treated vocabulary. Some challenges were encountered in training Stephen to use VRS but, through adaptations to the training process, were largely overcome. Importantly, regaining independent writing skills resulted in profound and life-changing improvements to social participation. This may have resulted in Stephen reconnecting with important aspects of his pre-stroke identity, and improving his self-esteem.

Conclusion

This case adds to a small evidence base indicating that training in the use of VRS, in combination with text-to-speech software, may be an effective way to address writing impairments in chronic aphasia for individuals with relatively well-preserved spoken output. Not only can these technologies improve the efficiency and communicative effectiveness of writing, they can also lead to significant gains in functional communication and social participation. Further research is needed trialing this approach with a larger group of people with aphasia.

Keywords

Aphasia; assistive technology; writing; social participation; therapy; digital participation.

Acknowledgements

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Introduction

This paper describes an experimental therapy study in a single case of severe acquired dysgraphia following stroke. A functional therapy approach utilising assistive technologies was taken, with the main focus on writing emails. The study was designed to explore effects of treatment employing Voice Recognition Software (VRS) on the participant's written language, communication and social participation.

People with aphasia are at risk of social isolation (e.g. Cruice, Worrall, & Hickson, 2006; Parr, 2007). Alongside other underlying factors, such as physical difficulties, reduced employment opportunities and aphasia severity, difficulties with written communication contribute to reduced opportunities for social participation. Production of written language is typically impaired to some degree in aphasia following stroke (Beeson & Henry, 2008). The nature and degree of impairment varies considerably between individuals, with difficulties occurring at sublexical, lexical, sentence, and text levels (see Whitworth, Webster, & Howard, 2014 for a review of word level impairments). Writing impairments can have a profound impact not only on functional communication, but also on self-esteem and social activity. For instance, Parr (1995) identified that changes in autonomy and social roles arising from reading and writing impairments were a source of concern to people with aphasia. Such concerns may be on the rise, given the increasing importance of written communication in modern life. Reading and writing skills are necessary for using the internet and mobile phones, which are central to accessing vocational, educational and social spheres (Thiel & Conroy, 2014).

> "*People with aphasia struggle to keep up with today's technology based communication and information sharing trends, because of their reduced ability to comprehend and compose written messages. As a result, the communication gap between people with aphasia and the rest of the world will continue to expand*." (Dietz, Ball & Griffith, 2011 p.759)

Regarding interventions, Van de Sandt-Koenderman (2011) discusses three complementary treatment approaches all of which play an important role and can incorporate technology in aphasia rehabilitation: disorder-oriented treatment, functional treatment, and participation-oriented treatment. Relatively little attention has been paid to acquired dysgraphia compared to treatment of spoken language in aphasia intervention studies, perhaps due to the dominance of spoken communication in everyday interactions (Nickels, 2002). Most writing intervention studies have been designed to address the underlying language disorder. While a few studies have investigated therapies at the sentence or narrative level (e.g. Mitchum, Haendiges & Berndt, 1993), most have targeted single word writing, for instance by targeting phoneme-to-grapheme correspondence or single word spelling (e.g. Beeson & Rapcsak, 2002; Panton & Marshall, 2008; Raymer, Strobel, Prokup, Thomason, and Reff (2010); Thiel & Conroy, 2014). Many studies have reported gains in the spelling of treated words, but often with limited or no generalisation to untreated words (see Whitworth, Webster, & Howard, 2014 for a review). This indicates that other approaches may be required alongside disorder-focused therapies in order to maximise functional gains.

Some studies have taken an explicitly functional approach to intervention by seeking to develop strategies that circumvent, without necessarily remediating, the underlying writing impairment. For instance, Mortley, Enderby & Petherham (2001) successfully taught an experimental participant, MF, a strategy of using his retained oral spelling skills to circumvent difficulties accessing written spellings. In another example, Panton & Marshall (2008) trained Ray to use functional strategies to assist him to take written notes during work meetings, alongside impairment-based therapy tasks that directly addressed his spelling difficulties.

Computer technologies have been incorporated into some functional therapy studies, either by focusing on digital communications, and/or utilising assistive technologies such as enhanced word processors and VRS. For instance, an early non-experimental single case study of functional strategies to enable a person with aphasia to write emails was reported by Pound, Parr, Lindsay & Woolf (2000). A more recent example by Menger (2010) described therapy using a simplified text and email system. This included a user-friendly interface with symbols, photographs and simple language as well as text-to-speech. Menger reported some success achieved in the clinic but without functional carryover to everyday writing.

An early study that utilised VRS technology involved training six people with acquired dysgraphia and five controls to use VRS on a set of functional vocabulary (Wade, Petherham & Cain, 2001). After five weeks of training, significant gains were reported in the participants with aphasia, with levels of recognition accuracy on the treated words comparable to controls. However, aphasic phrase-level accuracy remained variable and below controls' performance.

Bruce, Edmundson & Coleman (2003) reported a single case study using VRS. An experimental participant with mild-moderate fluent aphasia, MG, was trained to use Dragon NaturallySpeaking Preferred[RTM]. MG had limited written output, with spelling errors arising from letter selection difficulties and an impaired graphemic buffer. Previous treatment of his spelling difficulties had achieved only moderate success, but his spoken output was markedly superior to his written output, making him a suitable candidate for VRS. Therapy comprised 17 one-hour sessions over eight months, during which MG was trained to use the software, the software was trained to recognise MG's pronunciation, and he practiced writing and editing text using the technology. Following therapy the quantity and quality of his written output using Dragon increased. Some functional carryover to everyday communication was also reported, including increased contact with his children abroad through writing emails.

More recently, Estes & Bloom (2011) reported a further single case study of CH, an experimental participant with mild-moderate conduction aphasia, who was trained in general computer skills and using Dragon NaturallySpeaking^RTM VRS. The aim was to circumvent her acquired writing difficulties through harnessing her relatively preserved spoken output to operate VRS. Following ten one-hour training sessions CH achieved independence in using the technology. Like MG, the quantity and quality of her written output increased through using VRS, and she had a high level of dictation accuracy following intervention[1]. However, a second phase of intervention aimed at generalising skills to functional use of email and the internet achieved only very limited carryover. Estes & Bloom noted that previous studies of Alternative & Augmentative Communication devices had similarly reported functional gains in the clinical environment but inconclusive data regarding generalisation to natural environments.

This is perhaps unsurprising since people with aphasia may face a number of barriers to accessing technology, including impaired linguistic, cognitive, perceptual and motor skills subsequent to more general disorders often associated with aphasia (e.g. Egan et al., 2004; Nicholas et al 2005; Van de Sandt-Koenderman et al 2007). For instance, Egan discussed the impact of post-stroke cognitive impairments such as difficulty with sequencing steps to complete an activity and reduced problem-solving capacity, as well as difficulties using a standard mouse and keyboard due to motor impairments (p.267). Such factors may limit the potential for people with aphasia to generalise use of VRS outside the clinical setting, and thus limit potential gains in functional communication and social participation that could arise from improved writing abilities. This remains a serious problem for the aphasic population who are at significant risk of being disadvantaged by the so-called ‘digital divide’ (e.g. Elman, 2001; Van de Sandt-Koenderman, 2011).

