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Technology Enhanced Reading Therapy for People with Aphasia:

Findings from a Quasi-Randomised Waitlist Controlled Study

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Abstract

Purpose

This study investigated the effects of technology-enhanced reading therapy for people with reading impairments, using mainstream assistive reading technologies alongside reading strategies.

Method

The study used a quasi-randomised waitlist controlled design. 21 people with reading impairments following stroke were randomly assigned to receive 14 hours of therapy immediately or after a 6-week delay. During therapy, participants were trained to use assistive reading technology which offered a range of features to support reading comprehension. They developed skills in using the technology independently and in applying the technology to their personal reading goals. The primary outcome measure assessed reading comprehension, using Gray Oral Reading Test Fourth Edition (GORT-4). Secondary measures were: Reading Comprehension Battery for Aphasia Second Edition (RCBA-2); Reading Confidence and Emotions Questionnaire (RCEQ); Communication Activities of Daily Living Revised (CADL-2); Visual Analogue Mood Scales (VAMS); and the Assessment of Living with Aphasia (ALA). Matched texts were used with the GORT-4 to compare technology-assisted and unassisted reading comprehension. Mixed ANOVAs explored change between T1 and T2, when the immediate group had received therapy, but the delayed group had not, thus serving as untreated controls. Pre-therapy, post-therapy and follow-up scores on the measures were also examined for all participants.

Results

GORT-4 results indicated that the immediately treated group improved significantly in technology-assisted reading following therapy, but not in unassisted reading. However, the data were not normally distributed and secondary non-parametric analysis was not significant. The control group was unstable over the baseline, improving significantly in unassisted reading. The whole group analysis showed significant gains in assisted (but not unassisted) reading post therapy that were maintained at follow up. The RCEQ results improved significantly following therapy, with good maintenance of change. Results on all other secondary measures were not significant.

Conclusions

Technology-assisted reading comprehension improved following the intervention, with treatment compensating for, rather than remediating the reading impairment. Participants' confidence and

emotions associated with reading also improved. Gains were achieved after 14 therapy sessions, using assistive technologies that are widely available and relatively affordable, meaning that this approach could be implemented in clinical practice.

Introduction

Impaired reading is one of the many disabling consequences of stroke. As initially delineated by Dejerine (1892) this may be the sole language impairment or one of several aphasic symptoms. In either case, the consequences are profound, with reading for pleasure, work and functional purposes no longer available. Arguably, these consequences have increased with the growing importance of online written information (Dietz, Ball & Griffith, 2011). It is unsurprising, therefore, that at least some people with aphasia cite reading as an activity that contributes to quality of life (Cruice, Hill, Worrall, & Hickson, 2010) and list improved reading as one of the desired outcomes from aphasia therapy (Wallace et al, 2017).

Reading impairments following stroke have been extensively documented, with many individuals showing difficulties even at the single word level (see review in Purcell, Schubert & Hillis, 2015). Problems can reflect visual and attentional problems (e.g. Schuett, Heyward & Kendridge, 2008; Ellis, Flude & Young, 1987) or difficulties with word recognition (Paterson & Kay, 1982). Further difficulties can affect reading aloud and comprehending whole words (Patterson, Marshall & Coltheart, 1985) or applying grapheme phoneme conversion (Tree, 2008).

Disorders of reading at the text level have been relatively neglected in the research, despite the functional significance of this level of reading (Cherney, 2004; Webster et al, 2013). Difficulties with text are a likely consequence of single word reading impairments, but may also occur even if single word reading can be achieved (Coelho, 2005; Kim & Russo, 2010). Meteyard and colleagues (2015) outline the processing skills required for text level reading and show that these may variously break down in aphasia. Assessed skills included lexical comprehension, syntax, inferencing, and working memory. The ability to apply meta-cognitive strategies, e.g. enabling the reader to monitor their comprehension of the text and detect when this was failing, was also explored.

The emphasis on single word reading applies also to the treatment literature (Cherney 2004). In many studies, there was an attempt to restore a damaged reading mechanism, with gains assessed typically through single word tasks, such as oral reading (see Leff & Behrmann, 2008 for review). A recent systematic review (Purdy, Coppens, Brookshire Madden, Mozeiko, Patterson, Wallace & Freed, 2018) identified just 15 articles that attempted to remediate reading comprehension at the text level. Approaches included oral reading techniques, such as Modified Multiple Oral Reading (Kim & Russo, 2010) and Oral Reading for Language in Aphasia (ORLA, Cherney, 2010); cognitive treatments, e.g., attempting to remediate underlying attention deficits (Coelho, 2005); hierarchical reading of increasingly complex texts (Katz & Wertz, 1992; 1997) and strategic therapies (Cocks, Pritchard, Cornish, Johnson, & Cruice, 2013).

The level of evidence across the reading therapy literature is not strong. The preponderance of treatment studies (68/74) in the Aphasia Treatment Evidence Tables (Academy of Neurologic Communication Disorders and Sciences, 2018) were case studies or single subject designs. These tables cover studies published up to 2013. The Purdy et al re view (2018) identified only 5 group studies, and across all study designs quality ratings were variable. The most recent Cochrane review of aphasia therapy identified 9 randomised controlled trials that assessed reading and which provide moderate quality evidence that speech and language therapy (SLT) vs no SLT improves reading comprehension (Brady, Kelly, Godwin, Enderby, & Campbell, 2016). No conclusions could be drawn about the optimal intensity or duration of treatment, although intensity was only assessed in one trial, and duration in three. In addition, no preferred treatment technique emerged from the review, given that the trials used a range of treatment methods and outcome measures. A general treatment dilemma, flagged in relation to all studies covered by the review, was the need to show that therapy brings about change in language function. In the context of reading, this reflects a need to show change on everyday reading activities, such as reading for pleasure and for information. The criticism would certainly apply to the trials that assessed reading. Here measures were typically

Improved reading function, i.e. affecting everyday reading, might be promoted by treatments that adopt a strategic approach. Such treatments aim to compensate for, rather than remediate the impairment. This view is encouraged by evidence that even healthy readers employ strategic compensations when they undertake reading activities (Lynch, Damico, Abendroth & Nelson, 2013). For example, they read parts, rather than the whole of a text to extract the information that they need (sampling), and make predictions about upcoming text based on their real world knowledge. Collaboration when undertaking literary activities also features as a strategy. For example, JJ, investigated by Parr (1995), shared reading activities with his wife even before he had a stroke. Such strategies can acquire an increasing importance in aphasia. Lynch and colleagues (2013) studied the reading behaviours of three people with aphasia in naturalistic contexts. They uncovered 28 strategies employed by these individuals that promoted reading efficiency and comprehension and which enabled them to sustain social roles associated with reading. Many, although not all of these strategies also feature in healthy reading, such as sampling, prediction and collaboration. Knollman-Porter and colleagues (2015) investigated reading experiences and use of supports for six people with aphasia. They reported that a wide variety of strategies were used, relating to characteristics of the reading material (e.g. selecting shorter and less complex texts), self-directed strategies (e.g. scanning) and external aids, including text-to-speech technology.

Although few in number, there are accounts of strategic reading therapies in the literature. One approach attempted to improve attention and metacognitive skills. It was hypothesised that this would increase the cognitive resources assigned to reading, with benefits for comprehension. Across two studies, ten individuals received a six-week attention training programme (Lee & Sohlberg, 2013; Lee, Sohlberg, Harn, Horner & Cherney, 2018). Outcomes varied, but half of those involved showed improvements on an assessment of text reading comprehension.

