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RESEARCH REPORT

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Can a writing intervention using mainstream Assistive Technology software compensate for dysgraphia and support reading comprehension for people with aphasia?

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Abstract

Background: Stroke profoundly affects quality of life (QOL), including loss of employment, reduced social activity, shrinking social networks and low mood. Dysgraphia (impaired writing) is a common symptom of aphasia yet is rarely targeted in rehabilitation. Recent technological advances might challenge this, since much communication is now conducted digitally through writing. The rehabilitation of writing may therefore help to address the wider consequences of stroke and aphasia.

Aims: Can assistive technology (AT) training for people with dysgraphia: (1) improve written output, and are gains achieved only with AT? (2) improve reading comprehension scores, and are gains achieved only with AT? and (3) affect social participation, mood or QOL

Methods and Procedures: Design: A mixed-methods, repeated measures, small group study design was adopted (qualitative outcomes will be reported elsewhere).

Participants: Recruited from community settings, for example, Stroke Association communication support groups. Inclusion criteria: over 18 years old, aphasia due to stroke, acquired dysgraphia, writing more impaired than speech, fluent English prior to stroke, access to computer and Internet. Exclusion criteria: currently receiving speech and language therapy, significant cognitive impairment, neuromuscular/motor-speech impairments/structural abnormalities, developmental dyslexia, uncorrected visual/auditory impairments.

Procedures: Screening and diagnostic assessments at time T1 (first baseline). Outcome measures at T1; repeated at T2 (second baseline), T3 (end of intervention), T4 (3-month follow up). Social participation assessment and cognitive monitoring at T2, T3, T4. Intervention: Seven–ten hours individual therapy weekly and additional email support. Participants were trained to operate Dragon NaturallySpeaking (speech to text package) and ClaroRead (read writing aloud). Outcome measures were administered on pen and paper (control) and on computer, with AT enabled only at T3, T4.

Outcomes and Results: Computer narrative writing was significantly improved by AT training (Friedman's χ^2 (3) = 8.27, p = 0.041), indicating a compensatory effect of AT. Though reading comprehension significantly improved in the computer condition (Friedman's χ^2 (3) = 21.07, p = 0.001), gains could not be attributed to the AT. Gains were achieved only when measures were administered on the keyboard, with AT enabled. Thus, a compensatory rather than remediatory effect was suggested. Social network size significantly increased; there were no significant changes in mood/QOL. Individual success rates varied.

Conclusion and Implications: The customisable AT training was acceptable to participants and resulted in significantly improved narrative writing. Compensatory AT interventions are a useful adjunct to remediatory writing interventions and may particularly support functional writing.

KEYWORDS

aphasia, assistive technology, narrative, reading, writing

WHAT THIS PAPER ADDS

What is already known on this subject

- Writing is rarely spared in aphasia and may present as the most impaired communication modality. Yet, people with aphasia report that writing is seldom included in their rehabilitation. Many communication activities are now conducted digitally through writing, therefore rehabilitation of this is more important than ever before. This study sought to address whether an assistive technology (AT) software package can improve writing and whether any changes were compensatory or remediatory.

What this study adds to existing knowledge

- This group study found that AT training led to gains in written discourse and social network in people with aphasia and dysgraphia. Gains were not replicated in handwritten tasks, suggesting this was a compensatory therapeutic approach.

What are the clinical implications of this work?

- AT programs such as this may present speech and language therapists with a practical, pragmatic adjunct to writing or typing therapy, particularly for clients with chronic, intractable impairments for whom remediatory therapy may have a low chance of success.

INTRODUCTION

Quality of life (QOL) is profoundly affected by stroke (Sturm & Clendon, 2004). Specific impacts include loss of employment (Cain et al., 2022), reduced social activity (Cruice et al., 2006), shrinking social networks (Northcott et al., 2016) and low mood (Ayerbe et al., 2013). While many stroke-related factors bear upon these impacts, for many the presence and severity of aphasia are significant predictors (e.g., Hilari et al., 2010).

Writing is rarely spared in aphasia and may present as the most impaired communication modality (Rapp et al., 2015). Yet, people with aphasia report that writing is seldom included in their rehabilitation, reflecting the likely prioritisation of speech (Beeson & Rapcsak, 2015). Recent technological advances might challenge this prioritisation. Many communication activities are now conducted digitally through writing, such as text messaging, posting to social media, online shopping and banking. Thus, more than ever before, the rehabilitation of writing might help to address the wider consequences of stroke and aphasia.

Treatments for acquired dysgraphia (writing disorder) can aim to remediate the impairment or compensate for it. When remediation is the target, therapies attempt to improve the functioning of the cognitive processes that undertake writing (Kim et al., 2015). For example, Johnson et al. (2019) employed a range of semantic, word and letter based tasks, with a view to stimulating multiple components of the writing mechanism. Most remediation studies have focused on the writing of single words, although a few have addressed sentence- or phrase-level skills (e.g., Salis & Edwards, 2010). Remediation studies typically report improved spelling of practised words, with generalisation often occurring to words that were not included in therapy (e.g., Johnson et al., 2019 and see Thiel et al., 2015 for review). Gains in functional uses of writing are more rarely targeted and assessed (although see Beeson et al., 2013). Measures of wider impacts are also rare. One exception is the study by Thiel et al. (2016) in which participants (N = 8) practised spelling of 80 words, using copying and word selection tasks; they also maintained a diary of their everyday writing activities. Results demonstrated improved single word writing that, in six cases, generalised to untreated words; the group also improved in written picture description. However, wider gains in email composition were not achieved.

Compensatory treatment approaches aim to improve writing despite ongoing impairment. For example, Panton and Marshall (2008) promoted the use of note taking strategies in their single case study, such as using abbreviations and word substitutions. Advances in digital technology offer exciting opportunities for compensatory dysgraphia treatment and there is a growing body of literature in which digital devices either augmented therapy or were the key component (see Thiel et al., 2015 for review). An early single case example (Mortley et al., 2001) combined conventional oral and handwritten spelling tasks with computer practice using bespoke software. The participant demonstrated significant and well-maintained improvements in word spelling alongside striking functional gains: having been virtually unable to write pre-therapy, he was now able to write simple letters, both on the keyboard and in handwriting.

Other technology assisted dysgraphia therapies have used mainstream software packages. For example, Thiel et al. (2017) trained participants (N = 8) to use Co:Writer software, then carry out a hierarchy of writing tasks with its assistance. An email writing evaluation measure showed gains in word spelling across the group; some individuals also produced more content words post therapy. Gains were evident only when tasks were performed with the software and unassisted writing did not change.

Wade and colleagues (Wade et al., 2001) were the first to demonstrate that Dragon NaturallySpeaking, a speech-to-text package where users speak into a microphone at a normal rate and their speech is encoded as writing on the screen, can be employed by people with aphasia. Subsequently, three single case studies explored its therapeutic potential. In the first (Estes & Bloom, 2011), a naïve computer user successfully mastered operation of Dragon NaturallySpeaking but was unable to apply the skills she had learnt to independent work. Her performance in story retelling tasks was also markedly superior to spontaneous message production, suggesting limited generalisation. Bruce et al. (2003) and Caute and Woolf (2016) had more positive findings: both of their participants successfully learned how to use the software for email writing, and also produced a wide range of additional outputs including shopping lists, diary entries and letters lobbying a local member of the UK parliament. Findings from Caute and Woolf (2016) also suggest that therapy had an impact on the wider consequences of stroke and aphasia. They document an increase in the participant's social network following therapy and in his social activity. Perhaps most impressively, he achieved his goal of resuming voluntary work. Finally, Marshall et al. (2018) carried out a quasi-randomised controlled study of dysgraphia treatment (N = 21), supplementing Dragon NaturallySpeaking with the text to speech package WriteOnline which incorporates predictive text and wordbar vocabulary support. Following the intervention, participants showed gains on a functional writing assessment (email writing) evident in lexical content, grammaticality and quality ratings. Improvements in writing were recorded only when the technology was made available, and unassisted writing did not change.

To date, studies of technology enhanced writing therapy suggest that, with appropriate support, at least some people with aphasia can master relevant technologies and use them to improve the quality of their writing. Encouragingly, gains have been demonstrated on discourse tasks that reflect everyday writing activities, such as email composition. In most cases, effects seem purely compensatory, with benefits evident only when the technology is being used. Thus, it seems that practice with the technology does not remediate the writing impairment. However, as this has been explored in few studies further evidence is needed. Whether or not improvements in writing skills can ameliorate the wider impacts of stroke and aphasia also needs further exploration, with indicative positive findings emerging from only one case study so far (Caute & Woolf, 2016).