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[1] It should be noted that VRS accuracy is imperfect even for unimpaired speakers, with reported word recognition error rates of 21-34% (Hakkani-Tur et al, 2010), although accuracy is likely to be higher with more recent software versions

Related developments using VRS include its incorporation into diagnostic and therapy tools for aphasia. For instance, one study describes using Dragon NaturallySpeaking[RTM] to automatically transcribe narratives so as to increase efficiency in detection of linguistic features of Primary Progressive Aphasia (Fraser et al, 2013). Abad et al (2013) used VRS in their bespoke tool to treat aphasic word finding difficulties. VITHEA uses automatic keyword spotting to determine whether a target word (e.g. a picture name) is contained in the patient's utterance and thus to give feedback on accuracy. Initial evaluation with a limited set of target words showed promising results. Another application that has been explored is use of the speech prosthesis SentenceShaper[RTM] to enhance the spoken utterances of people with non-fluent aphasia, combined with VRS to facilitate production of written text (Dahl et al, 2008).

In summary, little research has been carried out on the use of VRS to compensate for writing difficulties in aphasia. A few small scale studies suggest that therapy for emailing and training in the use of VRS may be a useful approach for people with aphasic writing difficulties, but so far there is limited evidence for functional generalisation of therapy gains. Further, there has been little attempt to systematically explore whether gains in writing following VRS training result in changes to social participation. The current study was designed to build on previous studies of VRS training, and in particular to explore generalisation outside the clinical setting and impacts on social participation.

Research questions

1. Does training an individual with relatively preserved verbal output in the use of VRS improve their technology-assisted written output in terms of a) quantity (number of words produced) and b) quality, as assessed by ratings of communicative effectiveness?

2. Do gains in writing result in changes in social participation?

In addition, we explored whether intervention would result in changes to the participant's unassisted writing and spoken output, although we did not anticipate that these would change.

Methodology

This study was conducted at a university research clinic and received ethics approval from the university's Research Ethics Committee. The clinic offered each participant an individually-tailored programme of therapy. These were designed and evaluated as single-case studies.

The participant

At the age of 61, Stephen had a series of three cerebrovascular accidents (CVAs) within two months, the last of which caused aphasia. His first CVA was a right posterior parietal haemorrhage. No information was available about the type or location of the subsequent two strokes and no imaging data was available. He was a mono-lingual English speaker. He grew up in the North-East of England and had a mild regional accent.

At the time of his stroke, Stephen had retired as a secondary school headteacher and was working as a self-employed consultant. He had to stop working after his stroke, causing him considerable distress and frustration. He lived with his wife, daughter and grandson and had two other adult children. He was fully mobile and able to travel independently. His main activities were domestic tasks, including walking the dog, shopping, gardening and cooking.

Stephen received approximately two months of speech and language therapy from his local National Health Service (NHS) service. He self-referred to the Clinic at 1½ years post-onset, presenting with fluent aphasia characterised by anomia, severe dyslexia and dysgraphia. He used circumlocution and gesture to circumvent his word finding difficulties. In conversation he took long turns and was often tangential, not answering direct questions and deviating from the topic of conversation. He had significant auditory comprehension difficulties which particularly affected his understanding in busy, distracting situations and in group conversations. His hearing was not formally tested, but he reported no hearing difficulties.

Stephen's main concern, however, was his reading and writing. He reported being virtually unable to read or write e.g. experiencing difficulties reading the television guide. His wife reported that he required maximal assistance to understand basic printed material (e.g. menus, headlines) and was unable to fill out short forms or write messages. He wanted to be able to write emails and had begun to investigate software that could facilitate this. This included an unsuccessful attempt at using VRS which was available for free within a word processing package but was of low quality.

Background assessment

The Comprehensive Aphasia Test (CAT; Swinburn, Porter & Howard, 2004) was carried out to investigate Stephen's cognitive and language abilities. Table 1 shows Stephen's results at background assessment.

[Insert Table 1 here]

Auditory comprehension

Comprehension of spoken language was moderately impaired, with sentence comprehension particularly affected. Stephen had difficulties understanding reversible and embedded sentences.

Reading

Comprehension of written words and sentences was more impaired than auditory comprehension, with difficulties particularly at the sentence level. Reading aloud was severely impaired, especially for complex words and nonwords.

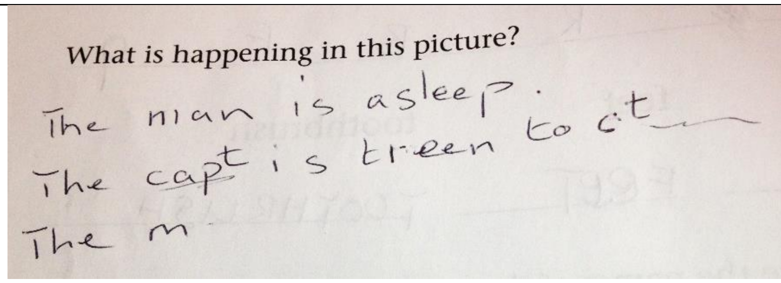
Spoken output

Stephen had severely impaired spoken naming. He used circumlocution and gesture to describe objects that he was unable to name (e.g. “something you chop with” for *knife*). Generative naming was severely impaired, particularly in semantic categories. Word finding difficulties were evident on spoken picture description. He used generic language (e.g. “them” for fish, “somebody” for the man) and circumlocution to compensate for his anomia, and was able to convey the key information about the scene (see Appendix 1). His repetition abilities were severely affected. He was unable to repeat complex words or sentences.

Written output

Written naming was severely impaired with particular difficulties in confrontation naming. Stephen was inconsistent in writing regular words to dictation (e.g. “Tan” for *pen*), but wrote one irregular word (yacht) suggesting inconsistent access to the orthographic output lexicon. He was unable to write a nonword, indicating impaired phoneme-grapheme conversion (N.B. The CAT writing subtest includes only one non-word). His output on written picture description was very limited (see Figure 1 below) and markedly more impaired than spoken picture description.

Figure 1. Background assessment: CAT written picture description



Stephen’s cognitive abilities were screened using the Wisconsin Card Sorting Test (WCST: Heaton, Chelune, Talley, Kay & Curtiss, 1993). Results indicated mild cognitive impairment which may have contributed to the difficulties he encountered in previous attempts to use technology (see Table 2).

[Insert Table 2 here]

Assessments of social participation explored Stephen’s social activities and social network (see Figures 6, 7 and 8 and Table 6). These were also used as outcome measures (see Design section). The Social Activities Checklist (SOCACT; Cruice, Worrall & Hickson, 2006) revealed that Stephen took part in 14 activities, mostly with his wife, but that he wanted to be doing more. Social Network Analysis (Antonucci & Akiyama, 1987) revealed a total of 30 people in Stephen's social network, including family, friends and neighbours, but no workmates.

Goal-setting

An in-depth goal-setting interview was conducted to explore how Stephen's aphasia had affected his language, communication, participation and well-being. From the outset, Stephen's primary goal was to return to work. He identified his difficulties with reading and writing as the main barriers to achieving this. He acknowledged that returning to paid employment was a very ambitious goal and wished to explore the possibility of doing voluntary work.

As Stephen's spoken output was an area of strength, it was agreed that therapy should explore use of VRS (Dragon Naturally Speaking) to enable him to write emails. Table 3 shows the therapy goals.

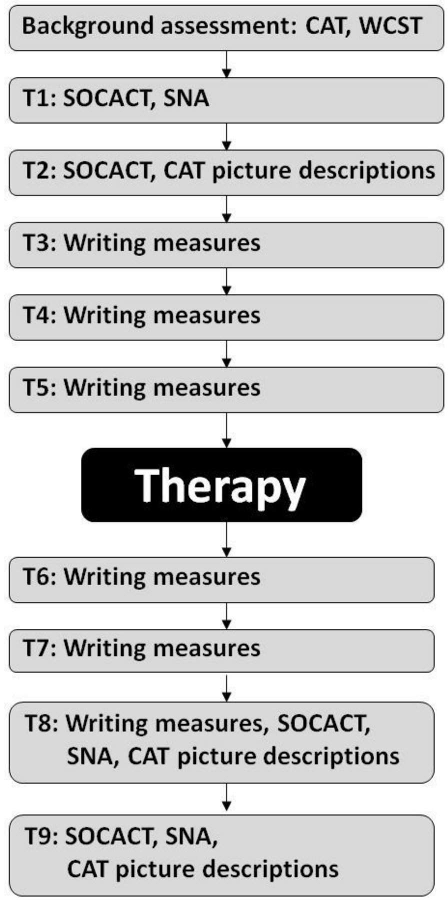
[Insert Table 3 here]

Design

A repeated measures, single case design was used (see Figure 2).