Cocks et al (2013) provided 11 hours of reading therapy to IW, who had mild aphasia and executive dysfunction following a subarachnoid haemorrhage 24 months previously. Treated strategies included blocking texts into manageable chunks, verbal summarising at the end of paragraphs and chapters, highlighting salient points and mind mapping of plot developments (e.g. specifying who was involved and what happened). Therapy was assessed by the Gray Oral Reading Test, Fourth Edition (GORT-4, Wiederholt & Bryant, 2001), on which IW improved to ceiling on oral reading rate and accuracy and close to ceiling on comprehension. She also completed a novel questionnaire which probed reading confidence and emotions (Reading Confidence and Emotions Questionnaire, RCEQ, Cocks et al., 2013). This showed post treatment gains of 5-7 points in confidence and 6-8.5 points in emotions (both assessed on a 10-point scale). The latter scores reflected increased pleasure in reading, together with reduced anxiety and frustration. IW also reported functional gains in everyday reading activities. She had read four novels over the intervention period, compared to just one in the two years since her haemorrhage.

Webster et al (2013) employed a range of strategies in therapy with 3 individuals with stroke related reading impairments (a fourth was treated with ORLA). These strategies included: chunking text, summarising the meaning of what had been read, identifying key words and key messages, and using mind maps. Outcomes varied, but all individuals showed some improvement in reading comprehension and reported changes in everyday reading. For example, one resumed her use of the local library and another was now attempting to read magazine and newspaper stories.

Although the evidence base for strategy-based interventions is in its infancy, a recent survey of clinicians in Australia found these to be the most widely used reading comprehension treatment for adults with acquired brain injury in clinical practice (Watter, Copley, & Finch, 2016).

Technological applications offer further opportunities to compensate for reading impairments. Indeed, even in the 1990s such compensations were being employed by the individuals investigated by Parr. For example, EC made use of TV text services (Oracle and Ceefax) instead of a newspaper,

as the presentation tended to be simpler, and benefited from a tape library in order to access books (Parr, 1995). Advances in digital technology since the millennium have opened up numerous other resources, which are increasingly part of mainstream devices. For example, e-readers, such as Amazon's Kindle and Fire tablets, enable the user to manipulate text size and layout, in order to achieve a more 'aphasia friendly' presentation (Rose, Worrall & McKenna, 2003; Worrall et al, 2005). They also incorporate dictionaries and mechanisms for recapping a plot and tracing key characters. Many provide a text to speech facility, so bypassing the need to read independently. Similar options are provided by assistive computer software, such as Claro Software. For example, this offers text to speech conversion, dictionaries, scanning and highlighting facilities.

While a number of technological reading treatments have been employed (e.g. Ong, Brown, Robinson, Plant, Husain & Leff, 2012) only one study explored the compensatory possibilities of high-technology mainstream digital devices (see Russo et al, 2017). Caute et al (2016) examined whether four individuals with post stroke reading impairments could learn to use a Kindle Keyboard 3G (Amazon) and whether use of the Kindle improved reading comprehension, participation in reading and enjoyment. After four, one-hour training sessions three of the participants reported in interviews that they preferred reading on the Kindle to printed texts. They also indicated that they read more frequently than before the training and that they were attempting more challenging texts. These interview findings were corroborated by results on the RCEQ (Cocks et al, 2013), where confidence scores increased significantly for three participants. Reading comprehension, however, as assessed by GORT-4 (Wiederholt & Bryant, 2001) was unaffected by use of the Kindle; i.e. comprehension scores when reading on the Kindle did not improve post training and did not exceed the comprehension of printed text.

The study reported in this paper extends the findings of Caute et al in a number of ways. It involved a larger sample of 21 people with aphasia and employed a stronger, randomised controlled design. Intervention was also more extensive. Two technologies were employed in the treatment,

depending on the participants' preferences and reading goals. These were: Claro Software[TM] and

Amazon's Fire 7 Tablet[TM]. Fourteen sessions provided training in the chosen technology and

developed skills in its use, through structured reading practice. The programme aimed to develop

autonomous use of the technology by the participants, and the ability to apply that technology when

addressing their personal reading goals. It was hypothesised that the enhanced therapy programme

would achieve reading comprehension gains not observed by Caute et al (2016). Such gains were

anticipated to be compensatory. Thus, it was hypothesised that participants would be enabled to

use the assistive technology during reading and, thereby, improve their comprehension of what was

read. In line with this hypothesis, gains were predicted when the technology was available on the

assessment tasks. However, unassisted reading was also assessed to identify whether any

remediation of reading occurred. Self-reported gains in reading confidence and enjoyment were

hypothesised as a result of therapy. These were explored with the RCEQ (Cocks et al, 2013). Reports

from people with aphasia suggest that loss of reading is associated with reduced functional

communication, mood and quality of life (Cruice et al, 2010). We therefore explored changes in

these wider dimensions as a consequence of therapy. The study strengthens the evidence base by

employing a quasi-randomised controlled design, which compared outcomes between an immediate

and delayed treatment group. The study hypotheses were:

- Technology enhanced reading therapy will improve reading comprehension, particularly

  when reading is assisted by the trained technology. The comprehension improvement will

  be maintained over a 6 week follow up period.

- Technology enhanced reading therapy will bring about self-reported gains in reading

  confidence and enjoyment, which will be maintained over a 6 week follow up period.

- Technology enhanced reading therapy will improve functional communication, mood and

  quality of life, with maintenance over a 6 week follow up period.

Method

This study formed one strand of the CommuniCATE project, which offered four types of technology-enhanced therapy to people with aphasia. The other strands targeted writing (Marshall et al., 2018), spoken discourse and conversation over Skype. The CommuniCATE project received ethical approval from the Bromley (London) NRES Committee (14/LO/1531). All participants gave informed written consent, using materials designed to be accessible to people with aphasia (Rose, Worrall, Hickson, & Hoffmann, 2011).

Participants

Participants were recruited from a number of sources including the ethically-approved City University aphasia recruitment database, referrals from SLTs, patient/family enquiries via email, and from stroke association groups.

The recruitment criteria were: participants had aphasia following stroke; they were at least four-months post-onset and medically stable; they did not have severely impaired cognition and had no secondary cognitive diagnosis, such as dementia; reading and auditory comprehension were not severely impaired; they were fluent in English before their stroke (first or second language users); they were not receiving any other speech and language therapy during their involvement in the project. They also needed to identify reading as a priority for intervention and have functional reading goals.

Recruitment criteria were established via a case history interview and language and cognitive screening. Six subtests (7, 8, 12, 13, 17 & 19) of the Comprehensive Aphasia Test (Swinburn, Porter, & Howard, 2004) assessed single-word level auditory and reading comprehension, expressive

language and repetition and were used to establish the presence of aphasia. The Cognitive Linguistic

Quick Test (CLQT, Helm-Estabrooks, 2001) was used to screen for severe cognitive impairment.

Participants were excluded from the reading strand if they had very impaired reading and auditory

comprehension (<9/15 correct on both the CAT written and spoken word to picture matching tests)

and if their Composite Severity Rating on the CLQT was severe (range 1.4-1.0).

Design

The study used a quasi-randomised, waitlist controlled design. After recruitment, participants were

randomised to an Immediate or Delayed therapy group. All participants completed baseline

assessments (T1). Those in the Immediate group then received 6 weeks of technology-enhanced

reading therapy, while the Delayed group received no intervention. After 6 weeks, all participants

were assessed again (T2). The Delayed group then received 6 weeks of technology-enhanced reading

therapy, while the Immediate group received no further intervention. Assessment was repeated (T3)

after this period. The Delayed group received a follow up assessment 6 weeks after their therapy

ended (T4). Therefore, all participants carried out pre-therapy, post-therapy and follow up

assessments, with the delayed participants being assessed twice before therapy.

Participants received no other speech and language therapy while taking part in the project, but

they continued with other forms of usual care, such as attending stroke support groups. Although no

therapy took place during the follow-up period, participants kept the technology they had used

during therapy on loan until their final follow up assessment, so that they could continue to use it

independently.

Randomisation was pragmatically determined, in line with clinic treatment schedules. This ensured

that the active phases of participants' assessment and treatment were aligned with the university

term times when the clinic was fully staffed by therapists and student SLTs. Numbers

1,2,3,5,6,8,11,18,19,20,21 were randomized to the Immediate group. All others were randomized to the Delayed group. Randomisation was conducted by order of recruitment.