The therapeutic relationship between reading and writing is another underexplored area. Both traditional and technological treatments of writing are likely to call upon reading skills, for example in order to monitor written production. Similarly, writing gains may be of limited functional benefit if the individual cannot read written communication received from others. However, our review of writing therapy studies suggests that very few explore participants' reading skills in order to inform therapy decisions (see Bowes & Martin, 2007 for an exception). A related question, and one also typically neglected in the literature, is whether therapy for writing enhances reading skills either through cross modality generalisation or from the reading practice that takes place during treatment. Johnson and colleagues (2019) provided comprehensive reading or writing therapy to eight individuals with acquired alexia and/or dysgraphia. Group results indicated that cross modality generalisation did take place; that is, those who received writing therapy ($N = 6$) improved in word reading accuracy and those who were treated with reading tasks ($N = 2$) demonstrated writing gains. Caute and Woolf (2016) compensatory technological therapy study used a text-to-speech package to support their participant's reading, and this had a positive impact on his ability to comprehend written text, though this was not formally assessed as part of the intervention. The study reported in this paper similarly employed a reading technology alongside Dragon NaturallySpeaking and evaluated post therapy impacts on reading with a standardised assessment ((Gray Oral Reading Test (GORT-4) Bryant & Wiederholt, 2001).

Study aims

This study expands on the positive findings reviewed here and improves the existing evidence base in the following ways. It focuses on mainstream technologies that are more widely accessible; it addresses reading as well as writing; and explores wider outcomes, including functional writing, social and QOL outcomes that are important to people with aphasia (Wallace, Worrall, Rose, Le Dorze, Cruice et al., 2017). Dragon NaturallySpeaking was selected for use in this study, supported by a text-to-speech software package, ClaroRead. The latter decodes written language by reading it aloud for auditory processing, in tandem with voice recognition software (VRS), in a 'voice' which can be modified for rate, volume, prosody and regional accent. This study aimed to augment the evidence for using voice recognition software in the treatment of dysgraphia. As in previous research (e.g., Marshall et al., 2018), it explored whether effects were purely compensatory, that is, evident only when technology could be used. Given the engagement of reading in therapy, and the provision of AT for reading, reading outcomes were also explored. Finally, we were interested in whether treatment would have an impact on some of the wider consequences of stroke and aphasia, such as reduced social networks and lowered mood and/or QOL.

Specific questions were whether assistive technology (AT) training for people with post-stroke aphasia and acquired dysgraphia:

1. Led to improved written output, as assessed by a written picture description and a constrained functional writing task, and whether gains were achieved only when writing was assisted by the trained technology.
2. Improved scores on a measure of reading comprehension, and whether gains were achieved only when reading was assisted by technology.
3. Impacted social participation, mood or QOL.

METHOD

Design

A mixed-methods, repeated measures design was adopted (qualitative outcomes will be reported elsewhere). Double baseline assessments (T1 and T2) were conducted 6 weeks apart, with no interim contact; AT was not installed on participants' computers until T2 assessment was completed. T3 assessments were conducted at the end of 7–10 week training, and T4 assessments at 3-month follow up. Participants retained the software at the end of the intervention and were able to use the software for independent practice during the intervention if they wished.

Participants

To be eligible for the study, participants had to:

- Be 18 years old or more;
- Have aphasia due to stroke, tested with the Comprehensive Aphasia Test (CAT) (Swinburn et al., 2004) (there was no cutoff score for the CAT; all eligible participants

had been independently diagnosed with aphasia by a speech and language therapist);
- Be at least 6 months post-onset and medically stable;
- Have acquired dysgraphia, tested with Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) (Kay et al., 1992); and with writing more impaired than speech.

People were included if:

- They were fluent in English prior to their stroke (based on self-report), with retained ability to participate in assessments and training activities delivered in English;
- They had access to a computer with an Internet connection, for home-based, self-directed practice.

People were excluded if:

- They were receiving SLT or participating in research with therapeutic goals during the project;
- They had significant cognitive impairment, assessed with the Cognitive Linguistic Quick Test (CLQT) (Helms-Estabrook, 2001);
- They had marked neuromuscular/motor-speech impairments or structural abnormalities, for example, cleft palate;
- They had a self-reported history of developmental dyslexia;
- They had uncorrected visual or auditory impairments.

Participants were recruited from community settings such as Stroke Association communication support groups and Connect—the Communication Disability Network. None had used AT before the intervention, though one had tried to do so without support and was unsuccessful.

Procedure

Assessment protocol

Assessments at T1 were conducted over two to three visits (university campus or participants' homes according to their preference), each of approximately 1.5 h duration, depending on participants' fatigue; at T2, T3 and T4, assessments were conducted over two visits of approximately 1.5 h duration. Tests using the same stimuli were presented in separate sessions in order to avoid priming effects. Likewise, assessments which were delivered in two different formats (pen and paper/keyboard) were administered at separate sessions and were counterbalanced to ensure technological versions were delivered first 50% of the time, at all test points. All assessments were conducted by the first author.

Training intervention

A training program was devised based on the compensatory technology studies described previously (Estes and Bloom (2011), Bruce et al. (2003), Caute and Woolf (2016)). Participants were shown an accessible slideshow of options for writing tasks and invited to identify and set their own goals from a range of options, with suggestions including reviews, for example, of films or sporting events, memories or descriptions, advice or support, instructions, shopping lists and creative writing. Many participants expressed an interest in composing emails, and some wanted to explore Internet shopping; these were both incorporated into the program. The number of tasks varied depending on participants' priorities; there was no task hierarchy as this was an intervention aimed at supporting each participant's functional writing.

The program was delivered by the first author, a clinical linguist and social scientist, and comprised 7–10 individual one-to-one sessions, once a week, each lasting approximately 1 h. These took place in a quiet room at the university, or at participants' homes, according to their preference. All participants were offered ten sessions, but some chose to have fewer, either due to feeling capable of continuing independent use of AT, concluding that the software had reached its potential to compensate for their deficits, or having other commitments. The program was piloted with two people with aphasia (PWA) who did not take part in the main study, to test its acceptability, design and refine training materials for the main study, and select appropriate outcome measures.

To ensure the intervention was described with sufficient detail, the template for intervention description (TIDieR checklist, Appendix 1) (Hoffmann et al., 2014) was used. A replicable intervention structure was repeated across participants which flexibly permitted customisation depending on participants' individual written discourse goals, for example, writing emails versus online application forms, and support needs, for example, competent information technology user versus beginner. Key components (Table 1) forming the basis of training for all participants were topic generation, trial and error dictation, performance monitoring including error management and editing, feedback and prompts for further editing, review of performance and key strategy identification and reinforcement.

TABLE 1 Intervention components.

Topic generation	Goal setting session discussing writing genres and topics, including previous writing and technology activities and future aims, supported with PowerPoint presentation. Participants experiencing particular difficulties with topic/genre generation were given specific examples, for example, writing about a recent televised cricket match, or describing photographs of landscapes and buildings.
Trial and error dictation	Introduction to Dragon NaturallySpeaking software: initial voice training, opening the program, wearing and adjusting microphone headset, activating the microphone, mastering blending verbal discourse with spoken commands for punctuation, navigation and microphone operation, listening back to dictated material for objective accuracy and subjective satisfaction.
Performance monitoring including error management and editing	Identification and location of errors in dictated text, finding an alternative, and correctly producing alternative in appropriate place in the text. Using ClaroRead, including techniques required for different programs, for example, hover + highlight in PDF, click + highlight in Microsoft Word. Particular care was taken to reinforce this stage with the five participants with single word reading deficits.
Feedback and prompts for further editing	Immediate verbal feedback regarding accuracy when required; often participants could independently assess this. In part judgements were based on genre, for example, formal letter to a social care provider more rigidly corrected than casual email to a good friend.
Review of performance	At the end of each session, participants gauged satisfaction levels. Brief verbal summary of activities undertaken and specific examples of success were given. Dictated outputs were saved and printed/emailed to participants according to preference. Key new learning written up in accessible format in time for their next session.
Key strategy identification and reinforcement	Successful strategies were explicitly identified and positively reinforced, supported by concrete, accessible explanations of why it had worked in the circumstances.

Measures

Measures used at each assessment point are summarised in Table 2. Outcome measures for reading and writing were administered in pen and paper format and on a computer with AT absent at T1 and T2 and AT (Dragon NaturallySpeaking and ClaroRead) enabled at T3 and T4 (keyboard condition).