Writing measures were developed following background assessment and goal setting, and administered three times pre-therapy (T3, T4, T5), and three times post-therapy (T6, T7, T8) during weekly probes. They were designed to be sensitive to the changes that therapy aimed to achieve, specifically whether VRS training improved the quantity and quality of Stephen's written output.

Figure 2. Flowchart showing the administration of assessments



A novel assessment measured Stephen's ability to compose emails before and after therapy. At each assessment point he was asked to compose three emails with varying degrees of constraint. In the "highly constrained" task he had five minutes to write an email to a familiar person arranging to meet them for food or a drink. An aphasia-friendly pictorial sheet prompted him to include the recipient, the type of invitation, and where and when they should meet.

For the "partially constrained" task, he was asked to compose an email within 10 minutes to a familiar person telling them some recent news. For the "unconstrained" task, he shared a real email that he had written independently at home. He could decide on the recipient and the content.

Emails were analysed for quantity (number of words); each word or word-like character string was counted, including those containing semantic or orthographic errors. Quality was measured using social validity judgments (Jacobs et al., 2001). Emails were rated by three speech and language therapy students who had no previous involvement in the study and who were blind to assessment time point. They were trained to follow Jacobs et al.'s rating procedure. This involved rating each email for how effective, informative, grammatically correct and comfortable it was to read. They allotted scores for each aspect on a scale of their choice. Scores were converted to a scale of 0-1 and averaged across the three raters before analysis.

Social participation measures investigated impact of writing gains. The Social Activities Checklist (SOCACT; Cruice et al, 2006) investigated the number of social activities Stephen took part in, as well as how often and with whom he engaged in these. Social Network Analysis (Antonucci et al, 1987) evaluated the number of people in his social network who were important to him. He was asked to put names into one of three concentric circles; an inner circle of people who were so close to him that he couldn't imagine life without them, a middle circle of close friends and family, and an outer circle of people he was not so close to, but who were still important to him. For each person he was asked to describe the nature of the relationship, contact frequency, and the main means of contact (e.g. phone, writing, in person).

SOCACT was administered at two pre-therapy baselines eight weeks apart (T1 and T2). Social Network Analysis was administered only once before therapy (T1) to reduce assessment burden. Both were repeated post-therapy (T8) and at maintenance assessment (T9) eight weeks later.

The impact of therapy on Stephen's underlying language impairment was also explored. It was hypothesised that this would not change. Spoken and written picture description subtests of the CAT were repeated at T2 and post-therapy (T8 and T9), to investigate changes in Stephen's ability to write unaided by VRS, and whether use of the software had affected his spoken output.

Stephen continued to use VRS between T8 and T9, although no therapy took place during this period.

Intervention

Stephen received 16 one-hour therapy sessions carried out twice a week. Half-way through the block, therapy was interrupted for two months when Stephen developed serious health problems due to a metabolic condition unrelated to his stroke. He was unable to practise using VRS during this period. When he returned to therapy he experienced increased fatigue, but had retained the skill level that he had achieved in using VRS prior to this absence.

VRS posed several challenges for Stephen. He had limited previous experience of computer technology. He was observed during the email writing assessments to have difficulty carrying out a number of basic computer tasks (see Table 4 below showing skills before and after therapy).

[Insert Table 4 here]

He had also made a previous, unsuccessful attempt at using a different type of VRS**.**

Although spoken output was an area of relative strength, Stephen had impaired auditory comprehension, making it difficult for him to monitor his output and identify errors made by the software. Secondly, his severe difficulties in reading aloud could prevent him from using the standard paragraph reading procedure for training Dragon**.** This required the user to accurately read aloud a whole paragraph from a book (e.g. "Charlie and the Chocolate Factory" by Roald Dahl). The software only saved the recording when the whole paragraph was read in one attempt.[2]

However, Stephen was extremely motivated, with a clear vision of what he wanted to achieve and huge determination to succeed. He was very proactive, for example, buying himself a laptop specifically for the project.

Materials

Stephen used Dragon NaturallySpeaking Preferred V10 on a Samsung Netbook, using the headset supplied with the software.

Therapy aims

1: Train Dragon to recognise Stephen's speech

Initially therapy focused on training Dragon to recognise Stephen's speech. The standard training method, reading aloud set texts, was attempted. This proved extremely challenging due to Stephen's difficulties reading aloud and repeating. Following a lot of rehearsal and prompting, he was able to read aloud four sentences from Charlie and the Chocolate Factory. However, he read these one at a time and

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[2] In recent versions of Dragon (e.g. Dragon 13 Home) the training process has been improved and is more accessible for people with aphasia- the user needs to talk into the microphone using connected speech but no longer needs to read aloud a set passage. The software is also available as an app for iPad and iPhone, which does not require any speech training.

was unable to read the whole passage continuously, meaning that the software did not save the recording. This approach was therefore not feasible for Stephen.

An alternative method was trialled. Stephen generated a list of 59 functional words and phrases that he would find useful when sending emails. These ranged from common social phrases (e.g. “How are you?”) to sentences including names of familiar places and people. During the first four sessions, Stephen practised dictating each item into Dragon once. If the software made an error, the therapist supported Stephen to correct the mistake, with the aim of increasing the software’s accuracy in recognising Stephen’s speech. On the first session accuracy was 83%. Errors were predominantly in names of people and places, numbers (e.g. train times) and in words with homophones (e.g. Hi written by Dragon as “High”). By the fourth session accuracy had increased to 90%. During the remaining sessions, the therapist continued to support Stephen to correct mistakes but therapy activities focused on writing emails. When the software made a mistake, Stephen preferred to delete the error and re-record it or re-type it rather than using Dragon’s procedure for training it to recognize words, which involved typing the target word into a dialog box and re-recording.

2: Train Stephen to operate the software

The basic features of Dragon software (e.g. open programme, turn microphone on/off, correct mistakes) were explained and demonstrated to Stephen during sessions and practiced several times. To promote independence in operating the software, Stephen was given step-by-step instruction sheets for operating the functions, incorporating screenshots with text boxes and arrows to direct him to particular keys or screen icons. They followed aphasia-friendly text principles (Worrall et al., 2005), using large text, wide spacing of lines and key words highlighted in bold (see example in Appendix 1). Stephen was encouraged to use these sheets to operate the software independently during sessions and at home.

When he was able to operate the software with minimal prompting, the same approach was used to support Stephen in learning to use email. Basic tasks were demonstrated in therapy sessions and illustrated with step-by-step instructions (e.g. how to open Googlemail, add email addresses to contacts list, compose a new email, enter email address and title, dictate mail).

3: Develop self-monitoring of written output

Stephen experienced difficulties monitoring his output and reading incoming emails due to impaired reading comprehension. Initially the Dragon text-to-speech function was trialed, but the speech quality was poor and incomprehensible to Stephen due to his auditory processing difficulties. Furthermore, it only read aloud text that had been dictated using the software, so could not read his emails.