Therapy

Treatment was manualised (see Appendix 1). Participants received an initial 1-2 hours of technology set-up training (see below), immediately followed by 12 one-hour therapy sessions delivered over 6 weeks (2 sessions per week). Treatment was conducted face-to-face, 1:1. Over half the sessions were delivered by students of speech and language therapy, working under the supervision of qualified therapists (AC, KM, CW). Most participants were treated in a University clinic. Two were treated in their own home and one at a community centre. Treatment was supplemented by independent homework practice.

Assistive Technology

Two assistive technologies were used, with a view to supporting individuals with a range of aphasic profiles and reading goals. These were Claro Software™, which can be used on a computer or tablet, and Amazon's Fire 7 Tablet™. An earlier version of the Fire 7, the Kindle Keyboard 3G™ had been used successfully in a previous pilot treatment study for people with acquired reading impairments (Caute et al., 2016).

The two technologies had a number of key similarities; they enabled the user to adjust the formatting to change the size and spacing of the text, as well as the colour of the text and background. They both included a dictionary feature, which enabled the user to look words up and connect to web entries such as Wikipedia. In addition, text-to-speech enabled the reader to listen to the text while reading. This was useful for people whose auditory comprehension was less impaired than their reading comprehension.

There were a several differences between the technologies. Claro Software could highlight the text as it read aloud. This feature was also available for some, but not all applications on the Fire 7 Tablet. Although the Fire Tablet's standard in-built text-to-speech feature did not enable highlighting of text, it was available on some downloadable apps for reading webpages and with "Immersion Reading". This feature, which became available in 2015 during the first year of the project, enabled users to link books to a professionally-narrated companion audiobook, so they could see the text highlighted as it was read aloud by an actor. The Fire Tablet included additional features to support reading of books, such as "X-ray", which summarized key terms, characters and passages in a book.

Participants used either Claro Software or the Fire Tablet in their therapy. Selection was made in discussion with their therapist, and took account of language screening results, reading goals, previous technology experience and preferences, as well as observations of participants trialing different equipment (see Figure 1). Participants with less severe reading impairments and whose goals included reading books were generally encouraged to use the Fire Tablet, as this had additional features to support the reading of books (e.g. synching to audiobook, X-ray feature). The Fire Tablet also enabled users to search for and download books by linking directly to Amazon's online bookstore. However, if they had more severe reading impairments or were already familiar with using a computer or iPad and/or owned one, Claro Software was considered. Technology selection was also informed by a novel Dynamic Assessment of Computer Learning (Caute, et al, in preparation). For example, this illuminated whether participants found it easier to use a tablet with touchscreen access (e.g. iPad or Fire Tablet) or a desk/laptop computer. Participants who worked with a Fire Tablet also had to be prepared to set up and use an Amazon account. The researchers discussed this with participants during the goal setting process.

Insert Figure 1 here: Factors considered when selecting technology

Claro Software was provided on either a laptop (ClaroRead^{TM}) or an iPad (ClaroSpeak^{TM}), with the choice dependent on participant preference and ability to use the touchscreen or mouse and keyboard interfaces. Cognitive functioning was also considered, including the ability to carry out a sequence of steps, as the ClaroSpeak app required users to perform a number of steps in order to copy and paste text from webpages into the app. If necessary, hardware was loaned to participants for the duration of the study.

Goal setting

A 1:1 goal setting discussion took place before therapy began, in order to identify individual reading goals. A reading interview (see Appendix 2) was devised to probe participants' past and current reading habits as well as their hopes for the future. A Talking Mats (Murphy, 1998) format with pictorial prompts was used to help participants rate their ease or difficulty in understanding a wide variety of reading material, such as books, newspapers, magazines, signs, websites, menus, etc. (see example in Appendix 3). Broad reading goals for the block of therapy were agreed upon. These focused on comprehension, rather than reading aloud. Examples included reading a novel, reading the news, discussing a book with friends, and using text-to-speech to share a book with a grandchild. These goals influenced the choice of technology used (see above) and the therapy tasks. For example, participants who wished to use ClaroSpeak on an iPad to read news practised copying and pasting text from a website into the ClaroSpeak app, whereas a participant who wanted to be able to discuss a novel with his friends and family practised summarizing the key points of a book and explored different formats to support him in reviewing or recommending a book verbally.

Technology set-up training

Immediately before the main block of therapy began, participants received two hours of initial technology set-up training with the chosen technology. This included connecting their device to their home wifi network, setting up an email and Amazon account and downloading reading material

or apps (see Appendix 5). During these sessions, the therapist demonstrated the key assistive features and facilitated the participant to select their preferred settings for text size and spacing, colour of text and highlighting and speed of text-to-speech. Where possible these preferred settings were set up as the default settings. Participants began to learn how to operate the basic features of the technology, such as switching on/unlocking the device, accessing reading material and listening to the text with text-to-speech. Participants were provided with a bespoke technology manual for Claro Software™ or the Fire Tablet™. This contained step-by-step instructions explaining how to use the key features of the technology, illustrated with screenshots and pictures (see example in Appendix 4). The manual was kept up-to-date, relating to the most recent software. It was adapted for individual participants so only relevant features were included. If participants reported or were observed to have difficulties using their manual, further adaptations were considered, e.g. further simplification of text or removal of pictures.

Therapy Content

Participants then received a further 12 hours of therapy. Therapy sessions contained the following components: 1) troubleshooting any technology issues encountered since the previous session, 2) review of reading completed since the previous session, 3) active reading during the session with support for reading comprehension and technology use, 4) setting reading goals for the next session.

An example of troubleshooting during the session would be reviewing any changes to the layout of the device if there had been a software update. Reading reviews included a review of the reading diary and a discussion of content read. Participants were asked to share a summary of information read to demonstrate their understanding and to engage in functional and enjoyable conversation about read material. Active reading during the session focused on ongoing training and confidence building in using the chosen technology. For example, encouraging someone who had mastered navigating the pages of the Fire Tablet to become more independent in searching for books to download via the online library. The active reading and review during the session was supported by

asking clarification questions and where necessary, mapping the read content on a mind-map to support understanding. Therapists would also increase understanding and retention of read material by adding notes to the Fire Tablet or demonstrating use of highlighting or the dictionary function. A common goal set during sessions would be completion of a chapter started during the session or reading additional news stories if this had been the focus.

All sessions contained these core elements, but the focus on sessions differed across the block of therapy, reflecting the participant's developing proficiency. Early sessions (1-3) focused on continuing to develop participants' proficiency and independence in operating the technology. Participants were supported to try the different assistive features and explore which they could operate independently. These sessions explored how much the different features helped them (e.g. whether they benefited from having lines spaced further apart), their capacity for learning to use the technology independently and how much support they would need (e.g. whether they could practice at home using the technology manual and whether they are motivated to do so). If necessary, goals were negotiated and modified in the light of these factors during the early sessions.

Sessions 4-10 formed the main intervention period. In addition to ongoing support to use the facilitative features of the technology, strategies were explored to support each individual in achieving their reading comprehension goals. Therapy did not target reading aloud, unless doing so facilitated a participant's comprehension. Examples included writing or highlighting key-words in a news article, looking up unfamiliar words in the dictionary or Wikipedia, summarizing passages/chapters and answering comprehension questions of varying levels of difficulty. See Appendix 5 showing details of participants' technology use, reading material and strategies.

Participants were encouraged to read at home between sessions. They were asked to read for at least 20 minutes per day, continuing the material they had practiced in therapy, e.g. completing a chapter started in therapy, or reading two more chapters of a novel. Each week, they were given a reading diary to take home in which to record what they had read, how often and for how long. The

diary was reviewed at the beginning of the following session and participants were asked to rate their enjoyment and satisfaction with their reading at home during the week.

Some participants had goals with participation elements, such as discussing a book with family members or using text-to-speech to share a book with a grandchild. Further technology training was provided to support these goals as necessary. For example, one participant learnt how to use the Fire tablet to share book recommendations with his family and friends through Facebook. Student SLTs received regular supervision, which included ongoing review of each participant's goals and discussion about the introduction of new materials and/or targets.

