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Mobile technology to support lexical retrieval during activity retell in primary progressive aphasia

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ABSTRACT

Background: Augmentative and alternative communication (AAC) strategies and tools developed for individuals with chronic aphasia have been found to facilitate generative language skills. There exists a need to identify effective AAC strategies and tools for individuals experiencing primary progressive aphasia (PPA), a neurodegenerative dementia, for which compensatory treatment paradigms are yet to be systematically evaluated.

Aims: To examine the treatment effects of a novel language compensation tool, CoChat, and to determine if lexical retrieval skills improve are maintained during activity retell with use of this AAC application.

Methods and procedures: Six individuals with PPA participated. The study was implemented using a single-subject alternating treatments experimental design to compare lexical retrieval during activity retell in three conditions: Absence of technology support, presence of photos only, and presence of CoChat app, with photo and labels. The number of target words produced by the participant during activity retell with a conversation partner was the primary dependent variable. There were two phases of this experiment: Three conditions presented in a fixed-order and three conditions presented in a counterbalanced order. For one participant, an additional implementation of CoChat was piloted at 6- and 9-month post-intervention to examine sustained effect of CoChat during activity retell.

Outcomes and results: In the fixed-order phase, results indicated a higher number of target words produced in the CoChat condition for all participants. In the counterbalanced phase, results indicated a higher number of target words in the CoChat condition for two-thirds of the participants. Maintenance probes showed same level of lexical retrieval at 6 and 9 months following intervention.

Conclusions: This single-case research design demonstrated that mobile technology compensatory strategies provide necessary support during natural conversations about personally relevant topics for people with PPA. CoChat, a newly developed mobile technology research app that uses social networks and an NLP engine to create a co-constructed external lexicon with visual scene display, significantly increased lexical retrieval during

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Glory Noethe's untimely death immediately preceded submission of this manuscript.

activity retell. Future research should further develop AAC strategies and tools that aid in maintenance of vocabulary access and communication participation for people with PPA over the course of disease progression.

Background

Primary progressive aphasia (PPA) is a neurodegenerative syndrome characterized by an insidious onset of language impairment with progressive loss of speech and language function caused by a form of frontotemporal lobar degeneration with different protein aggregates or Alzheimer's pathology (Mesulam, 2013; Mesulam et al., 2014). Originally defined as a distinct clinical syndrome in 1982 (Mesulam, 1982), PPA is currently classified into three variants: Non-fluent/agrammatic (nfvPPA), semantic (svPPA), and logopenic (lvPPA) (Bonner, Ash, & Grossman, 2010; Gorno-Tempini, Hillis, & Weintraub et al., 2011; Wilson et al., 2010). Each variant is characterized by a distinctive array of linguistic impairments and is associated with a typical cognitive, neuroimaging, and neuropathological profile. (Spinelli et al., 2017) The hallmark symptoms in svPPA include anomia and single-word comprehension difficulties; in nfvPPA, apraxia of speech and/or dysarthria, problems with grammar production or comprehension; and in lvPPA, word retrieval and repetition challenges. Mean age at onset is late 1950s (with a wide range). Rate of decline is variable, and there does not seem to be a gender bias (Mesulam, 2013). Epidemiologic data on prevalence of PPA are not available. A rough estimate can be derived, however, because the aetiology is in the clinical spectrum of frontotemporal dementia. Estimates of prevalence of frontotemporal dementia indicate that nearly 3–15/100,000 persons are affected, or approximately 10,000–45,000 people in the USA (Social Security Administration, 2012; Taylor, Kingma, Croot, & Nickels, 2009). There is a recognized lack of evidence regarding the efficacy of clinical interventions to help people living with PPA manage this debilitating disease (Kortte & Rogalski, 2013). Significantly, there are no current treatments to manage the impact of communication deterioration in PPA (Beeson et al., 2011; Dickerson, 2011). A few pharmacological trials have been conducted, yielding inconclusive results (Boxer, Lipton, & Womack et al., 2009; Kertesz, Morlog, & Light et al., 2008). The implementation of non-pharmacological interventions that compensate for progressive language loss must provide individuals with written and pictorial support that maximizes their communication potential (Croot, Nickels, Laurence, & Manning, 2009; Farrajota et al., 2012); emerging evidence suggests that compensatory strategies can enhance communication and quality of life (Carthery-Goulart et al., 2013; Nickels & Croot, 2009). The time is now to capitalize on interdisciplinary expertise from the fields of speech–language pathology and human–computer interaction in order to optimize technology's ability to enhance the lives of people with aphasia (Salis & Hwang, 2016).