Read&Write9 Gold® assistive software was introduced. This software was developed for people with developmental dyslexia and contained numerous features to support reading and writing. Stephen used its text-to-speech facility to read the emails he received and to check what he had written and make corrections. He set the text-to-speech with an increased inter-word pause length and found it helpful that the software highlighted the words as it read them. This therefore enabled him to use his relatively spared auditory comprehension to support reading comprehension.

Homework tasks

Stephen was given tasks to practice at home aimed at developing independence in his newly acquired skills. Examples of tasks included:

- Replying to an email from the speech and language therapist (SLT) with at least one piece of news
- Sending an email to a former work colleague
- Replying to a specific question in an email from the SLT
- Composing an email to his local Member of Parliament

He was encouraged to refer to his prompt sheets when carrying out tasks at home.

Results

Q1a. Does VRS training improve the quantity of written output?

Writing outcome measures

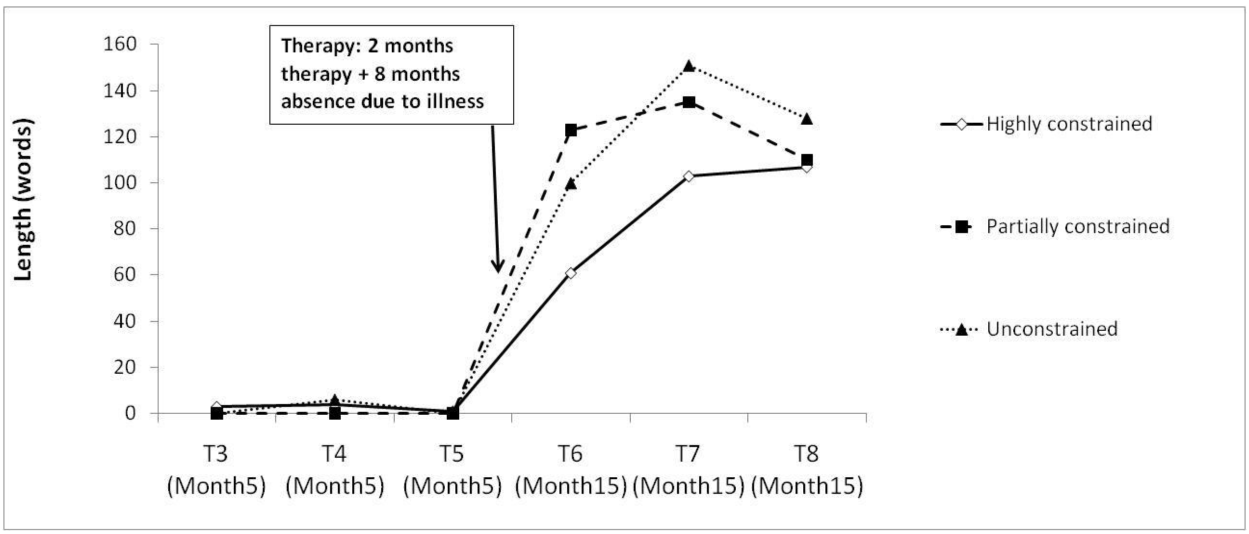
Before therapy Stephen was frequently unable to complete the task, particularly in less constrained conditions. Even when emails were attempted, he never wrote more than six words. Table 5 shows an example of Stephen's writing for each assessment before and after therapy.

[Insert Table 5 here]

Visual analysis shows that the quantity of writing increased markedly after therapy and gains were maintained. He showed the greatest improvement on the partially constrained task immediately post-therapy. Emails increased in length on all tasks between T6 and T7, possibly because he continued to practice using VRS independently at home. Table 6 shows the number of words written for the three emailing tasks at each time point. The data are also represented in Figure 3.

[Insert Table 6 here]

Figure 3: Email length (number of words in each email)



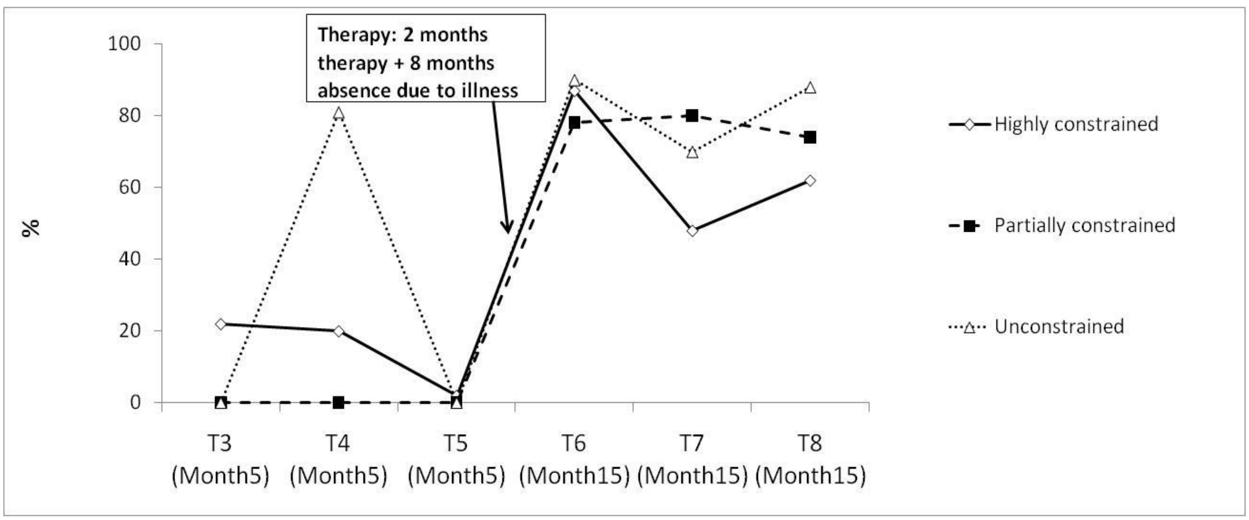
Q.1b Does VRS training improve the communicative effectiveness of writing?

Communicative effectiveness of emails was evaluated using social validity judgments (Jacobs et al., 2001). Ratings were analysed using a Friedman's test to identify change. Communicative effectiveness increased highly significantly on the three tasks (Highly constrained: $\chi^2(5)= 19.57$, p=.001; Partially constrained: $\chi^2(5)= 18.5$, p=.001; Unconstrained: $\chi^2(5)= 18.56$, p=.001 (all one-tailed)).

In order to verify that the change occurred after therapy, a planned comparison was used to compare the average of the three baseline probes with the average of the three post-therapy probes for each of the three emailing tasks. A Wilcoxon's signed ranks test was used.