Screening, profiling and monitoring

Language was screened using the CAT (Swinburn et al., 2004), a battery of assessments exploring all four language domains (speaking, listening, writing and reading). The language battery yields summary scores, which are then converted to standard T-scores (25–75).

Cognition was screened using the CLQT, a 10-item assessment of functioning in five domains (attention, memory, executive functioning, language, visuospatial skills) for use with adults with acquired neurological impairments. Scores yield severity ratings for each domain and a total composite severity rating ranging 0–4 (0–1 = severe, 1–2 = moderate, 2–3 = mild, 3–4 = within normal limits). The CLQT was administered at all time points to monitor for a decline in cognitive functioning, since this may have affected AT training progress.

Ten single word assessments were used from the PALPA (Kay et al., 1992) to establish the nature and severity of participants' single word spelling and reading deficits and their ability to name pictures aloud.

Outcome measures of written discourse

- *CAT written picture description*

Participants were given 3 min to write an account of what was happening in a picture. This provided a summary score from which a T-score was derived.

- *Constrained writing task*

In this task (Caute & Woolf, 2016), participants were given 5 min to compose an email to a friend, including a greeting, invitation to meet and ending. Three scores were derived and analysed: *total tokens* (total words), *lexical variety*, derived by counting types (total words minus repetitions), then calculation of a type-token ratio (type divided by token multiplied by 100 = percentage lexical variety, where higher scores indicate greater variety) and *social*

TABLE 2 Screening, profiling, monitoring and outcome measures.

T1 (Screening and first baseline)	T2 (second baseline 6 weeks later)	T3 (end of intervention)	T4 (3-month follow-up)
Screening assessments: CAT* language battery CLQT Profiling assessments of writing, reading and spoken picture naming: PALPA subtests 24, 40, 41, 42, 43, 45, 50, 53 (three formats: speaking, handwriting, writing with keyboard) Outcome measures of reading and writing, pen and paper and keyboard versions: CAT written picture description Constrained writing task GORT4 Outcome measures of QOL and mood: SAQOL 39 g, GHQ12	Monitoring: CLQT Outcome measures of reading and writing, pen and paper and keyboard versions: CAT written picture description Constrained writing task GORT4 Outcome measures of QOL and mood: SAQOL 39 g, GHQ12, SNA	Monitoring: CLQT Outcome measures of reading and writing, pen and paper and keyboard versions WITH AT SOFTWARE ENABLED: CAT written picture description Constrained writing task GORT4 Outcome measures of QOL and mood: SAQOL 39 g, GHQ12, SNA	Monitoring: CLQT Outcome measures of reading and writing, pen and paper and keyboard versions WITH AT SOFTWARE ENABLED: CAT written picture description Constrained writing task GORT4 Outcome measures of QOL and mood: SAQOL 39 g, GHQ12, SNA

Abbreviations: *CAT, Comprehensive Aphasia Test; CLQT, Cognitive Linguistic Quick Test, GHQ12, General Health Questionnaire; GORT4, Gray Oral Reading Test; PALPA, Psycholinguistic Assessments of Language in Aphasia; QOL, quality of life; SAQOL 39 g, Stroke and Aphasia Quality Of Life; SNA, Social Network Analysis.

validity judgement (Jacobs, 2001). Handwritten emails were first converted to typewritten format, with errors and strike-throughs included; recognisable attempts were deemed acceptable as this was a functional writing intervention. Five doctoral students, blinded to writing method and time point, conducted social validity judgement, scoring each email for effectiveness, informativeness, grammaticality and comfort. Scores were averaged across the raters before being analysed. The inter-rater reliability of such a scoring system, at least for informativeness and efficiency, has previously been demonstrated to be as high as 98% (Nicholas & Brookshire, 1993) and was not tested further in this study.

Outcome measure of reading comprehension: Gray Oral Reading Test (GORT-4)

The GORT-4 (Bryant & Wiederholt, 2001) is a test of oral reading comprehension, originally designed for use with children with dyslexia. It is composed of two sets (A and B) of 14 progressively longer and more complex passages of text, which a participant is instructed to read aloud as quickly and accurately as possible, followed by five multiple choice comprehension questions, scored correct or incorrect. In the full version of the GORT-4, a fluency score is also derived by measuring reading rate and combining this with the accuracy; in this study, rate was not measured since in the T3 and T4 AT conditions the texts were read by AT rather than the participants themselves. The comprehension questions are both read aloud by the assessor, and placed in front of the PWA, either on paper or on the screen. Both sets of texts and questions were typed into a Microsoft Word document in order that they could be delivered with or without AT enabled. The A and B passages were alternated, whereby, for example, if a participant received set A as the paper version and set B as the computer version at T1, the opposite would be the case at T2.

Outcome measures of social network, well-being and QOL

- *Stroke and Aphasia Quality of Life Scale-39 g (SAQOL-39 g)*

The SAQOL-39 g (Hilari et al., 2009) is a measure of health-related QOL for people with stroke and aphasia. It is an interviewer-administered self-report measure with 39 items covering three domains: physical, psychosocial and communication. It yields both domain scores and an overall QOL score, all of which range 1—5 with high scores indicating higher QOL.

- *General Health Questionnaire 12-item version (GHQ-12)*

The GHQ-12 (Goldberg, 1978) is an abbreviated version of the complete GHQ and is a self-report instrument to screen for emotional distress. The GHQ was developed for use in general population surveys, in primary care settings or among general medical outpatients, and uses a time frame of 'the past few weeks'. There are four responses per question (better than usual, same as usual, less than usual, much less than usual) which were scored with a two-point score that rates problems as absent or present (0-0-1-1). This gives a total score of 0–12, with higher scores indicating higher distress.

- *Social Network Analysis*

Antonucci and Akiyama's (1987) Social Network Analysis (SNA) diagram was designed to quantify the number of individuals in participants' networks, in three strata: innermost circle representing people to whom the subject is so close they find it hard to imagine life without them; middle circle for people whom the subject regards as not quite that close but still very important; outermost circle for people not yet mentioned but whom the subject feels sufficiently close to place them in their network. Overall scores from the number of people named in each circle can be calculated to monitor change in network size. SNA was administered at T2, T3 and T4 – it was omitted at T1 to reduce assessment burden.

Data analysis

Descriptive statistics were used to describe participants and their language and cognitive profiles and to summarise outcome measure scores. To compare outcomes across time, the Friedman's repeated measures nonparametric test was used because the sample was small. Significant changes were explored with pairwise comparisons (Mann–Whitney tests). Given the exploratory nature of this research, adjustments for multiple comparisons were not made. A beneficial effect of AT training would be demonstrated by improved scores on measures after training (T3 and T4) compared to baseline (T1 and T2). For assessments delivered in both pen and paper and keyboard formats (CAT, constrained writing, GORT-4) data for each format were analysed separately. This determined whether gains occurred only in the technology format, with technological assistance, which would point to a compensatory effect of AT.

RESULTS

Participant characteristics

Six people with aphasia were excluded as they did not meet one or more of the criteria for the study. Their characteristics were not documented. Ten people with aphasia took part in the study and Table 3 shows their characteristics. There were four female and six male participants, with an age range of 44–75 years old (mean = 58.2 years, SD = 10.5 years). All were substantially beyond the inclusion criterion of 6 months post-onset (range = 23 months to 14 years, mean = 6 years, 2 months, SD = 3 years, 7 months). Eight had ischaemic and two haemorrhagic strokes; half of the group had hemiplegia. Three left education after GCSE/O levels (11 years of British education), the remaining seven were university graduates (three with bachelor degrees, two with master degrees and two participants with PhDs). Three participants were already retired at the time of their stroke; a further two retired owing to stroke-related ill health. The remaining five had also left their former employment but two were working freelance/retraining and three volunteering.

Language and cognitive profiles

Descriptive statistics for the CAT and CLQT are provided in Table 4. As some scores were skewed and others were not, both means (SDs) and medians (interquartile ranges [IQRs]) are given to allow comparisons.

- *CAT*

T-scores on the CAT ranged 42–72. Examination of the mean (SD) group T-scores for comprehension of spoken language (62.60 (5.40)), comprehension of written language (63.90 (5.78)), repetition (57.30 (4.95)), spoken picture description (65.70 (6.93)), reading (58.70 (7.95)), writing (58.60 (5.06)) and written picture description (56.90 (9.05)) revealed generally better group performance on comprehension tasks and slightly poorer performance on language production tasks, with the exception of spoken discourse.