The final sessions (11-12) largely focused on facilitating the participant to maintain new skills after the therapy ended. Examples included learning how to purchase new books on the Fire Tablet, supporting an individual to join their local library in order to access free e-books, handover sessions with a family member or carer and ensuring that participants were able to use the technology manual to support their independence. Participants kept their device during the follow-up period and were encouraged to continue reading the materials practised during therapy, however, their use of the technology during the follow-up period was not formally monitored.

Treatment Fidelity

Intervention was guided by a treatment manual. This described the assessment and goal setting procedures and the structure and content of therapy. Case studies were used to illustrate how therapy could be adapted in response to individuals' treatment goals (see examples in Appendix 1). A fidelity checklist (see Appendix 6) of nine core treatment components was constructed from this manual, and from discussion with the lead therapist (AC). All treatment sessions were filmed and 24 session videos were selected for rating against the fidelity checklist. Half the sessions were from the initial stages of therapy and half from the later stages. Twelve were led by a student, 6 by a qualified therapist and 6 by both a therapist and a student. The selection was made blind to the video content

by a researcher who was not part of the treating team (KB). This researcher also carried out the fidelity rating. Each component was assessed as being present (score of 1), partially present (score of .5) or absent (score 0). Six videos were independently evaluated by a second rater to check reliability.

Outcome Measures

Three reading-specific measures investigated reading comprehension as well as confidence and emotions associated with reading. The primary outcome measure enabled comparison of technology-assisted and unassisted paragraph-level reading comprehension. Three further measures explored generalization to functional communication, mood and quality of life. All assessments were administered at each time point. Most post-therapy and follow-up assessments were administered by the treating therapist or student SLT.

Primary Outcome Measure: Gray Oral Reading Tests Fourth Edition (GORT-4, Bryant & Wiederholt, 2001).

GORT-4 is a text-level assessment of reading comprehension requiring participants to read a series of passages of increasing length and complexity. There are five multiple-choice comprehension questions per passage that assess literal, inferential, critical, and affective comprehension. Although it was designed for an educational context and has not been normed on adults over the age of 18, GORT tests have been used in previous aphasia studies (Caute et al, 2016; Cocks et al, 2013). In line with adaptations made to the administration of the GORT in Caute et al's study, participants were not required to read passages aloud. This meant that scores were obtained for reading comprehension, but not for fluency or accuracy.

GORT-4 includes two sets of 14 passages (Forms A and B), matched for difficulty. Both forms were administered at each time-point, with Form A presented on the relevant assistive technology, and Form B as printed texts. This enabled reading comprehension (number of questions answered

correctly) to be compared for the two presentation formats, both before and after therapy. For Claro Software, the GORT passages were presented in Word. For the Fire Tablet, a website was used to convert a PDF document into AZW3 format for Kindle devices (https://pdf2kindle.com). Comprehension questions for both forms were presented on paper and read aloud by the therapist. Participants were not allowed to look at the passages when answering the comprehension questions, thus relying on their memory of the text.

When administering Form A on the technological device before therapy, each text was presented with the font size and line spacing adjusted to look as similar as possible to the paper version. At post-therapy assessment, participants using tablets could benefit from pre-set presentation options on their devices, for example affecting font size and line spacing. Those using ClaroRead on a computer had the option to adjust settings at the time of the assessment (as settings were not automatically stored in the software). All participants were reminded that they could use the text-to-speech feature if they wished.

Order of administration (between Form A and Form B) was alternated between assessment time points. Participants scored a maximum of 5 points for each passage (i.e. 1 point per question answered correctly), with higher scores indicating better comprehension. The test was discontinued if the participant scored 2 or lower on one of the passages.

Secondary Outcome Measures

The Reading Comprehension Battery for Aphasia Second Edition (RCBA-2, LaPointe & Horner, 1998) assessed reading from printed texts at single-word, sentence and paragraph level. At T1 the full assessment (subtests 1 to 10, but excluding supplementary subtests) was administered for diagnostic purposes. At the remaining time points only the paragraph level subtests were administered (subtests 7-9) in order to reduce assessment burden. These paragraph level subtests,

from all time points, were analysed to explore the effects of therapy. This assessment was administered on paper, so no technological support was available.

The Reading Confidence and Emotions Questionnaire (RCEQ; Cocks et al., 2013) assessed confidence and emotions associated with reading using a 10-point self-rating scale. Participants rated their confidence in carrying out different reading-related tasks, confidence in remembering and understanding what they have read, and enjoyment and emotions associated with reading (frustration, anger, upset, and anxiety). Questions were read aloud by the therapist and clarified where necessary. Nineteen items were analysed, 12 relating to confidence and 7 relating to emotions (3 items relating to premorbid reading were omitted from the analysis). Scores on negatively framed items were reversed, so that total scores reflected most desirable confidence and emotional state.

Functional communication was assessed with the Communication Activities of Daily Living Revised (CADL-2; Holland et al, 1999). This standardised assessment of 50 items explored language use in everyday situations, such as going shopping. Ten items explicitly required participants to read text, including reading signs and a menu. In a further eight items written information was present, and supportive of the task. The assessment yields a total score of 100, with each item rated 0, 1, or 2 points.

Mood was assessed with the Visual Analog Mood Scales Revised Version (VAMS-R: Kontou et al, 2012). This measure, which was designed for people with aphasia, collects ratings on 8 mood states (afraid, confused, sad, angry, tired, tense, happy and energetic) using pictorial visual analogue scales. The score for each mood ranges from 0-100, with 100 being the maximal level of that mood and 0 being the minimal level. In line with previous studies (Thomas et al, 2013), only data from the 'sad' question was analysed.

The Assessment of Living with Aphasia (ALA, Simmons-Mackie et al, 2014) assessed aphasia-related quality of life. This self-report measure evaluated the impact of aphasia on five domains: language, participation, environment, personal and moving on with life. It produced an overall score which was analysed in this study.

Analyses

For the primary outcome measure, two sets of analyses were performed. The first used a three-factor mixed ANOVA, with time (T1 and T2) and test format (Form A and Form B) as within group factors and group (immediate and delayed) as the between group factor. A significant treatment effect would be indicated by a time x group interaction, showing that the immediate group (who had received therapy) improved, while the delayed group (who had not yet received therapy) did not. A three-way interaction (time x group x test format) would indicate an effect of therapy, but dependent on the test format.

The second analysis was carried out on combined data from all participants. These data were analysed using a within factor ANOVA. The two factors were time (pre-therapy, post-therapy and follow up) and format (Form A and Form B). Here a main effect of time would indicate a treatment effect, with pairwise comparisons showing a significant difference between pre- and post-therapy. A significant difference between pre-therapy and follow up would indicate maintenance of gains. A time by format interaction would signal that gains were more evident in Form A or B.

Secondary outcome measures were also subjected to two analyses. Firstly, a mixed ANOVA examined change over time between T1 and T2 and compared the Immediate and Delayed groups. Here a time x group interaction would signal a treatment effect. Secondly, a one factor ANOVA explored change over time, at pre-therapy, post-therapy and follow up, across combined data from all participants. Pairwise comparisons explored the locus of change if a main effect was present.

For all analyses, data were checked for normality. If data were not normally distributed, secondary non-parametric analyses were conducted.

Results

Recruitment and progression

The flow diagram (Figure 2) shows the number of people who were assessed for eligibility, recruited and completed each stage of the project. Although all participants progressed to their final data point there were missing data, for example due to illness.

Insert Figure 2 here: Study Flow Diagram

Treatment Fidelity

Treatment fidelity scores were high. Each treatment video was assessed against 9 criteria, with an overall mean score of 8.83 (S.D: 0.24). Fidelity scores did not vary as treatment progressed (early sessions mean score = 8.75 (.26); late sessions mean score = 8.92 (.19)). Fidelity was also high regardless of whether treatment was administered by a qualified therapist, student or both (therapist mean score = 8.75 (.27); student mean score = 8.92 (.19); both mean score = 8.75 (.27)). The interrater reliability of fidelity coding was high, with 94% agreement between raters.