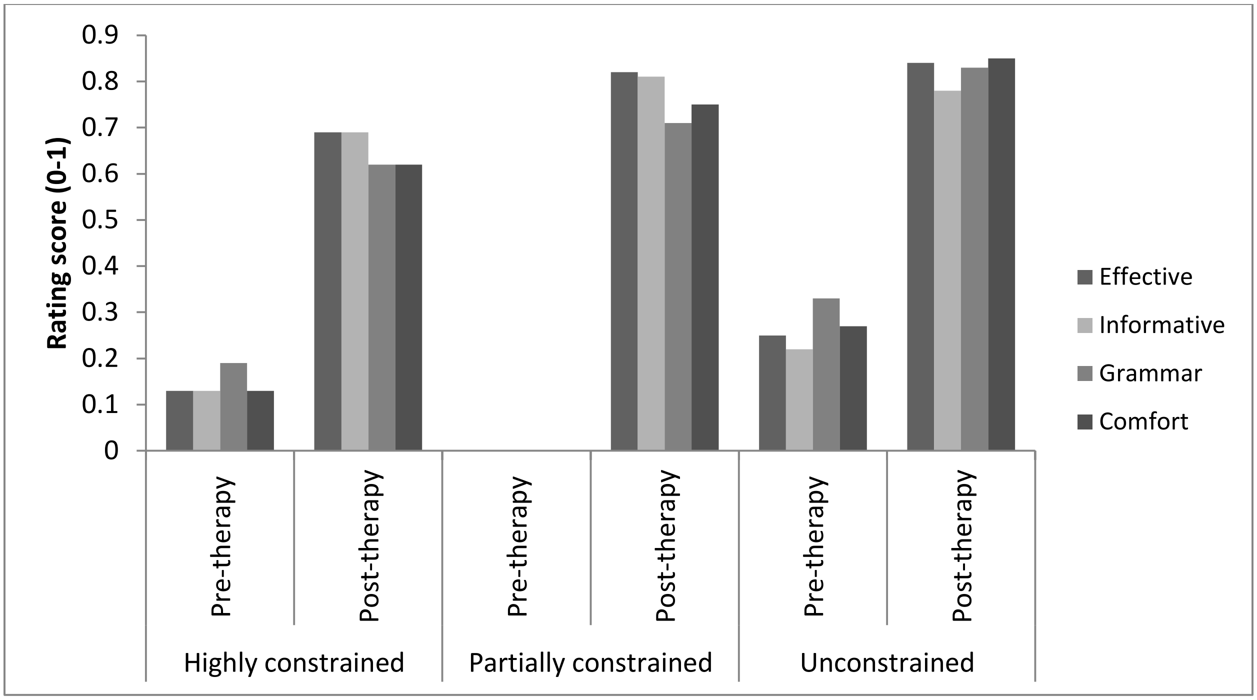
Scores improved significantly after therapy on all tasks (Highly constrained: Z= -1.841, p<.05; Partially constrained: Z= -1.826, p<.05; Unconstrained: Z= -1.826, p<.05 (all one-tailed)). See Figure 4 below.

Figure 4: Social validity scores on emailing tasks



Stephen improved on all four aspects of social validity (see Figure 5 below). Gains in grammar ratings were the least marked.

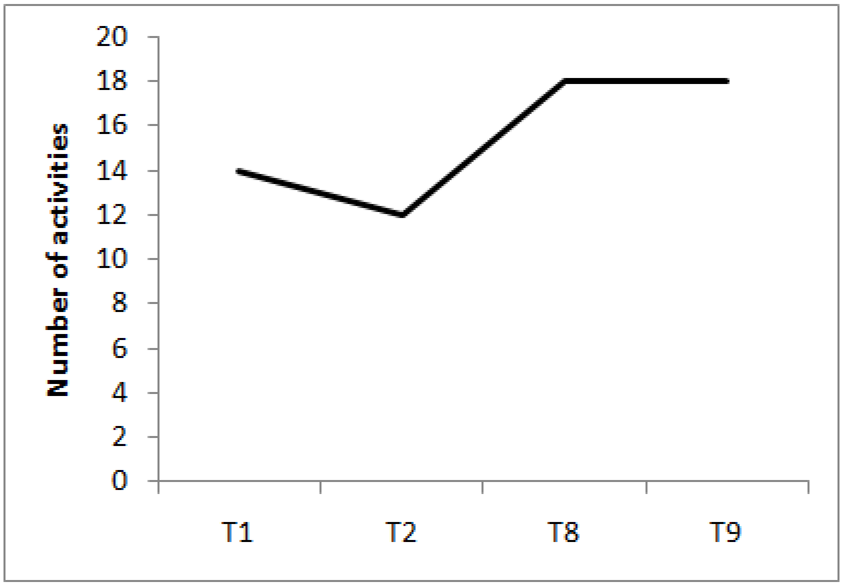
Figure 5. Scores on the four aspects of social validity judgments



Q2. Do gains in writing result in improvements in social participation?

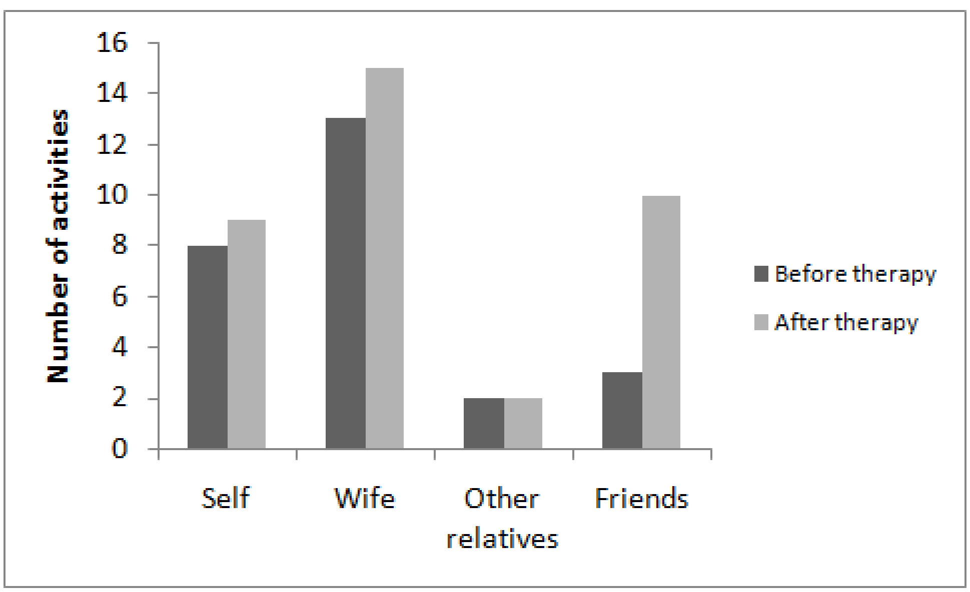
Stephen's results on the Social Activities Checklist (SOCACT) were analysed visually. Figure 6 shows the number of social activities increased from an average of 13 before therapy to an average of 18 after therapy. Gains were maintained at follow-up.

Figure 6. Results of SOCACT assessment



The range of people with whom he carried out activities also increased. Figure 7 below shows the main person he carried out different activities with before and after therapy. The main change after therapy was an increase in the number of activities carried out with friends.

Figure 7. Number of activities carried out with different people before and after therapy.

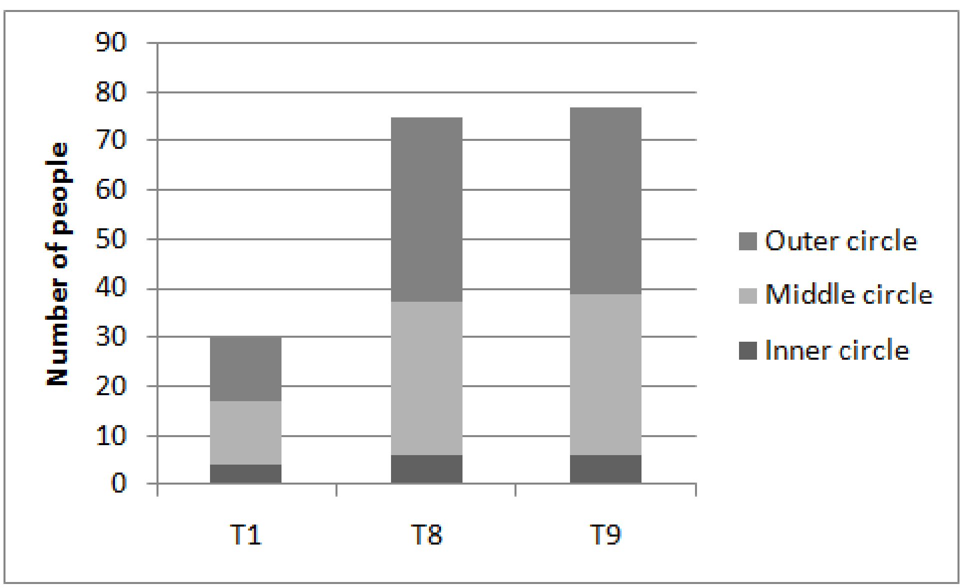


He also started attending activities such as professional events, committee meetings and conferences. A further change was that he reported reading daily after therapy, whereas he did not take part in activities related to reading before therapy. He used Read&Write Gold9 on his computer to read online news and an e-book reader to read books aloud.