TABLE 3 Participant characteristics (names are pseudonyms).

	Sex	Age at T1 (years)	Time post-onset at T1	Stroke type	Hemiparesis	Highest educational qualification	Occupation pre-onset	Employment status	Single word reading impairment
1 Peter	M	74	10 years 3 months	Ischaemic	N	Master degree	Lecturer/trainer specialising in dyslexia	Retired pre-onset	Y
2 Rohan	M	64	3 years 0 months (approx.)	Ischaemic	Y	Doctorate	Computer Science lecturer	Retired due to stroke	Y
3 Sarah	F	61	14 years 0 months	Ischaemic	Y	Master degree	Secondary school English and history teacher	Retired; full-time parent for 10 years pre-onset	N
4 Karen	F	49	5 years 0 months	Ischaemic	N	GCE 'O' levels	Secondary school secretary and Personal Assistant	Retired due to stroked; retraining	N
5 Albert	M	75	4 years 10 months	Ischaemic	N	Doctorate	Marketing for banking, pharmacology background	Retired pre-onset	N
6 Dean	M	44	1 year 11 months	Ischaemic	Y	GCE 'O' levels	Hotel locksmith	Retired due to stroke, volunteering	Y
7 William	M	52	7 years 2 months	Ischaemic	N	Bachelor degree	Journalist for international news agency	Retired due to stroke; volunteering	Y
8 Janet	F	55	6 years 0 months (approx.)	Ischaemic	N	Bachelor degree	Fashion designer	Retired due to stroke; freelance	N
9 Doreen	F	49	3 years 2 months	Haemorrhagic	Y	Bachelor degree	Substance misuse worker on Youth Offending Team	Retired due to stroke	Y
10 Simon	M	59	3 years 8 months	Haemorrhagic	Y	GCE 'O' levels	Quantity surveyor	Retired due to stroke, volunteering	N

TABLE 4 Group CAT and CLQT assessment scores (CAT $n = 10$, CLQT $n = 9$).

	Scale score range		Group score range	SD	IQR
Cognition: CLQT composite severity rating	0–4.0	T1	2.8–4.0	3.64 (0.44)	3.80 (3.45–4.00)
		T2	2.6–4.0	3.52 (0.58)	3.70 (3.05–4.00)
		T3	2.6–4.0	3.62 (0.51)	3.80 (3.30–4.00)
		T4	3.0–4.0	3.73 (0.39)	4.0 (3.40–4.00)
Language: CAT domain					
T-scores (conducted at T1 only)	25–75	Spoken comprehension	52–67	62.60 (5.40)	64.00 (60.00–65.00)
		Written comprehension	51–68	63.90 (5.78)	66.50 (59.00–68.00)
		Repetition	48–64	57.30 (4.95)	57 (54.25–62.00)
		Spoken picture description	57–75	65.70 (6.93)	64.50 (59.00–73.50)
		Reading	46–71	58.70 (7.95)	58.00 (54.00–66.00)
		Writing	50–65	58.60 (5.06)	59.50 (55.50–62.50)
		Written picture description	42–72	56.90 (9.05)	59.00 (51.75–61.25)

Abbreviations: CAT, Comprehensive Aphasia Test; CLQT, Cognitive Linguistic Quick Test; IQR, interquartile range (median).

- *PALPA*

The highest scores were achieved for spoken naming (77.5%–100%), while the range for written naming was very wide (7.5%–95%). Reading was less impaired, for example, synonym judgement (68.3%–100%); half the group showed either no sign of a reading deficit or slight, non-specific indications. Individual PALPA scores are given in appendix 2. All participants were markedly better at spoken than written naming, as this was one of the eligibility criteria.

- *CLQT*

Scores on the CLQT were relatively high and remained stable, with SDs ranging 3.52–3.73 and IQRs 3.70–4.00. There was no significant change in the group's cognitive performance over time: Friedman's χ^2 (3) = 6.45, $p = 0.092$ (Table 4).

Outcome measures of written discourse and reading comprehension

Descriptive statistics on outcomes of written discourse and reading comprehension are provided in Table 5. SDs and IQRs are provided as most CAT T-scores for written picture description in the keyboard condition (3/4) were skewed, as well as the tokens and lexical variety keyboard (6/8) and pen and paper (6/8) scores and 1/8 GORT scores (T2, pen and paper).

In answer to research question 1, on whether AT training for people with dysgraphia led to improved written output, there was no significant change in the pen and paper condition for the CAT written picture description and the three constrained writing tasks (Table 5) indicating the AT training program had no remediatory impact on participants' dysgraphia. Scores remained relatively stable across tasks, except for lexical variety where they seemed to decrease but to a small and non-significant effect.

In the technology (keyboard) condition, there was a significant improvement in group performance in the CAT written picture description, and in one element of the constrained writing task (total tokens). In contrast to the pen and paper condition, in the keyboard CAT written picture description median (IQR) T scores went from 61.00 (55.00–67.50) and 60.0 (49.00–71.00) at T1 and T2, to 75.00 (66.0–75.00) at T3 and were maintained at T4, 75.00 (62.00–75.00), Friedman's χ^2 (3) = 8.27, $p = 0.041$ (Figure 1), with the biggest change in scores occurring between T2 and T3. Despite this, none of the post-hoc pairwise comparisons were significant.

In the constrained writing task, in contrast to the pen and paper condition, total tokens in the keyboard condition increased from 16.00 (14.00–44.00) and 19.00 (12.50–48.00) at T1 and T2, to 95.00 (39.00–196.50) at T3 before dropping a little to 85.00 (49.50–273.00) at T4, Friedman's χ^2 (3) = 13.65, $p = 0.003$ (Figure 2). In post-hoc comparisons, the differences pre-intervention to post-intervention (T1 vs. T3, $p = 0.007$; and T2 vs. T3, $p = 0.007$) and pre-intervention to follow-up (T1 vs. T4, $p = 0.011$; and T2 vs. T4, $p = 0.011$) were significant. The differences between T1 and T2, and T3 and T4 were not significant.

There were no significant changes in lexical variety or social validity judgements in either the handwritten or

TABLE 5 Group descriptive statistics for assessments of written discourse and reading comprehension ($n = 9$).

		Scale score range		Group score range	SD	IQR
Narrative writing	CAT written picture description pen & paper T-score	25–75	T1	42–72	56.90 (9.05)	59.00 (51.75 - 61.25)
			T2	42–75	58.80 (12.26)	62.00 (42.00 - 67.25)
			T3	42–75	59.10 (12.71)	64.50 (42.00–67.50)
			T4	42–75	60.22 (12.32)	62.00 (47.00–70.00)
	CAT written picture description keyboard T-score*	25–75	T1	42–75	60.22 (9.54)	61.00 (55.00–67.50)
			T2	25–75	58.22 (16.92)	60.0 (49.00–71.00)
			T3	42–75	68.44 (10.77)	75.00 (66.0–75.00)
			T4	42–75	68.00 (11.24)	75.00 (62.00–75.00)
	Constrained writing pen and paper total tokens	N/A	T1	0–75	27.33 (23.85)	26.00 (7.50–42.50)
			T2	0–82	27.00 (27.10)	26.00 (.00–43.0)
			T3	0–94	27.78 (30.87)	26.00 (1.50–45.50)
			T4	0–93	30.22 (30.84)	26.00 (0–49.50)
	Constrained writing pen and paper % lexical variety	0–100	T1	0–100	68.64 (39.64)	83.70 (38.65–94.45)
			T2	0–100	60.30 (46.0)	82.00 (.00–100.00)
			T3	0–100	64.47 (38.02)	75.00 (35.7–90.4)
			T4	0–96.2	53.40 (40.64)	76.20 (.00–80.00)
	Constrained writing keyboard total tokens**	N/A	T1	0–139	35.78 (41.68)	16.00 (14.00–44.00)
			T2	0–174	39.56 (53.20)	19.00 (12.50–48.00)
			T3	4–248	113.44 (85.54)	95.00 (39.00–196.50)
			T4	1–428	152.11 (144.14)	85.00 (49.50–273.00)
	Constrained writing keyboard % lexical variety	0–100	T1	0–93.8	70.97 (28.58)	81.30 (64.90–88.35)
			T2	0–100	74.14 (30.08)	84.20 (67.85–91.65)
			T3	51.2–100	68.70 (16.85)	66.20 (51.25–80.20)
			T4	51.1–100	67.16 (15.15)	66.70 (54.40–73.00)
	Constrained writing pen & paper SVJ total score	0–40	T1	0–33.8	18.58 (13.38)	20.30 (3.70–31.50)
			T2	0–31.4	18.22 (13.83)	24.60 (.00–28.90)
			T3	0–37.4	17.31 (14.76)	25.20 (2.00–29.40)
			T4	0–33.2	18.26 (14.53)	27.40 (.00–30.25)
	Constrained writing keyboard SVJ total score	0–40	T1	0–36.0	21.11 (12.89)	29.60 (9.10–30.30)
			T2	0–37.4	22.89 (12.88)	25.20 (12.10–32.90)
			T3	8.0–33.0	23.24 (8.61)	25.60 (15.20–30.00)
			T4	3.0–33.4	21.87 (10.14)	24.40 (13.40–29.23)
Reading comprehension	GORT-4 pen & paper standard comprehension score	1–20	T1	1–9	4.30 (2.45)	3.50 (2.75–6.25)
			T2	1–9	4.10 (2.56)	3.00 (2.75–5.75)
			T3	1–8	4.50 (2.22)	4.50 (3.00–5.75)
			T4	1–9	4.67 (2.83)	3.00 (3.00–7.50)
	GORT-4 keyboard standard comprehension score**	1–20	T1	1–5	2.90 (1.29)	3.00 (2.00–3.50)
			T2	1–8	4.70 (2.31)	4.00 (3.00–7.25)
			T3	2–9	5.60 (2.17)	5.50 (4.00–7.25)
			T4	2–10	6.67 (2.65)	7.00 (4.50–9.00)