Participant Sample

Insert Table 1 about here

Details of the sample are reported in Table 1. The Immediate and Delayed groups did not differ with respect to age (t = -.156, p=.877), years in education (t=.292, p=.773), time post stroke (t=1.334, p=.198), CAT screening scores (t = 1.16, p = .261) and CLQT scores (z=.22, p = .82). Reading comprehension as assessed by the full RCBA-2 also did not differ (t = .29, p = .77).

Treatment Outcomes: Primary Outcome Measure

In our first hypothesis, we predicted that therapy would improve reading comprehension, particularly when participants could employ the trained technology. We also predicted that this improvement would be maintained over the 6 weeks follow up period.

Insert Table 2 about here

Table 2 depicts scores for the Immediate and Delayed groups on the GORT-4 over the four time points. Form A was administered on a computer or tablet, with the relevant treatment technology enabled. Form B was administered on paper. Thus, performance on Form A reflected technology assisted reading, while performance on Form B reflected unassisted reading.

The first analysis examined scores over the first two time points, between which the Immediate group received therapy, but the Delayed group did not. This used a three factor mixed ANOVA. The within factors were time (T1 and T2) and test format (Form A and Form B). The between factor was group (Immediate and Delayed). According to our hypothesis, we predicted a significant three way interaction. This should show that the Immediate group improved, while the Delayed group did not, with the gain for the Immediate group occurring largely when reading was assisted by technology.

The analysis produced a significant main effect of time (F (1, 19) = 19.677, p < .001; η2 = .509), showing that scores in both formats and across both groups improved between T1 and T2. There

was no significant effect of format (p = .206, η^2 = .083) or group (p = .977, η^2 < .001). Only one

interaction was significant: time x format x group (F (1, 19) = 6.518, p = .019, η2 = .255). The

descriptive statistics are crucial for interpreting this result. In line with our hypothesis, the

Immediate group improved between T1 and T2, and significantly on technology assisted reading (t =

-2.47, df 10, p <.05). However, the Delayed group was not stable. Rather they demonstrated a

significant gain in unassisted reading (t = -2.62, df 9, p <.05).

The T1 and T2 GORT-4 data were not normally distributed (Shapiro Wilk Test p <.05). Gains for each

group were therefore re-examined using non parametric, Wilcoxon Signed Ranks Tests. The

Immediate group results were just short of significant for Form A (Z = -1.92, p = .055); and

insignificant for Form B (Z = -0.77, p = .44). The Delayed group results were insignificant for Form A

(Z = -1.25; p = .21) and significant for Form B (Z = -2.14, p = .033).

Table 3 depicts scores for all study participants on the GORT-4 pre therapy, post therapy and at

follow up. Here, and in subsequent tables, pre therapy scores comprise T1 scores for the Immediate

group and T2 scores for Delayed. Post therapy scores comprise T2 for Immediate and T3 for Delayed;

and follow up scores comprise T3 for Immediate and T4 for Delayed. These data were analysed

using a two within factor ANOVA, with the factors of time (pre, post and follow up) and format

(Form A and Form B). According to our hypothesis, we predicted a main effect of time and a time by

format interaction.

Insert Table 3 about here

The analysis produced a significant main effect of time (F (2, 34) = 6.77, p = .003, η2 = .285).

Although combined scores improved over each time point, only one pairwise comparison was

significant, between pre therapy and follow up (p = .001). Test format was also significant (F (1, 17) =

12.24, p = .003, η2 = .419), with Form A outstripping Form B. There was also a significant interaction

(F (2, 34) = 8.639, p = .001, η2 = .337). From the descriptive statistics it is evident that technology

assisted reading (Form A) improved over time, while unassisted reading did not. Indeed the gain on

Form A was significant between pre therapy and post therapy (t = 3.45, p = .003); and between pre

therapy and follow up (t = 4.7, p <.001). The change between post therapy and follow up was not

significant (p = .09)

The pre therapy, post therapy and follow up GORT-4 data were not normally distributed (Shapiro

Wilk Test, p <.05). Secondary Friedman's Tests were therefore conducted on the Form A and Form B

data. Results for Form A were significant (Chi Square = 13.154, p = .001). Post hoc comparisons using

the Wilcoxon Test showed that scores increased significantly between pre and post therapy (Z = -

2.23, p = .006) and between pre therapy and follow up (Z = -3.42, p = .001). The comparison between

post therapy and follow up was not significant (p = .079). The Friedman's Test on the Form B data

was not significant (p = .985).

Treatment Outcomes: Secondary Outcome Measures

Unassisted reading comprehension was further assessed with the paragraph level sub-tests from the

RCBA-2. Scores at each time point, for the immediate and delayed group, are reported in Table 4.

Pre therapy, post therapy and follow up scores for both groups combined are reported in Table 5. A

two factor mixed ANOVA examined scores at T1 and T2, with group (Immediate and Delayed) as the

between factor. This analysis produced no significant main effects and no interaction (time x group

interaction p = .693, $\eta 2$ = .008). A one factor ANOVA examined change over time (pre therapy, post

therapy and follow up) for the whole group. The main effect was not significant (p =.12, $\eta 2$ = .11).

Thus there was no evidence of change on this measure.

Insert Table 4 about here

Insert Table 5 about here

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In our second hypothesis, we predicted that therapy would bring about durable self-reported gains in reading confidence and emotions, as assessed by the RCEQ.

Scores on the RCEQ, from T1 to T4, are reported in Table 6. The first analysis used a two factor mixed ANOVA to examine changes between T1 and T2 on total scores, with group (Immediate and Delayed) as the within factor. Our hypothesis predicted a time x group interaction, showing improvement in the immediate but not in the delayed group.

Insert Table 6 about here

The analysis produced a main effect of time (F (1, 18) = 11.023, p = .004, η2 = .38). This arose because combined scores over both groups improved. There was also a main effect of group (F (1, 18) = 4.87, p = .04, η2 = .213), with the Immediate group scoring more highly than the Delayed group. Crucially for our hypothesis there was a significant interaction (F (1, 18) = 12.17, p = .003, η2 = .403), arising because the Immediate group improved, but the Delayed group did not.

The second analysis of the RCEQ examined change over time for all participants between pre therapy, post therapy and follow up (see Table 7). This analysis produced a significant main effect of time (F (2, 38) = 28.884, p <.001, η2 = .63). Planned comparisons were significant for pre therapy vs post therapy (p <.001) and for pre therapy vs follow up (p<.001) but not for post therapy vs follow up. Thus in line with our hypothesis, scores improved after therapy, and were maintained at follow up. Although our analyses of the RCEQ data were conducted on total scores, the descriptive data (Tables 6 and 7) show that participants reported improvements in both reading confidence and enjoyment.

The last analyses examined whether therapy induced change in functional communication, as assessed by the CADL-2; mood, as assessed by the Sad question on the VAMS - R; and quality of life, as assessed by the ALA. Scores for each test over the four time points are reported in Table 8. Pre, post and follow up scores, across all participants, are reported in Table 9.

Data from each test were entered into two factor mixed ANOVAS, with the factors of time (T1 and T2) and group (immediate and delayed). Here a treatment effect would be signalled by a time by group interaction, showing greater improvement in the Immediate group compared to the Delayed group. None of the analyses produced this interaction (CADL-2: $p = .477$, $\eta2 = .027$; VAMS Sad $p = .753$, $\eta2 = .005$; ALA $p = .183$, $\eta2 = .092$).

Change over time on pre therapy, post therapy and follow up scores were analysed with one factor ANOVAs. If there was a main effect, planned comparisons were conducted to explore the source of that effect. Only the ALA analysis produced a significant main effect of time ($F (1.54, 27.66) = 4.0$, $p = .039$, $\eta2 = .182$). Planned comparisons were only significant for pre therapy compared with post therapy ($p = .03$).