Stephen's social network grew following therapy, with marked gains in the number of people in his middle and outer circles (see Table 7 and Figure 8).

[Insert Table 7 here]

Figure 8. Social network size before and after therapy



Increases were primarily due to emergence of a large group of "workmates", many of whom Stephen met through taking on a new voluntary work role. He also reported getting back in touch with former colleagues. He was in contact with more members of his extended family and reported having more friends and being involved with more groups. The number of people with whom he had frequent contact (at least once a month) increased, while the number he saw rarely decreased.

In terms of how he contacted people in his network, three new forms of communication emerged; emailing, writing and Skype™. In contrast, his use of the telephone declined. He also reported a doubling of the number of people he saw in person, due to the voluntary work he had taken up and increased contact with friends and relatives.

In contrast, his ability to write unaided by technology, as measured by the written picture description subtest of the CAT (Swinburn, et al., 2004), did not change (see Table 8 below).

[Insert Table 8 here]

However, there were some indications of change in spoken picture description, with output becoming more accurate, informative and well-structured (see Appendix 2 for full transcripts) particularly at maintenance testing (Background assessment=36, T2=38, T8=41, T9=72). It was not possible to analyse this data statistically.

Discussion

Our results provide clear evidence that VRS training significantly improved Stephen's writing. An initial question was whether training would increase the quantity of writing. Before training, Stephen found writing laborious and highly frustrating, and without VRS was only able to produce 0-4 words per email across nine baseline probes. Following training, his technology assisted writing was considerably more efficient and less frustrating. The number of words produced using VRS across nine post-therapy probes increased to 61-151, despite his underlying writing impairment remaining unchanged as shown by his CAT written picture description. Considering just those email tasks which were time limited, the mean number of words per minute increased from 0.5 to 18 in the highly constrained condition, and from 0 to 12.3 in the partially constrained condition. Thus it is clear that VRS vastly improved his writing efficiency. This is comparable to Bruce et al's report that MG's writing efficiency on CAT picture description increased from 12 words in thirty minutes to 84 words in eight minutes using VRS, and Estes & Bloom's report that, after training, CH was able to write only 11 words unaided but 57 words using VRS on a narrative writing task.

A further question was whether VRS training would improve the communicative effectiveness of Stephen's writing. This was measured using social validity judgments (Jacobs et al., 2001) by raters who were blinded to assessment time point, and showed that emails written post-therapy were significantly more effective, informative, grammatically correct, and comfortable to read. Thus there is now growing evidence that, at least for individuals with superior spoken output, VRS can vastly improve both writing efficiency and communicative effectiveness.

It is worth considering these findings in relation to evidence of outcomes from therapies that directly address underlying writing impairments. Of note is that most studies addressed single word rather than text level writing, and many report gains primarily on treated words (Whitworth, Webster & Howard, 2014). This suggests that traditional impairment therapies may require a much higher dose of treatment to achieve functional writing gains equivalent to those achieved through VRS training, and indeed that VRS training may exceed the degree of improvement in functional writing that can be achieved through impairment therapy, since gains are not limited to a treated vocabulary set.

Arguably the most important findings from this study relate to changes in Stephen's social participation. Just as Bruce et al observed that MG achieved his goal of using email to keep in touch with his children, our study has gone even further in demonstrating that regaining independent writing through VRS training can result in profound and life-changing improvements to an individual's social participation. In particular, Stephen's day-to-day use of writing and emailing to communicate increased. An attempt was made to monitor the number of emails Stephen sent and received each week at each of the six assessment time points for therapy-specific assessments. However, this measure proved problematic since the number of emails he received increased so much after training that he started to delete messages, making an accurate comparison of the number of emails received before and after therapy impossible. Nevertheless, it was clear that the volume of Stephen's correspondence increased after therapy. He reported daily contact with friends and family via email. His range of written communications increased, most notably to include work-related emails. His wife observed that, following therapy, Stephen was able to carry out reading and writing activities independently using the computer (e.g. writing messages and reading the news), although he remained unable to do the same activities independently on paper.

Linked to his increased use of written communications was a marked increase in both the range of Stephen's social activities, and the size and diversity of his social network. This resulted in part from undertaking a new voluntary role that involved consultancy, training and committee membership. He reported that this role would have been impossible without VRS and text-to speech software. By using the technology he was able to correspond and read minutes of meetings. Stephen reported much greater satisfaction with his ability to communicate via email following therapy, as well as wider benefits from using the technology including that he had started to shop online and to access online information such as news websites. There was anecdotal evidence that these gains may have helped Stephen reconnect with important aspects of his pre-stroke identity, improving his self-esteem. He summed this up by stating that *"My life is beginning to come back to being my life*" and "*Stephen's back!*". Thus VRS and text-to-speech technologies have the potential to address some of the concerns around changes in social roles and identity identified by people with aphasia in Parr's (1995) study.

Stephen's therapy adopted a clearly compensatory approach. It was not anticipated that intervention would result in changes to his underlying language impairment. Nevertheless, we observed informally that there appeared to be improvement in his self-monitoring of spoken output. Prior to therapy, Stephen's speech was fluent but often tangential and lacking in content due to his severe anomia. During training Stephen became more aware of this, presumably because VRS combined with text-to-speech gave him clear feedback of his spoken utterances. He developed a strategy of pausing to think carefully about what he wanted to say prior to dictating. We had the impression that this strategy may have begun to generalise into his spoken output even when not using VRS. Although there is no strong evidence of this, the difference in pre- and post-therapy CAT Spoken Picture Description narratives may support this hypothesis. There are other anecdotal reports of improvements in self-monitoring of spoken output following VRS training (Kyriacou & Bruce, 2005). Future research might explore potential impacts of VRS training on spoken output more systematically.

A further question that might be considered is how much training is necessary for a person with aphasia to achieve independent use of VRS. Evidence so far suggests that there may be considerable variation between individuals. In our study, Stephen achieved independent use and functional generalisation following 16 sessions. Bruce et al trained MG over 17 sessions, following which he too was able to use the software independently and generalised his skills to functional communication including writing emails to his children.   However, Estes & Bloom observed that 10 sessions were sufficient to train CH to use VRS independently within the clinic environment, but that a further four weeks of home transfer practice, (including writing tasks with clinician feedback several times a week, together with peer support and a weekly IT training session with a volunteer) were insufficient to achieve functional generalisation. They questioned whether short-term outcome-based training is sufficient for people with chronic aphasia to transfer technology skills to everyday use, and noted that performance in the clinical environment may not be a good predictor of independent usage.