Abbreviations: CAT, Comprehensive Aphasia Test; GORT, Gray Oral Reading Test; IQR, interquartile range (median); Social Validity Judgements.
*$p < 0.05$.
**$p < 0.01$.

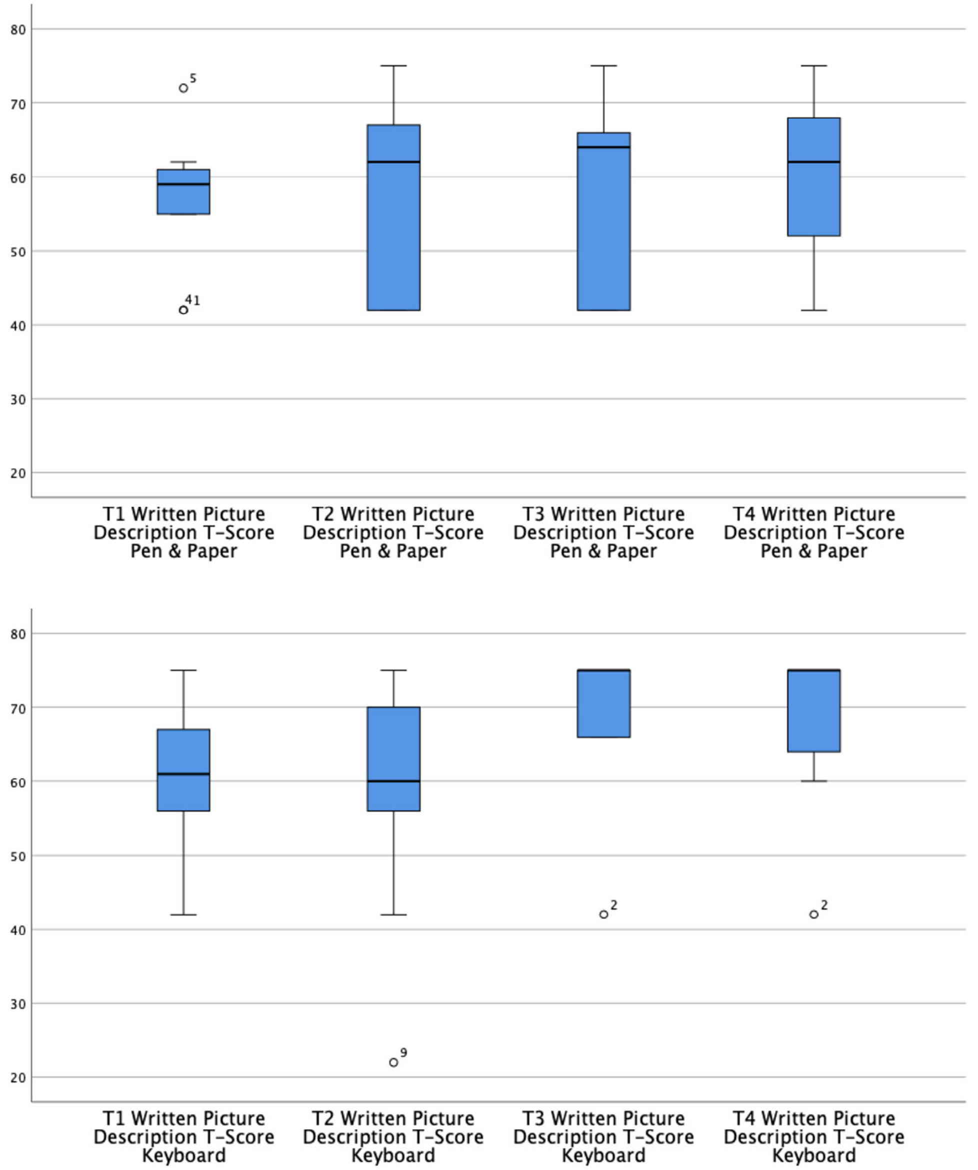

FIGURE 1 Pen and paper (top) and keyboard (bottom) CAT written picture description. Abbreviation: CAT, Comprehensive Aphasia Test. [Colour figure can be viewed at wileyonlinelibrary.com]

AT-assisted constrained writing task. However, we noted that as participants became familiar with using AT the writing tasks they attempted became more complex and ambitious, which may have affected both ratings of lexical variety and social validity judgements. For example, they produced long, conversational emails rather than brief notes, as shown in William's writing in Figure 3. Here the brief message was conventionally typed at T2 while the longer one was dictated at T3:

In answer to research question 2, on whether AT training improved scores on a measure of reading comprehension, there was no significant change over time in the pen and paper version of the GORT-4, suggesting the intervention had no remediatory effect on dyslexia. In the technology version, GORT-4 reading comprehension test scores significantly increased over time: Friedman's χ^2 (3) = 21.07, $p < 0.001$. Figure 4 illustrates that scores improved at each assessment point, even before treatment began. In post-hoc comparisons all differences were significant ($p < 0.017$), except T2 vs. T3 $p = 0.053$ and T3 vs. T4 $p = 0.158$). Therefore, the change could not be linked to intervention.

Outcome measures of social network, well-being and QOL

These measures were used to answer research question 3 on the impact of AT training on social network size, well-being and health-related QOL. Scores on the measures are