Discussion

This study evaluated a novel therapy for people with aphasic reading impairments. Treatment employed digital technology with the aim of compensating for the impairment, and so improving

reading comprehension, confidence and enjoyment. Wider gains in functional communication, mood and quality of life were also hypothesised. Treatment was specified in a manual, and adherence to the core components of that manual was good, as assessed by fidelity checking. The fidelity results also showed that delegation of sessions to student practitioners induced no drift from the treatment protocol. All participants completed the therapy as prescribed in the manual. This discussion will review the outcomes of therapy against the initial hypotheses. It will appraise the study limitations and make proposals for further research.

The first hypothesis stated that technology enhanced reading therapy would improve reading comprehension, particularly when reading was assisted by the trained technology, and that benefits would be maintained over a 6 week follow up period. This hypothesis was largely upheld. Results on the primary outcome measure (GORT-4) showed that reading comprehension improved post therapy in the technology assisted format and that gains were maintained. This pattern was clearly demonstrated in the combined data across all participants. Here, both parametric and non-parametric analyses showed significant gains after therapy that were maintained at follow up. In terms of the degree of change, participants gained an average of 10 comprehension points, which equates to 2 additional passages read and understood. In contrast, results in the first analysis, comparing the Immediate and Delayed group across T1 and T2, were more difficult to interpret. The ANOVA showed a time x group x format interaction, indicating that the Immediately treated group improved in technology assisted reading, while the Delayed group did not. However, as data were not normally distributed, a non-parametric analysis was also employed, and this fell just short of significance. ANOVA is typically not recommended when N is small and data are not normally distributed. However, studies have shown that the risk of type 1 error is low (Lix, Keselman & Keselman, 1996), even with small samples and substantial deviations from normality (Blanca et al, 2017). Given these findings, and the overall trend in the GORT-4 data, an effect of therapy on assisted reading comprehension can be argued.

Unassisted reading was unchanged by therapy. This was clearly demonstrated by the results from the RCBA-2, where scores were stable over time for all participants. Scores on the unassisted format of GORT-4 were less stable. This was particularly the case for the Delayed group, whose scores improved significantly between T1 and T2. Accounting for this change is difficult. The T1 result was unusually low for reasons that are unclear. However, the improvement was clearly unrelated to therapy, since it occurred over the untreated baseline period. It could be due to a practice effect, but this seems unlikely given that the following score (at T3) declined. Wiederholt & Bryant (2012) reported concerns about the GORT-4's multiple choice format and produced an updated version (GORT-5) requiring open rather than multiple choice responses. However, despite these concerns the authors of the current study decided that GORT-4's multiple choice format was more suitable for people with aphasia, as inaccurate responses to open questions could be due to expressive language difficulties as well as impaired reading comprehension. Critically, neither the immediate nor the delayed group demonstrated change on the unassisted version of the GORT-4 following therapy. Rather the combined scores on Form B across all participants showed a small decline from pre to post therapy and from pre therapy to follow up.

As hypothesised, findings from the assessments of reading comprehension indicate that the benefits from therapy were compensatory. Participants were able to use their trained technologies and reading strategies to access written information despite their reading impairments. These impairments were unaffected by the therapy, and became evident when unassisted reading was attempted. Results mirror those obtained from technologically enhanced writing therapies, which have similarly produced compensatory outcomes (Marshall et al, 2018; Thiel et al, 2017). However, they contrast with the results of several studies which have delivered therapy focussing on reading strategies without technology. For example, Cocks et al (2013) and Webster et al (2013) reported improvements in paragraph-level reading comprehension following a block of therapy, as assessed

by the GORT-4 and Discourse Comprehension Test (Brookshire & Nicholas, 1993) respectively. This may reflect a difference in the amount of time spent working on reading strategies, with a large part of therapy time in this study dedicated to technology training. The maintenance of gain indicated that technological and strategic competences were sustained after therapy was withdrawn, albeit over a brief follow up period. This may reflect the fact that the technology was still available to participants after therapy ceased.

Our second hypothesis predicted that therapy would bring about self-reported gains in reading confidence and emotions, as assessed by the RCEQ, and that these gains would still be evident at 6 weeks follow up. This hypothesis was also upheld. The first analysis showed a clear effect of therapy on this measure, as the Immediately treated group improved, whereas the as yet untreated Delayed group did not. The Delayed group also improved once therapy was instigated; and the combined data showed that treatment effects were maintained at 6 weeks follow up.

The importance of using patient reported outcome measures (PROMs) in therapy evaluations has been stressed (Wallace, Worrall, Rose & Le Dorze, 2016). These aim to show that treatment effects are not just evident on decontextualized clinical tests, but are also felt by the recipients of therapy. It is encouraging that participants in this study reported greater confidence and fewer negative emotions in relation to their reading activities following intervention. The combined descriptive data showed that total mean confidence ratings changed from 51.20 pre-therapy to 75.25 post-therapy. As there were 12 items relating to confidence, this equates to an average score per item of 4.27 before therapy rising to 6.27. Total mean emotion ratings changed from 33.80 pre-therapy to 50.42 post-therapy. Across the seven items relating to emotions, this equates to an average score per item of 4.83, rising to 7.20 post-therapy. Thus, in both domains, participants moved from the lower portions of the scale (< 5) to the upper portions (e.g. between 'somewhat confident' and 'completely confident'), gains similar in magnitude to those reported by Cocks et al (2013) for confidence (5/10-

7/10) and emotions (6/10- 8.5/10). These findings, therefore, help to establish the clinical as well as statistical significance of the treatment gains.

As anticipated, the enhanced therapy programme in the current study led to gains in technology-assisted reading comprehension not observed by Caute et al (2016). Whereas Caute et al reported that reading comprehension was unaffected by using the Kindle, the current study found that compensatory gains occurred, with technology-assisted reading out-stripping unassisted reading at all post-therapy assessment points (see Table 2 and 3). Furthermore, the current study found significant improvements in both confidence and emotions associated with reading, whereas Caute et al reported gains in confidence only. The more positive findings in the current study could be due to the larger dose of therapy (14 vs 4 sessions), the more intensive delivery (twice vs once a week), the broader remit of the intervention which included technology training and application to personalised reading goals, or a combination of these factors.

As in Caute et al's study, the positive findings were supported by anecdotal reports of participants increasing their level of reading activity. Appendix 5 details the wide range of reading materials read by participants, many of whom were very limited in their reading activity before the project. For example, participant #4 did not read at all before starting the project, other than attempting to read TV subtitles. During the intervention period, she read news on the BBC app, two short books ("QuickReads") and three full-length autobiographies. She bought a Fire 7 of her own to enable her to continue reading after the end of the project.

The third study hypothesis stated that technology enhanced reading therapy would improve functional communication, mood and quality of life, with maintenance over a 6 week follow up period. This hypothesis was not upheld. Almost all analyses of data from CADL-2, VAMS-R (Sad) and ALA were insignificant. When data across all participants were analysed, there was a main effect of

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time on the ALA, with a significant pre to post therapy improvement. However, it is difficult to claim a treatment effect from this one finding.

It was hoped that improved access to written text might have wide reaching benefits for our participants. For example, this might open up enjoyable reading activities and give access to a wealth of on- and off line information. The lack of change on our broader measures was therefore disappointing. The sensitivity of the measures to any therapy induced change might be a factor. For example, most of the items in CADL-2 do not involve reading, and the originators of the VAMS acknowledge that test – retest reliability can be affected by fluctuating mood states in those tested (Stern, 1996). The fact that therapy was low dose and focussed on just one modality of language may also have been crucial. Previous aphasia interventions have improved measures of functional communication and quality of life, an example being the Aphasia LIFT programme (Rodriguez et al, 2013). However, this involved far more treatment hours (a mean 75.3) than were provided in our study, and more multi-dimensional, intensive and comprehensive intervention.