Compensatory language intervention for PPA

Treatment for PPA comprises both impairment-directed therapies aimed at naming and lexical retrieval skills and compensatory strategy approaches (Beeson et al., 2011; Fried-Oken, Mooney, & Peters, 2015; Fried-Oken, Rowland, & Gibbons, 2010). The

compensatory treatment approach includes low- and high-tech solutions commonly used within the field of augmentative and alternative communication (AAC) (Fried-Oken et al., 2010). A number of case reports highlight the benefits of compensatory strategies for individuals with PPA (Cress & King, 1999; Murray, 1998). AAC strategies and tools are traditionally offered after restorative treatment is no longer effective, in a stage-based protocol (Rogers & Alarcon, 1998). However, most AAC clinicians strongly recommend integration of AAC strategies early in the disease process, in conjunction with restorative language treatment (Beukelman, Fager, Ball, & Dietz, 2007; Fried-Oken, Beukelman, & Hux, 2012; Kagan et al., 2008). Mobile technologies that are pervasive within the general population are becoming popular as socially acceptable AAC intervention tools for individuals with aphasia, dementia, and language impairment (Dietz, Weissling, Griffith, McKelvey, & Macke, 2014), and may do the same for adults experiencing progressive language loss. An associated explosion of AAC apps created for language impairment has occurred (McNaughton & Light, 2013; Ramsberger & Messamer, 2014). This has resulted in immediate availability, low fixed costs, and acceptance by families and friends.

One popular use of mainstream mobile technology is networking through social media apps, a group of Internet-based applications that are centred on social interaction. These social interactions can include creating, sharing, and exchanging information and ideas (Bertot, Jaeger, & Hansen, 2012). According to current social media statistics, Facebook has 1.9 billion users and Pinterest has 150 million users (Chaffey, 2017). Recent statistics show that 74% of all online adults use social networking sites. Additionally, one-third of U.S. states are expecting to see more investment in broadband Internet access, increasing the potential user base of social media in the future (Adams et al., 2016; Smith, 2014). Social media apps with photos offer people with language impairments the potential to support communication, allow for spontaneity, and provide an easy and socially acceptable way to stay connected (McNaughton & Light, 2013). As mobile technologies, social media and associated applications become standard modes of electronic communication, individuals with PPA must have these tools to harness the power of digital communication and maintain verbal participation as they lose language skills. Unfortunately, people with PPA may present with a variety of barriers to use of digital communication modalities, including physical challenges (impaired fine motor control), language challenges (decreased ability to add written text), cognitive changes (reduced initiation and problem solving), limited literacy skills, and technological barriers (platforms not supported in AAC devices; lack of knowledge or access to equipment) (Caron & Light, 2015; Hynan, Murray, & Goldbart, 2014). These challenges must be considered when designing and teaching individuals with PPA to use digital forms of communication.

Natural language processing (NLP)

Within the last decade, NLP techniques have been applied to AAC devices, and will continue to significantly affect AAC technology (McCoy, Arnott, Ferres, Fried-Oken, & Roark, 2013). NLP refers to computerized processing of human language to analyse, modify, augment, or generate words, word sequences, or text for machine applications (Bird, Klein, & Loper, 2009). NLP is particularly well suited for AAC devices and apps intended for use by adults who are computer literate but have lost language

competence due to chronic disease. For such users, NLP techniques should be used to help build word sets, essentially forming their "external lexicon" over time. Traditional AAC applications provide users with words that are often chosen by other people; picture labels usually are inserted by a parent, spouse, or therapist. NLP is the ideal function to automatically provide content to the user's vocabulary, without needing pre-stored selections from the family or therapist. With this support, users can continue to be active, independent participants with their social networks in communication interactions.