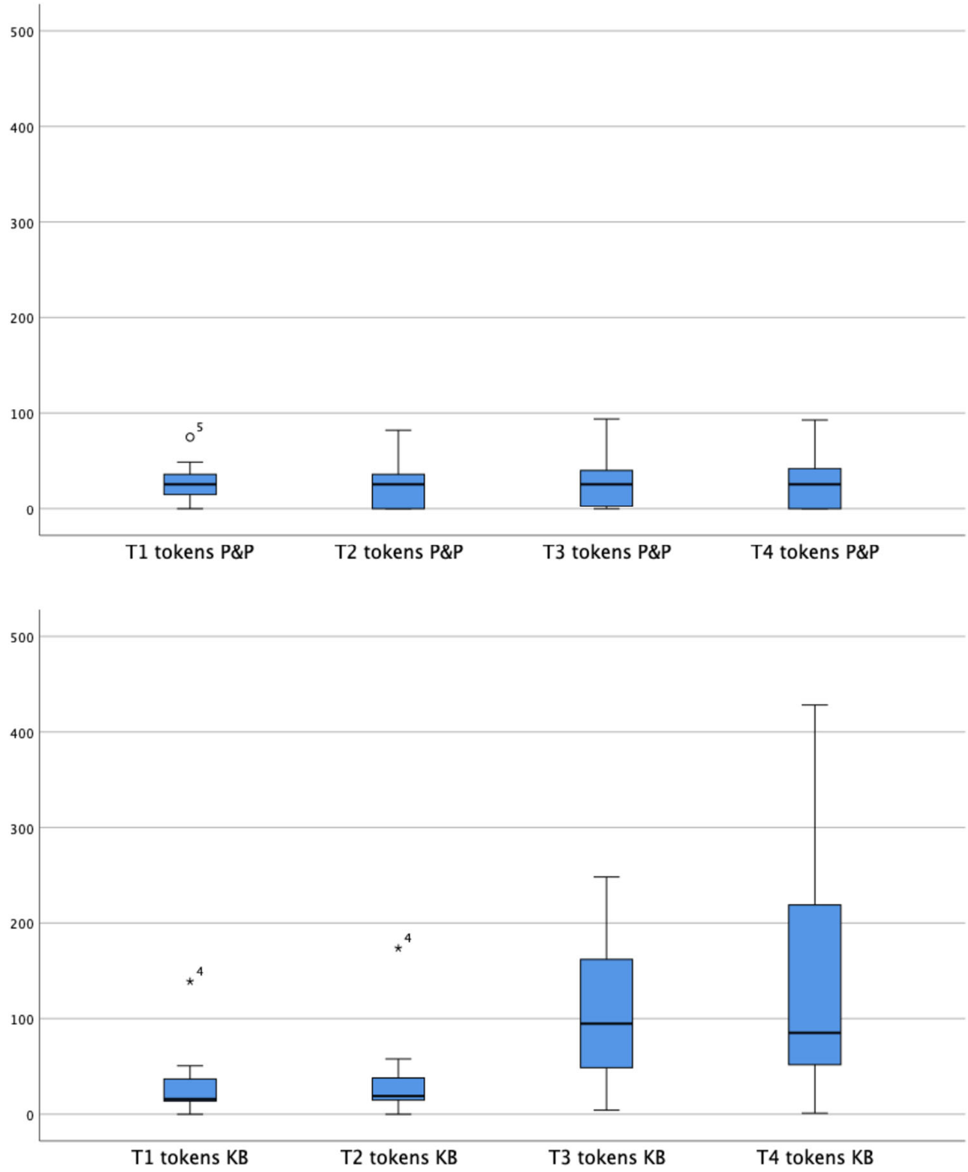

FIGURE 2 Pen and paper (top) and keyboard (bottom) constraining writing—total tokens. Abbreviations: KB, keyboard; P&P, pen and paper. [Colour figure can be viewed at wileyonlinelibrary.com]

reported in Table 6. Most scores on the SAQOL-39 g were normally distributed whereas most scores on the GHQ-12 and social network sizes were skewed, therefore both SDs and IQRs are listed.

Social network size

The size of participants' social networks varied widely. The smallest had six individuals (Rohan, T3) while the largest had 65 (Edward, T2 and T3). In terms of changes, three people said their social network was unchanged, while the other seven described increases (Range = 1–6). Despite the variability and overlap in the data, there was a significant increase in the overall size of participants' social networks from pre-intervention to follow-up, Friedman's χ^2 (3) = 10.64, $p = 0.005$ (Figure 5). In post-hoc comparisons, differences were significant between T2 and T4 ($p = 0.017$) and T3 and T4 ($p = 0.042$)

GHQ-12 and SAQOL-39 g

The GHQ-12 IQR scores were low across time (1.00–2.00) and there were no significant differences across time. There was wide variability within the group's scores across all time points. Group scores on the SAQOL-39 g showed a trend towards higher scores across time for two of the three domains (communication and psychosocial) and for overall score. The differences were not significant.

Hi caroline,

Wonderful news, ~~on and~~ another son!! congatulation, well done. In st. geages or chelsea?

Sometimes my speech drawn up dried up, completely. I don't know why but it was so awful. Is it is it my processing of speech or the speech therapy with Dragon software? Which is it?

New paragraph

Best time doing anything about talking is morning. I'm rested and ready beginning a new day. Between two and three was worse I think is because I have food. My body is concentrating for absorbed nutrients not talking. On the younger I have a rest in the afternoon; eating is tiring!

Around 4 or 5 my speech improved and until about 10 or 11. Curiously it's the effort of talking about one hour was hard when I was talking with my son my daughter. I think it's because they are young and old also teenagers have a different level of speech - actually is a grunt. They are not good speech therapy!

FIGURE 3 Writing samples from T2 and T3 (William).

DISCUSSION

This group study explored whether AT training led to gain in written discourse, reading comprehension and psychosocial outcomes in people with aphasia and dysgraphia. In terms of written discourse, the group made significant gains in the technology-assisted CAT picture description over time, with the largest gains made from before to after intervention, suggestive of a treatment effect. These gains were not replicated in the pen and paper condition.

In the second writing outcome measure, the constrained writing task, there was significant increase in the number of tokens produced, again confined to the AT condition. Thus all improvements in writing were evident only when the AT could be employed, since handwritten production did not change. It seemed that participants learnt to use the AT to compensate for their writing impairment. That impairment was not remediated, unlike the encouraging results from other studies (e.g., Panton & Marshall, 2008).

The measure of lexical variety did not change, even when AT was available. This is perhaps less surprising than it first appears. To illustrate, two portions of the first author's doctoral thesis (Moss, 2017) were randomly selected and analysed using the same calculation method and tool as for the participants' constrained writing task data. The first portion was an opening paragraph, Section 8.3.1 (page 153), while the second was the whole of the same section. For the first, the type-token ratio yielded a lexical density score of 63.2%, while for the second, longer section the lexical density score dropped to 50.4%. As both were written by the same author, on the same day, regarding the same topic, it is reasonable to state that this reduction is attributable to increased length. In view of this, since technology use produced longer texts in the participant group, the stable lexical density score indicates that both tokens and types must have increased in parallel (e.g., the token score did not just go up because the person was repeating the same words over and over again). Therefore, it appears a count of token and type would have been more useful in this assessment.

There was no significant improvement in SD group social validity judgement (SVJ) ratings for either handwritten or typed condition over time, neither in any sub-measure (effectiveness, informativeness, grammaticality, comfort) nor in the SD total score. Therefore, use of AT software appeared to have no impact on how the group of participants' narrative compositions were judged by independent raters. This was a disappointing finding given that the participants themselves gave positive qualitative assessments of their written output when supported with AT. Lustig and Tompkins (2002) reported a similar finding in their writing intervention designed to avoid prolonged articulatory struggle for their participant with dyspraxia of speech, whereby only shorter utterances received higher ratings for communicative efficiency and comprehensibility after training. In the AT study it is possible that, as in the lexical variability scores described, the length of texts may have had a confounding effect on these ratings. Indeed, one rater described this anecdotally, remarking that even though the shorter messages were telegraphic and contained less informative content, they were clearer in form and therefore more comfortable to read (rater 4, personal communication, 2016). Caute and Woolf (2016) observed a similar pattern, whereby one very short and uninformative email at T2 received higher SVJ