Positively, Stephen and MG's cases indicate that, at least in some individuals with chronic aphasia and relatively preserved spoken output, a fairly short VRS training period can result in extensive generalisation to independent, functional communication and life-changing gains in social participation. This is despite the fact that using VRS posed several potential challenges for Stephen. One was his limited prior experience of computer technology. While working as a school headteacher before his stroke he had a secretary, and had never needed to master computer use. He had been unable to use a computer since his stroke, therefore it was anticipated that he might struggle to learn to operate the computer and software. Further, he had made a previous, unsuccessful attempt at using VRS at home which he and his wife had found extremely frustrating. Regarding Stephen's aphasia, although his spoken output was relatively preserved, his language deficits could have hampered his use of VRS. He presented with severe anomia. He had impaired auditory comprehension, making it difficult for him to monitor his spoken output and to identify errors made by the software. In addition he had severe difficulties in reading aloud, making the standard procedure for training Dragon to recognise an individual's speech - reading set passages aloud - problematic. However, through adaptations to the training process, coupled with Stephen's strong motivation to succeed, these difficulties were largely overcome. Although no formal long-term follow up was carried out within the study, the researchers remain in informal contact with Stephen and observe that therapy gains have been fully maintained. For example, Stephen sent us the following email a year after therapy finished:

> *Hi Anna.*
>
> *I'm sorry, we seem to run away. I would like to put on record your work has helped me to improve two-level* where I can go back to work. More importantly, I can enjoy life! Thank you.*
>
> *Best wishes*
>
> *presumed target: to a level

Future research might try to evaluate the generalizability of this approach and identify baseline factors, such as linguistic and cognitive skills, that predict outcomes. It is interesting that Stephen's poor performance on the Wisconsin Card Sorting Test did not correspond with his success in developing independent technology use. Informal observations suggested that he had retained strong cognitive abilities, demonstrated for instance through high level functioning in everyday life such as the ability to undertake a training and consultancy role. This may have assisted him in acquiring technology skills. Similarly, Van de Sandt-Koenderman found no clear relationship between results on the Weigl Card Sorting Test and ability to learn to use an AAC device by 26 people with aphasia. Thus it may be that the cognitive skills required for VRS learning are not easily assessed through card sorting tests. Two follow up studies at City University London are evaluating VRS training with up to forty individuals with chronic aphasia. They are using the Cognitive Linguistic Quick Test (Helm-Estabrooks, 2001) as a cognitive screen. This measure assesses a wider range of domains than card-sorting tests, including attention, memory, executive functions, language, and visuospatial skills, and may help to inform decisions about candidacy, as well as the nature and duration of training required.

Conclusion

Although further research is needed, Stephen's case adds to a small evidence base suggesting that training in the use of VRS, in combination with text-to-speech software, may be an effective way to address writing impairments in chronic aphasia for some individuals with relatively well-preserved spoken output. Not only can these technologies improve the efficiency and communicative effectiveness of writing, they can also produce significant gains in functional communication and social participation. Further, there may be efficiency savings in terms of therapy resources required to achieve these gains through assistive technologies compared with traditional impairment therapies addressing single word spelling. Such technologies are becoming increasingly mainstream, with VRS now incorporated into standard mobile phone and computer applications. As well as reducing costs, this should ensure that the use of such technologies by people with aphasia is considered socially acceptable. VRS technologies have advanced rapidly over the past fifteen years in improving recognition accuracy and reducing requirements for training, with further refinements anticipated in future. Whilst this highlights the need for technology based interventions to be flexible and responsive to a rapidly changing market, it is likely that VRS technologies will become increasingly effective and accessible. They may thus afford even greater opportunities to address the disabling consequences of aphasic writing impairments in future, and so reduce the digital divide.

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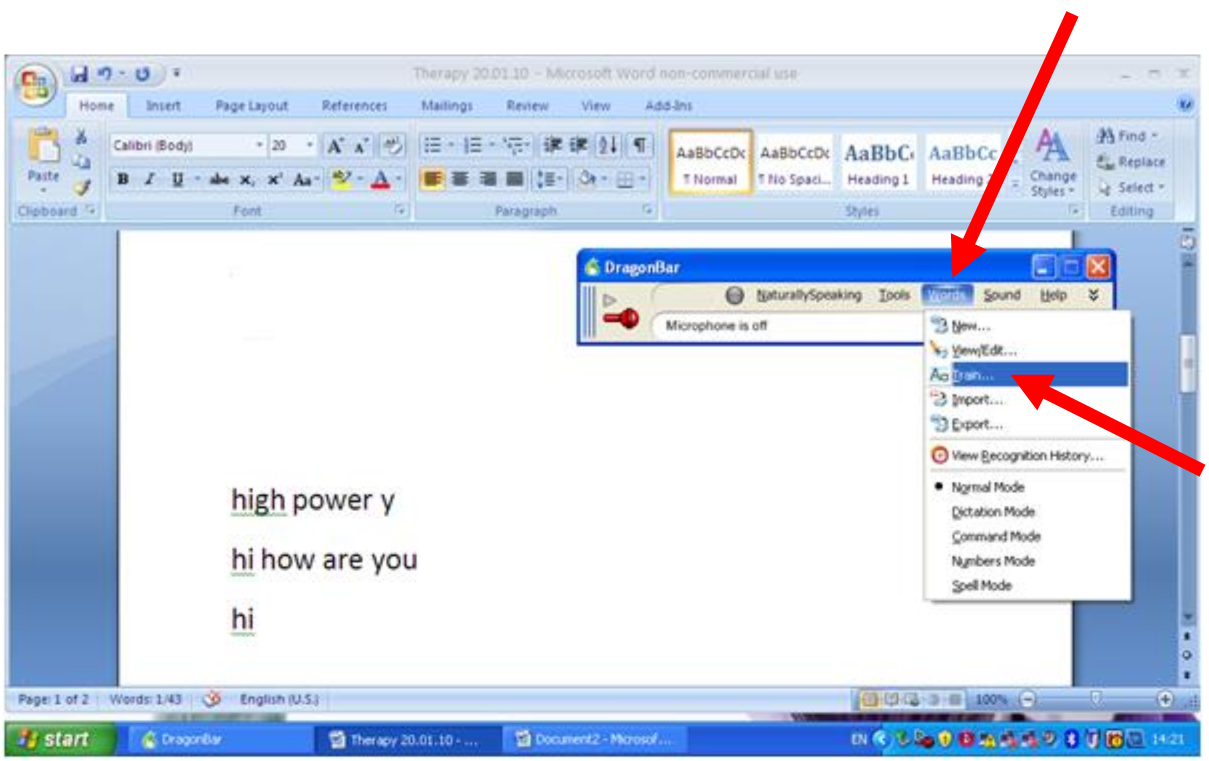
Appendix 1. Example of training materials showing one step in how to correct a recognition mistake.

If Dragon has made a **mistake**, go to:

- Dragon toolbar
- Words
- Train



Appendix 2. Transcripts of Stephen's CAT spoken picture description

Background assessment	Most of the people, somebody's asleep. A cat is trying to get, this is what one of our cats does a lot of with our garden outside, trying to get them all. The little boy wants to wake this person up because the little boy wants to play and why not. And this person's had a cup of tea, probably quite a long day. And the cat's about to get shouted at because all this stuff is going to land on him and wake him up, and the little boy's about to go, "Dad, Dad, the cat's trying to get them". (*Prompt: What about this?*) They're probably not turned on because he wouldn't be asleep, maybe, if it was, he'd be listening to some nice stuff like out of this. (*Prompt: What about this?*) The cat? He's trying to catch the.. I can't say the word… the fish. He's had his cup of tea, so there's nothing for him to knock over. Total score= 36
T2	There is a man asleep and he's got his feet up…and he's had a cup of tea, probably empty now. And a little boy wants him to play. She's trying to get this little boy to play. And the cat up here is trying to get some of their fish, because the cat likes fish and by doing that he's dropped this stuff over and that's going to get this man annoyed because he's going to be made to wake up. And the little boy is going to say, "Dad, Dad" or probably Grandad looking at the size of him, "Grandad the cat is trying to get the fish". The Grandad is taking no notice. He's probably drunk, it's probably Sunday afternoon. Total score= 38
T8	This is a little boy. He's sitting down and his granddad is asleep and he's trying to waken up his granddad coz he's the .... the cat is trying to get the fish and he's knocked over some books, they're gonna land on the grandad's head and that'll wake him up anyway so the little boy needn't worry too much and the little girl has got his feet up which I would be told off big time if that was me. And there's an empty cup where he's had his tea. Oh, I mean there's these .... so he can .. watch his music, his CDs over there. That's a nice little plant in the corner. About it, isn't it? The little boy's got a nice little car and it's probably getting close to his time to go to bed. There's enough there to keep him hung. Total score= 41