The purpose of this study was to examine the treatment effects of CoChat, a novel research AAC app that incorporates NLP techniques, on lexical retrieval skills during activity retell. We hypothesized that when individuals with mild-to-moderate PPA are supported by the CoChat app during an activity retell, they would improve or maintain word finding skills compared to unsupported conditions.

Method

This study was approved by the University Institutional Review Board. To facilitate understanding of the consent process by persons with PPA, communication supports were used, including repetition, clarification, and aphasia-friendly forms.

Participants

Six adults diagnosed with PPA by a board-certified neurologist, using criteria from Gorno-Tempini et al. (2011), participated in this study, three males and three females between 58 and 80 years of age. Participants were recruited based on their appearance in a university communication disorders clinic, so to some extent they constituted a convenience sample for a population with a relatively low prevalence rate. All met study inclusion criteria: English as primary language; presence of a spouse, family member, or close friend to serve as a conversation partner; communication deficits as the presenting symptoms isolated over a 2-year period; corrected visual acuity better than 20/50; functional hearing at conversational level (less than 40 dB loss); functional reading comprehension at the phrase level; and a Clinical Dementia Rating (Morris, 1993) with supplemental language and behaviour ratings <2. Additionally, as identified during the standardized language assessment process, participants exhibited at least two core features of one of the three PPA variants: Motor speech deficits, agrammatism, impaired confrontation naming, impaired word retrieval in spontaneous speech, impaired repetition, and/or impaired comprehension of complex syntax. Finally, all participants were required to demonstrate operational proficiency with both the tablet and the CoChat app prior to the technology-based intervention, thus ensuring no physical or technological barriers to the intervention. Table 1, which presents participant demographic characteristics, PPA variant, and language/cognitive assessment results, is followed by short descriptions of each participant.

Alice. Alice is a 73-year-old, right-handed woman diagnosed with PPA 4 years prior to study enrolment. She worked as a cardiology nurse for over 28 years, retiring from her career shortly after her diagnosis because of difficulties communicating at work. Alice self-reports as talkative before her diagnosis. She presents with the agrammatic variant

Table 1. Demographic and clinical characteristics of participants with primary progressive aphasia.

		Participants with primary progressive aphasia					
		Alice	Elizabeth	Don	Warren	Cathy	James
Gender		F	F	M	M	F	M
Age		73	80	62	72	63	58
Years of education		15	15	16	20	16	16
Occupation		Nurse	Accountant	Physical therapist	Engineer	Accountant	Sheriff
PPA variant		nfvPPA	nfvPPA	svPPA	lvPPA	svPPA	nfvPPA
Months post symptom onset		~48	~30	~18	~24	~14	~20
Familiarity with mobile technology		Yes	Yes	Yes	Yes	Yes	No
WAB-R, AQ (100)	Lower score indicates greater severity	88	61.6	93.6	83	97.7	96.2
WAB-R, reading CQ (10)	Lower score indicates greater severity	6.2	9.1	9.1	9.1	10	10
BNT-R (60)	Lower score indicates greater severity	59	31	59	40	58	57
ACE-III (100)	Lower score indicates greater severity	87	78	86	69	91	87
PASS (33)	Higher score indicates greater severity	10	14	2.5	1.5	0.5	5.5

WAB-R, AQ: Western Aphasia Battery-Revised, Aphasia Quotient (Kertesz, 2006); BNT-R: Boston Naming Test-Revised (Nicholas et al., 1989); PASS: Progressive Aphasia Severity Scale (Sapolsky et al., 2011); ACE-III: Addenbrooke's Cognitive Examination-Third Edition (Hsieh et al., 2013).

of PPA. At time of enrolment, her primary mode of expression was writing (single words to paragraph length), supplemented by single-word verbal utterances. She describes using a variety of communication supports, including a PPA wallet card, a communication book, pre-written scripts for telephone use, and whiteboard application on her iPad. Alice demonstrates current active use of mobile technology with both the iPad and iPhone. Her communication partner (CP) is her husband of 49 years.