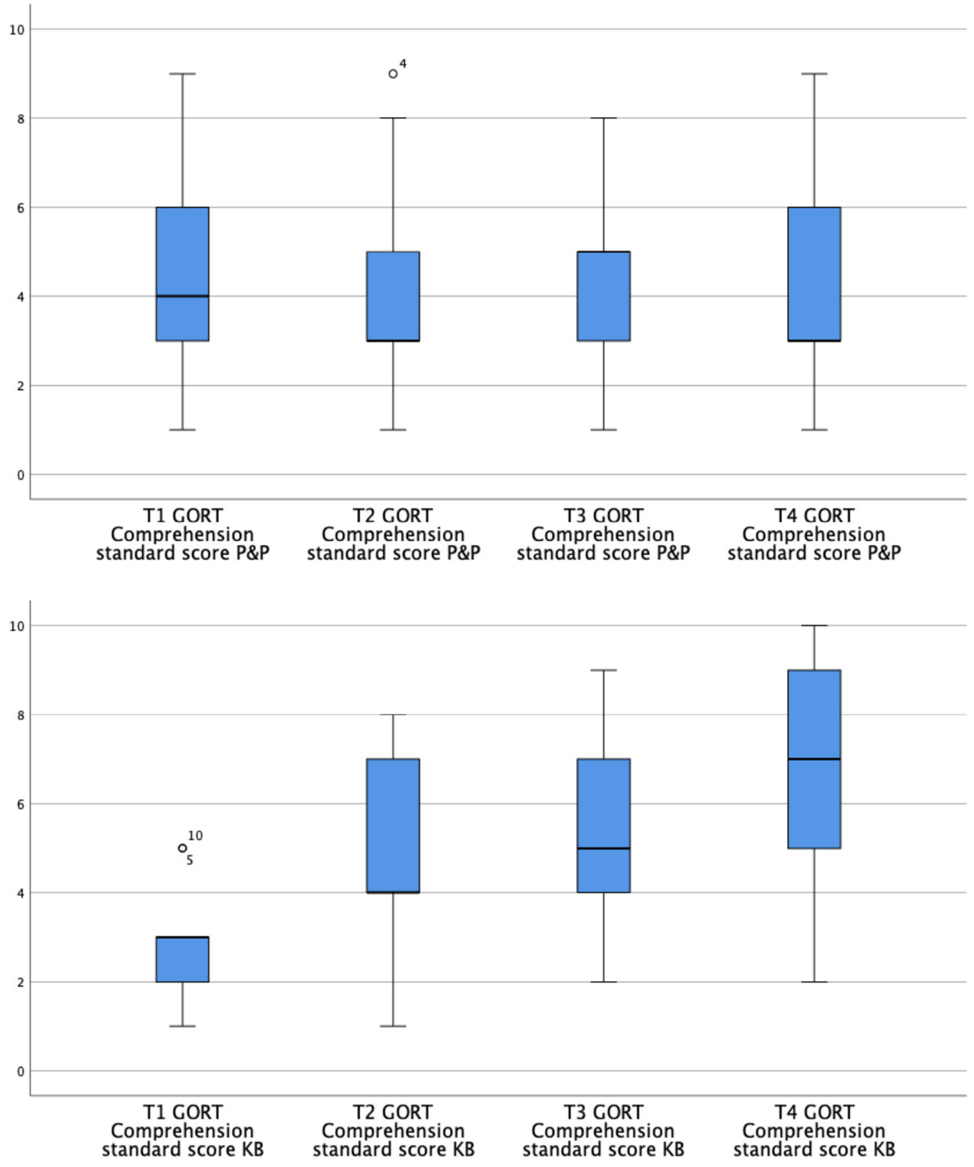

FIGURE 4 GORT-4 pen and paper (top) and keyboard scores (bottom). Abbreviations: GORT, Gray Oral Reading Test; KB, keyboard; P&P, pen and paper. [Colour figure can be viewed at wileyonlinelibrary.com]

ratings than longer and more informative emails that contained some errors. To a degree this may be because the likelihood of error naturally increases with text length, even for non-impaired writers. This was a training program designed to improve and generalise functional writing, which could include the ability to produce a greater volume of written discourse. On reflection, instructions to raters could have more explicitly indicated that they were primarily being asked to assess ability to compose novel, spontaneous written output.

Aphasic idiosyncrasies may also be more apparent in longer, more expressive passages of text, and given that, as described previously, it is rare to see uncorrected samples of aphasic writing, limited exposure to this kind of non-standard writing may have influenced raters' views of its acceptability.

It may be that the group of participants themselves were accepting of imperfect but broadly comprehensible text as a consequence of producing more writing. Finally, the task was rather pedestrian so could not hugely benefit from improved quantity of writing; a more creative writing task might have elicited different judgements.

In relation to reading comprehension, there was no improvement over time when participants undertook the paper version of the GORT-4, suggesting AT training had no significant remediatory impact on conventional reading comprehension at the narrative level. There was a significant improvement on the GORT-4 reading

TABLE 6 Group descriptive statistics for assessments of social network, mood and quality of life ($n = 9$).

	Scale score range		Group score range	SD	IQR
Social network size	N/A	T2	7–65	22.67 (13.78)	23.00 (10.50–32.00)
		T3	6–65	24.33 (14.08)	23.00 (13.00–32.50)
		T4	9–54	26.33 (13.65)	23.00 (16.00–34.50)
Mood (GHQ-12)	0–12	T1	0–11	3.67 (4.12)	2.00 (.00–7.00)
		T2	0–12	3.00 (5.12)	1.00 (.00–6.50)
		T3	0–12s	2.56 (3.81)	1.5 (.00–3.50)
		T4	0–12	1.78 (3.87)	1.00 (.00–1.00)
Quality of Life (SAQOL-39 g) physical subdomain	1–5	T1	2.4–4.8	3.93 (0.74)	4.10 (3.55–4.55)
		T2	2.9–4.9	4.01(0.75)	4.00 (3.40–4.80)
		T3	2.6–4.9	3.93 (0.87)	4.20 (3.00–4.70)
		T4	2.4–4.9	4.01 (0.81)	4.10 (3.50–480)
Quality of Life (SAQOL-39 g) communication subdomain	1–5	T1	2.1–4.4	3.56 (0.78)	3.70 (3.00–4.25)
		T2	2.9–4.7	3.77 (0.65)	3.70 (3.20–4.45)
		T3	2.0–4.7	3.80 (1.01)	4.00 (2.95–4.65)
		T4	2.7–5.0	3.93 (0.76)	4.00 (3.35–4.65)
Quality of Life (SAQOL-39 g) psychosocial subdomain	1–5	T1	1.8–4.5	3.26 (0.90)	3.30 (2.45–3.90)
		T2	1.1–4.2	3.31 (1.06)	3.60 (2.70–4.10)
		T3	1.3–4.4	3.33 (1.02)	3.80 (2.60–4.00)
		T4	2.1–4.4	3.53 (0.79)	3.70 (2.95–4.25)
Quality of Life (SAQOL-39 g) overall score	1–5	T1	2.2–4.4	3.58 (0.71)	3.80 (3.05–4.05)
		T2	2.4–4.4	3.68 (0.72)	3.90 (3.00–4.25)
		T3	2.0–4.4	3.64 (0.91)	4.20 (2.85–4.30)
		T4	2.5–4.7	3.78 (0.71)	3.90 (3.20–4.35)

Abbreviations: GHQ, General Health Questionnaire; IQR, interquartile range (median); SAQOL, Stroke and Aphasia Quality of Life scale.

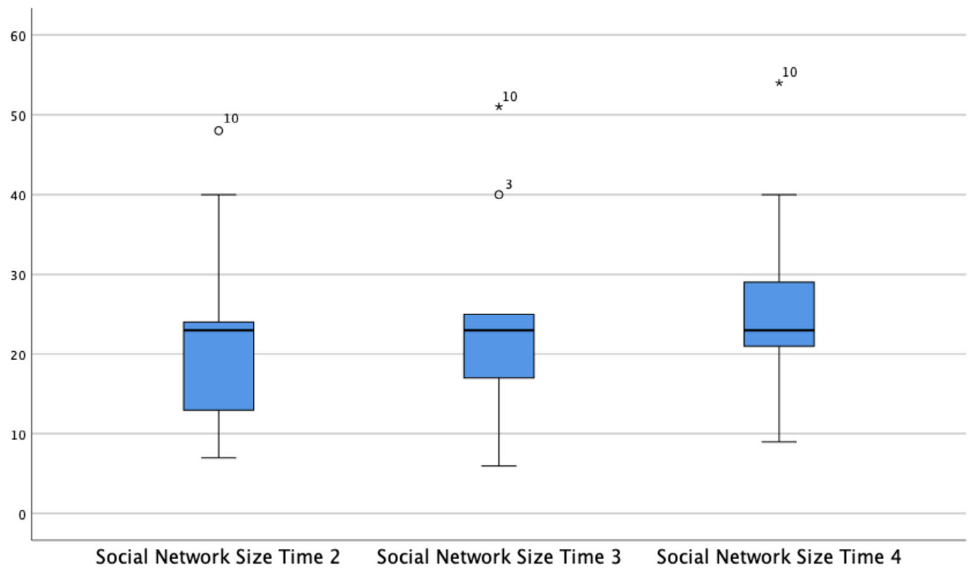

FIGURE 5 Group social network size. [Colour figure can be viewed at wileyonlinelibrary.com]

comprehension test over time in the technology condition. Though scores at T4 3 month follow up had risen, suggesting that independent use of the AT was possible, scores had risen at all time points. Gains were not greater in the post-intervention period. This result needs to be interpreted with caution. It likely points to a lack of treatment effect. However, it could also be that the unfamiliar synthesised speech output resulted in suppressed scores at T1, confounding the main effect of time. In this study, the emphasis was on writing, with reading engaged for checking output. The results suggest that such incidental involvement of reading may be insufficient to affect competencies, even in the technology-assisted condition, and that reading needs to be the specific focus of treatment in order to demonstrate change. Given the gradual gain in GORT-4 scores it may be that the test is prone to practice effects. Further it is not an aphasia-specific measure; identifying a good test of textual reading comprehension in aphasia is challenging. Use of AT to compensate for reading impairments in aphasia nevertheless warrants further investigation: Caute et al. (2015) found four people with aphasia reported improved reading confidence and enjoyment following training in the use of e-readers, despite no change in their reading comprehension; Caute and Woolf (2016) findings suggested reading AT was useful but its impact was not specifically measured, while Adams (2006) was more equivocal, observing increases in reading rate but not in comprehension. Finally, in a recent 2019 study, Caute et al. randomly assigned 21 people with reading impairments following stroke to receive 14 h of therapy immediately or after a 6-week delay. During therapy, participants were trained to use assistive reading technology that offered a range of features to support reading comprehension, and were assessed pre- and post-therapy with the GORT-4 to compare technology-assisted and unassisted reading comprehension. The whole-group analysis showed significant gains in assisted (but not unassisted) reading after therapy that were maintained at follow-up. Participants' confidence and emotions associated with reading also improved.