A number of limitations in this study should be acknowledged. CommuniCATE was a service and student education project, making it difficult to attain some rigorous research standards. Therefore, testing was not blind to time point or group allocation, and follow up was limited to 6 weeks. While there was no attrition, some data are missing, mainly at follow up. Reasons were illness, loss of compliance because of assessment burden, and tester error. The improvement shown by the control group during a period of no treatment, raises the possibility that there was a learning effect on the primary outcome measure. Regarding a secondary outcome measure, the RCEQ, it is important to acknowledge that subjective rating scales are open to response bias, and that higher scores reported post-therapy can be influenced by participants' desire to be better following treatment, to please the researcher, or to appear more favourable to the researcher. Indeed, in this study most of the pre and post testing was undertaken by the treating qualified or student SLT, so bias is quite possible.

Conversely though, there was no change in RCEQ for the Delayed group during the control period, suggesting that bias due to pleasing the researcher or wanting to appear favourable was unlikely. Overall, PROMs are crucial in rehabilitation research (Wallace et al. 2016) and should include evaluating the impact of the treatment from the person's perspective, so further attention needs to be devoted to the PROM. Bias in such scales can be mitigated in future research by refining the tool by including positively and negatively worded questions of the same construct and considering other completion options (e.g. self-administration).

The sample is younger than the typical stroke population (Engelter et al, 2006), with a mean age of 56 years. This skew may have been induced by the need to travel to the University clinic and, possibly, the technological focus of the project. It may have meant that the participants had fewer comorbidities and more experience in using technology in comparison to the general stroke population. They may have been more mobile and therefore had greater access to different activities and opportunities to participate.

The study results are not informative about the active component of therapy, and whether these differed across individuals. For example, for some participants, provision of and basic training in the technology may have been sufficient, while others may have needed more therapeutic input to use the technology productively. Further background testing, particularly exploring the nature of participants' dyslexia, might also have been informative about patterns of impairment that are most supported by this approach.

Future research could explore candidacy by examining the relationship between participant profiles and treatment gain. Testing different variants of the therapy might also investigate the active components, for example by comparing technology training only with technology training plus reading strategies. Future research could explore whether this compensatory approach can be

combined with impairment level therapies. A larger study could also compare different types of assistive technology. Stronger, level III evidence would be provided by a large scale Randomised Controlled Trial, including an economic evaluation. A longer follow up period could explore whether people with aphasia are able to use the technology in the longer-term and the factors that support or hinder them in doing so.

Future studies could explore the use of different reading assessments as the primary outcome measure. One of the key reasons for selecting the GORT-4 for the current study was its inclusion of two sets of matched texts, which enabled comparison of technology-assisted and unassisted reading. As the results of the current study indicate that benefits of therapy were compensatory, with no improvements evident in unassisted reading, future studies could use an assessment with a single form as the primary outcome measure. For example, the RCBA-2 or the silent reading version of the Discourse Comprehension Test (DCT, Brookshire & Nicholas, 1993) could be used to investigate technology-assisted reading. A potential advantage of the RCBA-2 is that participants can back refer to the text while responding to questions, and therefore do not need to rely on their memory of the text. In contrast to the GORT-4's multiple choice items, the DCT requires yes/no responses to questions. This may mean that there is less potential for errors caused by difficulty understanding response options.

Conclusion

This study explored a novel text-level reading intervention, using assistive technologies that are widely available and readily affordable. The intervention improved participants' reading comprehension when using the technology, indicating that treatment compensated for, rather than remediated the impairment. Participants' confidence and emotions associated with reading also improved, although there were no indications of wider changes in functional communication, mood or quality of life. Despite the tailored approached to therapy, with different assistive technology

options and personalised goals, treatment fidelity was strong. Given the availability and affordability of the technologies and that gains were achieved after low dose, low intensity intervention, this is an approach which could be implemented in clinical practice.

References

Academy of Neurologic Communication Disorders and Sciences, Aphasia Treatment Evidence Tables

https://aphasiatx.arizona.edu/written-language-reading

Behrmann, N., & Byng, S. (1992). A Cognitive Approach to the Neurorehabilitation of Acquired Language. *Cognitive neuropsychology in clinical practice*, 327.

Blanca, M., Alarcón, R., Arnau, J., Bono, R. & Bendayan R. (2017) Non-normal data: Is ANOVA still a valid option? *Psicothema, 29*(4), 552-557. doi: 10.7334/psicothema2016.383.

Brady, M. C., Kelly, H., Godwin, J., Enderby, P., & Campbell, P. (2016). Speech and language therapy for aphasia following stroke. *The Cochrane Library*.

Brookshire, R.H. & Nicholas, L.E. (1993). *Discourse Comprehension Test.* Tuscon, AZ: Communication Skill Builders.

Caute, A., Cruice, M., Friede, A., Galliers, J., Dickinson, T., Green, R., & Woolf, C. (2016). Rekindling the love of books–a pilot project exploring whether e-readers help people to read again after a stroke. *Aphasiology*, *30*(2-3), 290-319.

Caute, A., Galliers, J., Marshall, J., Monnelly, K., Woolf, C. (in preparation). The development of a novel Dynamic Assessment of Computer Learning.

Cherney, L. R. (2004). Aphasia, Alexia, and Oral Reading. *Topics in Stroke Rehabilitation, 11*(1), 22-36.

Cherney, L. R. (2010). Oral reading for language in aphasia (ORLA): Evaluating the efficacy of computer-delivered therapy in chronic nonfluent aphasia. *Topics in Stroke Rehabilitation*, *17*(6), 423-431.

Cocks, N., Pritchard, M., Cornish, H., Johnson, N., & Cruice, M. (2013). A "novel" reading therapy programme for reading difficulties after a subarachnoid haemorrhage. *Aphasiology, 27*(5), 509-531.

Coelho, C. (2005). Direct attention as a treatment for reading impairment in mild aphasia. *Aphasiology, 19*(3), 275-283.

Cruice, M., Hill, R., Worrall, L., & Hickson, L. (2010). Conceptualising quality of life for older people with aphasia. *Aphasiology*, *24*(3), 327-347.

Déjerine, J. (1892). Contribution à l'étude anatomopathologique et clinique des différents variétés de cécité verbale. *Mémoires de la Société de Biologie*, *4*, 61-90.

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

Ellis, A. W., Flude, B. M., & Young, A. W. (1987). "Neglect dyslexia" and the early visual processing of letters in words and nonwords. *Cognitive Neuropsychology*, *4*(4), 439-464.

Engelter, S. T., Gostynski, M., Papa, S., Frei, M., Born, C., Ajdacic-Gross, V., ... & Lyrer, P. A. (2006). Epidemiology of aphasia attributable to first ischemic stroke: incidence, severity, fluency, etiology, and thrombolysis. *Stroke*, *37*(6), 1379-1384.

Estabrooks, N. H. (2001). *Cognitive Linguistic Quick Test (CLQT).* The Psychological Corporation.

Holland, A. L., Frattali, C., & Fromm, D. (1999). *Communication activities of daily living: CADL-2*. Pro-Ed.

Katz, R. C., & Wertz, R. T. (1992). Computerized hierarchical reading treatment in aphasia. *Aphasiology*, *6*(2), 165-177.

Katz, R. C., & Wertz, R. T. (1997). The efficacy of computer-provided reading treatment for chronic aphasic adults. *Journal of Speech, Language, and Hearing Research*, *40*(3), 493-507.

Kim, M., & Beaudoin-Parsons, D. (2007). Training phonological reading in deep alexia: does it improve reading words with low imageability? *Clinical Linguistics & Phonetics*, *21*(5), 321-351.

Kim, M., & Russo, S. (2010). Multiple Oral Rereading (MOR) Treatment: Who Is It For? *Contemporary Issues in Communication Science and Disorders, 37*, 58-68.

Knollman-Porter, K., Wallace, S. E., Hux, K., Brown, J., & Long, C. (2015). Reading experiences and use of supports by people with chronic aphasia. *Aphasiology*, *29*(12), 1448-1472.

Kontou, E., Thomas, S. A., & Lincoln, N. B. (2012). Psychometric properties of a revised version of the Visual Analog Mood Scales. *Clinical Rehabilitation*, *26*(12), 1133-1140.