Elizabeth. Elizabeth is an 80-year-old, right-handed woman who lives alone, recently widowed. She was diagnosed approximately 2.5 years prior to enrolment and presents with the agrammatic variant of PPA. Alice was a comptroller of a large manufacturing firm prior to retiring over 15 years ago. Always a talkative person, she had to learn alternative modes of communication secondary to her diagnosis; she proudly demonstrates skilled use of her iPad and iPhone. Writing and use of a keyboard are Elizabeth's strengths, with reading comprehension intact for sentence-level material. Her CP is her best friend of 45 years.

Don. Don is a 62-year-old, left-handed man who lives with his wife (and CP) of 31 years. Diagnosed with PPA 18 months prior to enrolment, he retired from his physical therapy position because of spoken and written English challenges. He presents with semantic variant of PPA. Don considers himself a "somewhat" talkative person prior to his diagnosis. He is highly familiar with mobile technology, using a variety in daily life. Although he does not use any communication supports, he is very familiar with the concept as he is the father of an adult son with severe autism. At time of enrolment, Don was communicating exclusively with verbal speech, punctuated by word-retrieval difficulties.

Warren. Warren is a 72-year-old, right-handed man who lives with his partner of 9 years. He retired from a career as a petroleum engineer almost 10 years ago and was diagnosed with PPA approximately 24 months before entering our study. A self-reported "extremely quiet" person prior to his diagnosis, Warren remains a man of few words. He

presents with the logopenic variant of PPA, characterized by anomia with initial reports of mild memory changes. Extremely engaged in his community, Warren is an active user of his iPad and iPhone.

Cathy. Cathy is a 63-year-old, left-handed woman who lives with her husband of 40 years. She was diagnosed with PPA approximately 14 months prior to enrolment. Previously employed as an accountant, Cathy spent the past 20 years as a homemaker. She self-reports as talkative before her diagnosis. Cathy presents with the semantic variant of PPA. Experiencing few limitations at the time of enrolment, Cathy communicates primarily through speech with mild anomia. Cathy validates current active use of mobile technology with both the iPad and iPhone.

James. James is a 58-year-old, right-handed man who lives with his wife of 17 years in a rural community. James was diagnosed with PPA 20 months prior, and recently retired from his 30-year career as a sheriff. He presents with the agrammatic variant of PPA. James reports he was never a talkative person and has no previous experience with mobile technology. James' communication was characterized by halting, dysfluent two- to three-word utterances, primary supplemented by his highly verbal wife (and CP).

Materials

The intervention used an Apple iPad (fourth generation, model #A1460) to take photos and display the CoChat application.

CoChat

CoChat is an AAC iOS-platform application newly developed for research purposes. It is not available for purchase or download. CoChat is constructed on NLP features, social media use, and just-in-time principles. It generates lexical displays on a tablet based on user-captured photos, related comments, and an automatically curated list of target words. The user takes photographs with her tablet's built-in camera and shares the photos instantly with her simulated social network. Family, friends, and familiar CPs who know her respond to the images by posting comments in real time. Using the comments received from the social network, CoChat applies NLP techniques to automatically produce a set of 10 highly relevant target words which are placed around the original photo to form a visual scene display (VSD) on the user's tablet (see Figure 1). For example, a user wants to tell his daughter about the new forested lot he bought next to the river. He takes a picture of the lot. The image immediately uploads to the research server for comments. A simulated social network adds comments such as, "The forest has many green trees. The Nestucca River is a great location for your next house." CoChat's NLP engine automatically analyses these comments to create a list of the 10 most salient items, or target words, for the display. Later that evening, the user brings up the CoChat display to support an enjoyable conversation with his daughter.