T9	There's a man asleep in his chair and the man could be me. Maybe it's a hot day or a Sunday or he's been, maybe he's been to work or watching the news and he's had a cup of tea and he's just drifted off. His grandson maybe, he is has been playing with him and he's got a car and he's going "Grandad, Grandad" because the cat who's up there is trying to get the fish, and if he gets them he'll probably eat them, and of course the cat has knocked over some of the books and that will wake up the man and if the boy hasn't woken him up I suppose the books will. I don't suppose he's listening to anything but he could be listening to the news. It's a nice room and there's plenty of space to do what you want to do. He's listening to the Beatles cos I like the Beatles. "Grandad, Grandad, get up!" Well he's got a book underneath and that'll be the newspaper maybe. He's had a good time I would imagine. And it can't be the end of the day, oh I suppose it could be, the little boy could have had a wash to go to bed. I think it's probably Sunday afternoon. Actually he has got part of the book or the newspaper under his left hand so that's what he's been doing and he's drifted off to sleep. Total score= 72

Table 1. Background assessment: CAT results

CAT Subtest	**Score**	**T-score**
Cognitive Total	**34/38**	N/A
Spoken Word Comprehension	27/30	55
Spoken Sentence Comprehension	18/32	50
Comprehension of Spoken Paragraphs	4/ 4	60
Comprehension of Spoken Language Total	**49/66**	**51**
Written Word Comprehension	22/30	46
Written Sentence Comprehension	15/32	48
Comprehension of Written Language Total	**37/62**	**48**
Reading Words	12/48	46
Reading Complex Words	0/6	40
Reading Function Words	4/6	49
Reading Non-words	0/10	40
Reading Total	**16/70**	**46**
Repetition of Words	2/32	41
Repetition of Complex Words	0/6	38
Repetition of Non-words	2/10	46
Repetition of Digit Strings	4/14	43
Repetition of Sentences	0/12	39
Repetition Total	**8/74**	**41**
Naming objects	3/48	44
Naming actions	4/10	50
Word fluency total	7	51
Naming Total	**14/58**	**46**
Spoken picture description	28	**58**
Writing: copying	21/27	47
Writing picture names	2/21	44
Writing to dictation	8/28	48
Writing Total	**31/76**	**47**
Written picture description	2	38

Table 2. Background assessment: WCST results

Subtest	Score	Comments
Total number of errors	7th percentile	Mildly impaired
Perseverative responses	32nd percentile	Average
Perseverative errors	30th percentile	Average
Non-perseverative errors	1st percentile	Moderately impaired
% conceptual level responses	7th percentile	Mildly impaired
Learning to learn score	<1st percentile	

Table 3. Therapy goals

Communication	• Train Dragon to recognise Stephen's speech with 70% accuracy.
	• Use Dragon to write
	  ○ social emails/letters to family and friends
	  ○ email to a former work colleague
	  ○ letter to Member of Parliament and local health service commissioners about services for aphasia

Participation	• Use email to contact friends and family more often • Share news with friends more often • Find out about friends' news more often
Well-being	• Feel more involved with friends, feel more "in the loop" • Feel more confident about expressing opinions to others in writing

N.B. These goals were set collaboratively with Stephen. The wording therefore reflects his own wishes and aspirations, not all of which were amenable to accurate measurement.

Table 4. Computing skills observed during emailing tasks before and after therapy.

	Before therapy (T3)	After therapy (T6)
Turn on computer	X	✓
Log on to computer	X	✓
Connect to internet	X	✓
Logging into email account	X	X
Saving emails	X	X
Reconnecting to internet when connection lost	X	X
Exiting webpages	X	✓
Shutting down	X	✓

Table 5. Examples of emails written before and after therapy

Task		
Highly constrained	**Pre therapy (T4)**	Pete. lunces? Paces. Stephen.
	Post therapy (T6)	Mr Johnson. I'm looking forward to a meeting on the Monday the 15th. I hope the time of 12.15 is convenient for you. I have arranged lunch for all 15 colleagues at the University. Everyone is looking forward to meeting him for the first time. If this is not convenient for yourself. Please e-mail me at 276 5321.
Partially constrained	**Pre therapy**	[Unable to carry out task}
	Post therapy (T6)	Ben It was great meeting you at the weekend. You may be wondering, who has written this letter to, and the answer is merely. I found out about some software, which I'm using for first-time and it seems to be really good. I hope that will continue to be so, as I still wish to write the book. Perhaps the next time we meet you and I can discuss some of those silly things we did together in the 70s. I'm not sure that anybody would believe any of them, although we will have to say to them is actually true. I hope the dog is well and have almost convinced me that I should acquire one for myself. All best wishes. Stephen.
Unconstrained	**Pre therapy (T4)**	Hi. Have a good weekend. Stephen.
	Post therapy (T6)	Hi Louise. So good to hear from you. Albert looks a joy, and I'm sure he will continue to be so. Attached are a couple of my own – I only have about 1000 so far. As you know, we have finished the work so far and, I have to thank you for all your help. I was never a great writer of letters. So please do not be disappointed if to have just a few sentences. The software is incredible! I am starting to do some work, and who knows I may earn some money!! See you soon. Stephen.

Table 6. Email length (number of words) before and after therapy.

	T3	T4	T5	T6	T7	T8
Highly constrained (5 minutes)	3	4	1	61	103	107
Partially constrained (10 minutes)	0	0	0	123	135	110
Unconstrained (no time limit)	0	6	0	100	151	128

Table 7. Results of Social Network Analysis.

	Pre-therapy (T1)	**Post-therapy (T8)**	**Post-therapy (T9)**
Numbers in network:			
Total number in network	30	75	77
Total number in inner circle	4	6	6
Total number in middle circle	13	31	33
Total number in outer circle	13	38	38
Nature of relationship:			
Family	5	6	6
Other relatives	1	8	8
Spouse/partner	1	0 (spouse categorised as family)	0 (spouse categorised as family)
Individual friends	18	26	26
Workmates	0	27	29
Neighbours	5	6	6
Undifferentiated groups	0	4	4
Formal groups	0	0	0
Frequency of contact:			
Daily	2	7	7
Weekly	1	33	33
Fortnightly	5	23	23
Monthly	2	7	9
Rarely	9	3	3
Yearly	11	4	4
Type of Contact:			
Live with them	2	3	3
See/visit them	27	57	59
Telephone	19	14	16
Letter/write	0	3	3
Email	0	41	43
Skype	0	6	6

Table 8. CAT written picture description at all assessment time-points.

Background assessment	**T2**	**T8**	**T9**
The man is asleep. The capt is treen to ct____ The m *(Total score= 0)*	T_ _ man is am_ T…. Cat *(Total score= 2)*	Cat is a *(Total score= 2)*	Te.. *(Total score= -1)*

Figure captions

Figure 1. Background assessment: CAT written picture description

Figure 2. Flowchart showing structure of project

Figure 3. Email length (number of words)

Figure 4. Social validity scores on emailing tasks

Figure 5. Scores on the four aspects of social validity judgments

Figure 6. Results of SOCACT assessment

Figure 7. Number of activities carried out with different people before and after therapy.

Figure 8. Social network size before and after therapy