In terms of potential broader benefits of AT training, a significant effect on network size was observed between T2 baseline and follow up. This may suggest that training helped participants enhance their social contacts, in keeping with the findings of Caute and Woolf (2016). Though administered pre-intervention (T2) this measure was not administered at T1, so a stable baseline was not established. However, participants were all at least 23 months post stroke, so were not subject to the rapid social changes that occur in the acute phase of recovery. As a result, their network was unlikely to change markedly over the 6 weeks prior to intervention. Emailing was a particularly popular activity, and some participants were able to make contact with friends with whom they had lost touch for the first time since stroke; this was pleasing since stroke and aphasia have a particularly detrimental impact on friendships (Northcott & Hilari, 2011). Changes to social networks in this study did not generally appear to be driven by one particular sub-group of a network expanding, however. This may reflect the length of time since onset, and the resultant adjustment to a chronic condition; nevertheless, it is a promising finding since social networks tend to be negatively affected by stroke, and particularly aphasia, even at the chronic stage of illness (Northcott & Hilari, 2011).

There was no significant group change in either wellbeing or QOL ratings after the AT training program, despite encouraging positive trends in both assessments over time. Qualitative findings (in preparation) indicated the quality of social contact was bolstered by writing treatment, and this had a positive psychological impact not only on the aphasic writers themselves but also on the recipients of their correspondence. However, this was a small group, with a wide degree of variability within the sample, which reduced the power of the analysis. It may be that with a larger sample these trends could have reached significant levels. Alternatively, an increased treatment dose, with a more intensive or longer program, could have made more difference to these scores.

Besides the email writing tasks described here, reflective writing was a commonly chosen activity, with many participants choosing to write about memories and past experiences, including their stroke. This may be of therapeutic benefit, in a similar way to the outlet for self-expression PWA and carers of PWA created for themselves through the use of blogs (Winkler et al., 2014). As in the Moss et al. (2004) study, while some participants edited signs of aphasia out of their work, others consciously elected to leave errors in, to demonstrate their everyday difficulties to correspondents and raise awareness of the reality of living with dysgraphia.

Little is known about precisely which treatments for people with stroke and aphasia produce measurable effects on wellbeing or QOL. The evidence in this area is emerging with two recent randomised trials demonstrating secondary gains for QOL for a naming treatment (Efstratiadou et al., 2019) and a functional communication treatment (Breitenstein et al., 2017). Compensating for writing impairments may both encourage functional written communication with others and allow people to forge connections which strengthen or expand their social networks. Since it is known that both communication impairments and social isolation are predictors of low mood and poor QOL, it was anticipated that changes in access to writing could affect these psychological factors. Though this was not the case in this study, it is acknowledged that this was a small exploratory study, and AT training to improve access to writing is still a promising intervention to investigate in a larger trial. Clinical judgement suggests that well-being and QOL may be promoted best by programmes of multicomponent treatment, targeting language, communication and participation goals. AT training for writing might form a useful component to such a programme. Finally, several participants reported continuing to use AT independently, including to write and respond to correspondence from the first author, suggesting it was valued by them.

Limitations of the study

The group of individuals who took part in this study were not typical of the wider stroke population, both in terms of age and education levels. The average age of first stroke in the United Kingdom is 68 for men and 73 for women (NICE, 2022), while the age range of this group was 44–75, with a SD age of 58.2. Furthermore, stroke is more likely to affect people with lower incomes. While income data were not collected from participants in this study, they were a highly educated group, and most had worked in managerial or professional roles. However, our review of traditional and technological writing therapy studies indicated that while the current group may have been unusual in relation to the wider stroke population, they were similar to the sub-group of PWA who have engaged in therapeutic research studies specifically for dysgraphia. In a small number of studies, individuals had writing therapy due to the severity of their aphasia (e.g., Beeson, 1999; Robson et al., 2001) or severity of dysarthria or dyspraxia (e.g., Lustig & Tomkins, 2002) which limited their ability to use other modalities. Besides these individuals in single case experimental designs though, recipients of writing therapy tended, like the participants in the current study, to be highly educated and keen writers pre-stroke and still of working age; some were still in employment (e.g., Bowes & Martin, 2007). These were people, like the majority of the AT group, for whom loss of functional writing had the potential to cause major and wide-ranging changes in their everyday lives and circumstances and it is likely that this user profile influenced the motivations, expectations and goals of the group. Adopting Parr's (1995) social model of literacy, it seems entirely reasonable and appropriate that this group would self-select as candidates for writing therapy.

Yet it is worth considering whether the AT compensatory model described here would generalise to a more typical client group. The candidate in the current study who most closely fitted this profile was Dean. Though young (44 years old), Dean was less highly educated than the rest of the group and writing had not been a daily activity for him. Nevertheless, in the AT programme, Dean was very capable of producing a wide range of written texts and mastered technological procedures with ease. He needed more support than some other members of the group in order to perform tasks such as creating a strong written argument but was quick to adopt these skills once they were modelled and reinforced, and was highly motivated. Therefore, while user profile may influence choice of writing activities and level of additional support required, there does not appear to be a compelling case that a more typical stroke patient could not benefit equally from the AT therapy. A further indicator of its wider potential might be that the recruitment target of 10 participants was reached by screening 16 individuals, suggesting that candidacy criteria were not unduly narrow and could have attracted a larger sample if required.

A further limitation of the study was that there is currently no standard measure of functional discourse writing, necessitating the use of a somewhat crude constrained writing task. As discussed, the scoring matrices for this task may also benefit from revision. Tasks of this nature have been used in other writing studies with positive findings (e.g., Caute & Woolf, 2016; Marshall et al., 2018). Finally, owing to its modest scope, outcome measures were administered and in most cases scored by the therapist rather than a blinded assessor, which introduces the risk of bias (though note that the social validity judgement ratings were scored by blinded judges).

We did not explicitly test whether access to AT alone, without the intervention and support, would be sufficient to improve functional writing. However, observation data (to be reported separately) indicated an array of operational and other challenges which we regard as insurmountable without careful training. Interview data (also to be reported separately) also indicated that participants themselves felt support was required. This is further supported by the failed attempt by one participant to use the AT prior to the study; this participant went on to produce substantial emails and complete many writing tasks during the intervention.

Lastly, this was an exploratory study and the sample size was small with no control group. A natural next step following this study would be to conduct a larger well-powered study including a control group, which could evaluate the outcomes of the training with more participants and also aim to further elucidate issues such as whether specific dysgraphia diagnoses affect candidacy.

CONCLUSION

This study demonstrated that PWA can learn to employ AT to assist with writing difficulties and that AT can have a positive impact on their production of written text. Gains were achieved after a modest and non-intensive intervention therapy dose, making the approach replicable in practice, though we acknowledge that therapists or their clients may choose to reduce the dose in order to focus on other modalities. The technology used was mainstream, and VRS is increasingly becoming a standard feature of everyday information technology devices. AT programs such as this may present speech and language therapists with a practical, pragmatic adjunct to writing or typing therapy, particularly for clients with chronic, intractable impairments for whom remediatory therapy may have a low chance of success. It was hypothesised that therapy might also enhance reading ability, given that participants had to proof read and edit their work. In fact, gains in reading were not established, partly because of an unstable baseline on the relevant measure. Further exploration into the role of reading in writing therapy, and possible impacts on reading measures would be merited.

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DATA AVAILABILITY STATEMENT

Data are available on request.

PATIENT CONSENT STATEMENT

All participants consented to anonymous data use and storage by the research team.

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

No reproduced material.

COMPETING INTERESTS STATEMENT

The authors have no competing interests to declare.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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