CoChat's NLP computational pipeline consists of four steps: Preprocessing, named entity recognition, key term identification, and semantic expansion. CoChat's NLP engine automatically analyses the social network comments, mines large vocabulary databases, and uses state-of-the-art machine learning algorithms to identify related words which become the lexical prompts for a user. Simply put, NLP first removes non-useful words from the comments ("Wow!", "the", "it"), then identifies proper nouns, highlights words

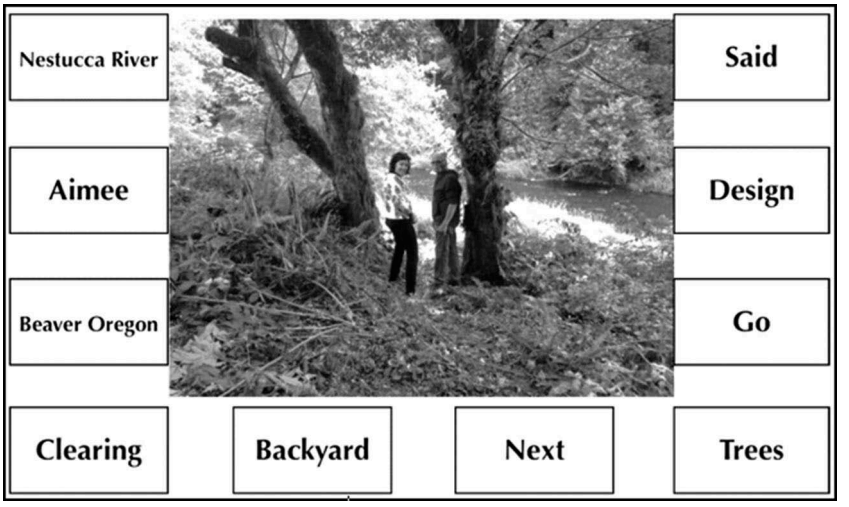

Figure 1. CoChat app user interface.

that occur more frequently in the comments than would be expected, and finally adds words that are relevant but not redundant. The result is a co-constructed external lexicon from three sources: (1) Personally relevant photo that the person with PPA captured in real time; (2) comments from the social network; (3) a set of target words generated from NLP techniques. CoChat creates a customized VSD on the participant's tablet with the 10 target words surrounding the original photo.

Response definitions

The primary dependent variable was number of target words produced verbally by the participant during activity retell with a CP. As discussed below, the participant was trained to retell the activity, and the partner was trained to ask specific WH-questions to elicit generative language in an unstructured conversation, with and without CoChat. Target words for all participants in each condition were the 10 words generated by the NLP engine that surround the picture described in the CoChat section. A research associate (RA) used an event recording method to tally the number of times target words occurred during conversations between participants and their CPs for each intervention condition (Ayers & Ledford, 2014). Each conversation was videotaped for later review and verification of online data collection results.

Experimental design

An alternating treatments experimental design (Barlow, Nock, & Hersen, 2009; Wolery, Gast, & Ledford, 2014) compared the effects of no technology, photo-only, and CoChat conditions on the number of target words spoken during each conversation. This research design is well suited for comparing the effects of multiple interventions, or conditions, where the behaviour of interest is reversible, the treatment conditions can