LaPointe, L., & Horner, J. (1998). *RCBA-2: Reading Comprehension Battery for Aphasia–Second Edition*. Austin, TX: Pro-Ed.

Lee, J. & Sohlberg, M. (2013) Evaluation of attention training and metacognitive facilitation to improve reading comprehension in aphasia. American Journal of Speech Language Pathology, 22 (2), 318-333.

Lee, J., Sohlberg, M., Harn, B., Horner, R., & Cherney, L. (2018): Attention Process Training-3 to improve reading comprehension in mild aphasia: A single-case experimental design study, *Neuropsychological Rehabilitation*, DOI: 10.1080/09602011.2018.1477683

Leff, A. P., Spitsyna, G., Plant, G. T., & Wise, R. J. S. (2006). Structural anatomy of pure and hemianopic alexia. *Journal of Neurology, Neurosurgery & Psychiatry, 77*(9), 1004-1007.

Leff, A. P., & Behrmann, M. (2008). Treatment of reading impairment after stroke. *Current Opinion in Neurology*, *21*(6), 644-648.

Lix, L. M., Keselman, J. C., & Keselman, H. J. (1996). Consequences of assumption violations revisited: A quantitative review of alternatives to the one-way analysis of variance F test. *Review of Educational Research, 66*, 579-619.

Lott, S. N., Sample, D. M., Oliver, R. T., Lacey, E. H., & Friedman, R. B. (2008). A patient with phonologic alexia can learn to read "much" from "mud pies". *Neuropsychologia*, *46*(10), 2515-2523.

Lynch, K. E., Damico, J. S., Abendroth, K. J., & Nelson, R. L. (2013). Reading performance subsequent to aphasia: Strategies applied during authentic reading. *Aphasiology, 27*(6), 723-739.

Marshall, J., Caute, A., Chadd, K., Cruice, M., Monnelly, K., Wilson, S. & Woolf, C. (2018). Technology enhanced writing therapy for people with aphasia: Results of a Quasi-Randomised Waitlist Controlled Study. *International Journal of Language and Communication Disorders*. DOI: 10.1111/1460-6984.12391.

Meteyard, L., Bruce, C., Edmundson, A. and Oakhill, J. (2015). Profiling text comprehension impairments in aphasia. *Aphasiology, 29*(1), 1-28.

Murphy, J. (1998). Talking Mats: Speech and language research in practice. *Speech and Language Therapy in Practice*, 11-14.

Ong, Y. H., Brown, M. M., Robinson, P., Plant, G. T., Husain, M., & Leff, A. P. (2012). Read-Right: a "web app" that improves reading speeds in patients with hemianopia. *Journal of Neurology*, *259*(12), 2611-2615.

Parr, S. (1995). Everyday reading and writing in aphasia: Role change and the influence of pre-morbid literacy practice. *Aphasiology*, *9*(3), 223-238.

Patterson, K. & Kay, J. (1982) Letter by letter reading: Psychological descriptions of a neurological syndrome. *Quarterly Journal of Experimental Psychology, 34A*, 411-441.

Patterson, K., Marshall, J. C. & Coltheart, M. (1985) *Surface Dyslexia: Neuropsychological and Cognitive Studies of Phonological Reading*. Hillsdale NJ: Lawrence Erlbaum Associates.

Purcell, J. J., Schubert, T. M., & Hillis, A. E. (2015). Acquired impairments in reading. *The Handbook of Adult Language Disorders*, 3.

Purdy, M., Coppens,P., Brookshire Madden, E., Mozeiko, J., Patterson, J., Wallace, S. & Freed, D. (2018). Reading comprehension treatment in aphasia: A systematic review. *Aphasiology*, DOI 10.1080/02687038.2018.1482405

Rodriguez, A. D., Worrall, L., Brown, K., Grohn, B., McKinnon, E., Pearson, C., & ... Copland, D. A. (2013). Aphasia LIFT: Exploratory investigation of an intensive comprehensive aphasia programme. *Aphasiology, 27*(11), 1339-1361.

Rose, T., Worrall, L. & McKenna, K. (2003) The effectiveness of aphasia-friendly principles for printed health education materials for people with aphasia following stroke. Aphasiology, 17: 947–963.

Rose, T. A., Worrall, L. E., Hickson, L. M., & Hoffmann, T. C. (2011). Aphasia friendly written health information: Content and design characteristics. *International Journal of Speech-Language Pathology*, *13*(4), 335-347.

Russo, M. J., Prodan, V., Meda, N. N., Carcavallo, L., Muracioli, A., Sabe, L., ... & Olmos, L. (2017). High-technology augmentative communication for adults with post-stroke aphasia: a systematic review. *Expert Review of Medical Devices*, *14*(5), 355-370.

Schuett, S., Heywood, C. A., Kentridge, R. W., & Zihl, J. (2008). The significance of visual information processing in reading: Insights from hemianopic dyslexia. *Neuropsychologia*, *46*(10), 2445-2462.

Simmons-Mackie, N., Kagan, A., Victor, J. C., Carling-Rowland, A., Mok, A., Hoch, J. S., ... & Streiner, D. L. (2014). The assessment for living with aphasia: Reliability and construct validity. *International Journal of Speech-Language Pathology*, *16*(1), 82-94.

Sinotte, M. P., & Coelho, C. A. (2007). Attention training for reading impairment in mild aphasia: A follow-up study. *NeuroRehabilitation, 22*(4), 303-310.

Ska, B., Garneau-Beaumont, D., Chesneau, S., & Damien, B. (2003). Diagnosis and rehabilitation attempt of a patient with acquired deep dyslexia. *Brain and Cognition*, *53*(2), 359-363.

Swinburn, K., Porter, G., & Howard, D. (2004). *Comprehensive aphasia test* (Vol. 40). Hove: Psychology Press.

Thiel, L., Sage, K., & Conroy, P. (2017). Promoting linguistic complexity, greater message length and ease of engagement in email writing in people with aphasia: Initial evidence from a study utilizing assistive writing software. *International Journal of Language & Communication Disorders*, *52*(1), 106-124.

Thomas, S. A., Walker, M. F., Macniven, J. A., Haworth, H., & Lincoln, N. B. (2013). Communication and Low Mood (CALM): A randomized controlled trial of behavioural therapy for stroke patients with aphasia. *Clinical Rehabilitation*, *27*(5), 398-408.

Tree, J. J. (2008). Two types of phonological dyslexia–A contemporary review. *Cortex*, *44*(6), 698-706.

Wallace, S. J., Worrall, L., Rose, T., & Le Dorze, G. (2016). Core outcomes in aphasia treatment research: An e-Delphi consensus study of international aphasia researchers. *American Journal of Speech-Language Pathology*, *25*(4S), S729-S742.

Wallace, S. J., Worrall, L., Rose, T., Le Dorze, G., Cruice, M., Isaksen, J., ... & Gauvreau, C. A. (2017). Which outcomes are most important to people with aphasia and their families? An international nominal group technique study framed within the ICF. *Disability and Rehabilitation*, *39*(14), 1364-1379.

Watter, K., Copley, A., & Finch, E. (2016). Treating reading comprehension deficits in sub-acute brain injury rehabilitation: Identifying clinical practice and management. *Journal of Communication Disorders*, *64*, 110-132.

Webster, J., Morris, J., Connor, C., Horner, R., McCormac, C., & Potts, A. (2013). Text level reading comprehension in aphasia: What do we know about therapy and what do we need to know? *Aphasiology, 27*(11), 1362-1380.

Wiederholt, J. L., & Bryant, B. R. (2001). *Gray oral reading tests* (4th ed.). Austin, TX: Pro-Ed.

Wiederholt, J.L., & Bryant, B.R. (2012). *Gray oral reading tests* (5th ed.). Austin, TX: Pro-Ed.

Worrall, L., Rose, T., Howe, T., Brennan, A., Egan, J., Oxenham, D., & McKenna, K. (2005). Access to written information for people with aphasia. *Aphasiology*, *19*(10/11), 923-929.