be alternated quickly, and the amount of time available is somewhat limited. Of the different data characteristics analysed with single-case research designs (SCRD; e.g., changes in level, trend, and variability), overlapping data between conditions is most relevant for evaluating the effects of alternating treatments designs. Ideally, if the primary comparison phase shows differentiation among the treatment conditions, a subsequent phase using the superior condition alone is implemented. A follow-up phase of this superior condition also is recommended (Barlow & Hersen, 1984). Using the What Works Clearinghouse (2014) design standards, the designs for all participants Met Standards (i.e., at least five datapoints per experimental condition). This research design allowed for demonstration of intra-subject and inter-subject replication of the experimental effect, thus controlling for potential threats to the internal validity of the design and demonstrating initial generality of the effect. In addition, the rapid changing of conditions in an alternating treatments design allowed primary data collection to be completed within a 3-month time period, which helped control for potential maturation threats from further language degeneration that might occur across a longer time period (Farrajota et al., 2012). In general, single-subject research designs are particularly well suited to AAC investigations, as they provide rigorous experimental control of individualized interventions with heterogeneous populations (McReynolds & Kerns, 1986; Thompson, 2015) and allow clinical investigations of low-prevalence disorders where large samples that generate statistical power sufficient for group comparisons are not feasible (Odom et al., 2005).

Based on this design, it is important to note that only six participants were needed to test the hypothesis. The logic of SCRD requires each participant to serve as his or her own control (i.e., participants are exposed to both baseline and treatment conditions), reducing the need for large numbers of participants to demonstrate the effect of an intervention. In addition, equal numbers of participants within different phases of a study are not required in order to meet the design standards for demonstration of effects for SCRD (What Words Clearinghouse, 2014), and the same individuals can participate in more than one phase.

Procedure

Pre-intervention sessions

All participants and their CPs engaged in six pre-intervention sessions in their homes to complete consenting, cognitive/language assessment, tablet operations training, activity retell training, and CP training.

Cognitive/language assessment. Assessments were conducted to measure spontaneous speech, auditory comprehension, repetition, reading, and naming abilities with the Western Aphasia Battery-Revised (Kertesz, A. 2006). Confrontation naming was measured using the Boston Naming Test-Revised (Nicholas, Brookshire, Maclennan, Schumacher, & Porrazzo, 1989). Cognitive skills of attention, memory, verbal fluency, language, and visuospatial abilities were screened using the Addenbrooke's Cognitive Examination-Third Edition (Hsieh, Schubert, Hoon, Mioshi, & Hodges, 2013)

Tablet operations training. All participants were required to demonstrate operational proficiency with both the tablet and the CoChat app prior to the technology-based intervention. This step ensured that any observed changes in participant responses were the result of the experimental condition rather than an adaptation effect often observed when learning to use technology (Gast & Ledford, 2014). An RA demonstrated how to operate the tablet and app through direct instruction for multistep routines. Skill acquisition training included an errorless, fading-of-cues protocol (Ehlhardt & Kennedy, 2005).

Instructional targets were identified by analysis of procedural steps necessary to access and use the app (Powell et al., 2012). These included ability to (1) turn on the tablet, (2) swipe to navigate between pages, (3) access the CoChat app, (4) take a photo within the app, (5) select "confirm" to send photos to simulated social media network, and (6) reopen the CoChat lexical display upon receipt of target words. (See Appendix A.) Participants were required to achieve 100% mastery on initial training and at the beginning of each data collection visit.

CoChat activity retell training for participants with PPA. A two-step training ensured that participants were sufficiently familiar with the CoChat display to use it as a support during the conversational task. First, participants were instructed to read each word aloud and visually scan the entire CoChat display. Simple, consistent instructions were developed to reduce confusion and focus on relevant content (Ehlhardt & Kennedy, 2005). For step two, conversational coaching was implemented with sample CoChat displays preloaded onto the tablet. The criterion for mastery was 100% consistency in providing three accurate details about three sample CoChat stories. (See Appendix B.)

CoChat activity retell training for CPs. To ensure consistency across the three conversations, CPs were trained in the "5 Ws + H" technique used in journalism, where information about "who, what, when, where, why and how" is elicited. This technique has been shown to systematically evoke answers considered to be basic information for getting the complete story on a topic (Spencer-Thomas, 2012).

Determine participants' preferred communication activities. Participants and their CPs were queried about preferred activities at home or in the community that could be used for data collection visits. An activity list was generated for use across all experimental conditions.

Experimental conditions

An RA met each participant at a chosen location where they engaged in an activity and took photos that captured contextually rich, personalized scenes. Locations included a local bakery, neighbourhood park, backyard garden, and bookstore. The photos were sent automatically through CoChat to a second researcher waiting to provide comments. In this way, a typical social networking interaction was simulated, where a friend sends photos through social media for comments. The second researcher followed a set of labelling rules that ensured that comments described the photo meaningfully and avoided semantically empty expletives typically produced in social media (i.e., looks great, amazing!, way to go!). Appendix C shows labelling rules.

The participant and RA then returned home where the participant engaged in an activity retell with a CP who was not familiar with their outing. Conversations were conducted in three treatment conditions during each data collection visit: (1) *No technology*, participants described the activity without any aided support; (2) *photo-only*, participants described the activity using the support of the photograph on the iPad; and (3) *CoChat app*, participants described the activity using the support of the CoChat app (photo + 10 target words) on the iPad. With this experimental design, it is not possible to collect data in a fourth words-only condition, since the words were curated from simulated social network annotations to the photos. The question of whether a list of words alone could affect target word production is an interesting investigation with this population, but cannot be implemented in this experiment because the words were strictly the result of the CoChat photos. User feedback was obtained after each visit.

Intervention

Phase one: fixed-order conditions. The treatment conditions were initially set in a fixed-order sequence: No technology, then photo-only, and finally CoChat. This order prevented an intervention effect where the initial presence of contextual cues might influence word finding in the other conditions (Wolery et al., 2014). For example, the CoChat condition provides written word cues not present in the photo-only condition and the photo-only condition might provide more word finding cues than no technology condition. Each of the four participants, Elizabeth, Don, Warren, and Alice, completed six data collection visits, with three fixed-order conditions at each visit, for a total of 18 conditions.

Phase two: counterbalanced conditions. While the fixed-order sequence of conditions originally was implemented to provide a more accurate representation of the effect of each treatment condition, it also presented the potential for a practice, or interaction, effect between conditions. Specifically, if better outcomes were observed for the third (final) condition, it could be due to prior conversation exposure during the first two conditions. To address this potential threat to the internal validity of the research design, a second intervention phase was added to systematically counterbalance the three conditions in each of the six visits. There were three participants in this phase: Don, who participated in Phase one and requested participation in all continuing research projects, and two new participants, Cathy and James. All procedures were identical to those discussed in Phase one; however, the three conditions were counterbalanced. For example, a participant might describe the activity first with support of CoChat, then with no technology, and finally with photo-only. Each of the three participants completed six data collection visits, with three counterbalanced-order conditions at each visit, for a total of 18 conversations. James participated in an additional visit.

Pilot phase: maintenance of most effective condition. A third pilot phase was added to observe whether CoChat was an effective compensatory lexical support at 6- and 9-month post-intervention for language loss in neurodegenerative disease. For this pilot phase, the most effective treatment condition, activity retell with CoChat support, was implemented with a single participant, Don. None of the other participants were available

for the pilot study, otherwise data would have been collected and reported. All procedures were identical to those discussed in Phase one but there was only one conversational condition. Data collection visits in the pilot phase served as maintenance probes to observe the sustained effect of CoChat within the context of new activity retells. There were three visits at each interval with one condition only for a total of three conversations.

User feedback

User feedback was collected at the end of each visit. First, participants and partners were asked during which condition the conversation felt easiest and why. Second, the User Experience Questionnaire (UEQ), a tool designed for rapid measurement of a user's experience with technology (Laugwitz, Held, & Schrepp, 2008), was administered to participants only, to elicit their impressions about the CoChat app.

Procedural fidelity

The primary author administered all procedures. To ensure the intervention was implemented consistently, an order of operations checklist was developed to track the 23 discrete and specific steps of the intervention for each condition (Sanetti, Fallon, & Collier-Meeka, 2011). The primary author documented each step at each visit. A total of 30% of all visits for each participant were randomly selected for scoring procedural integrity. These were evenly distributed across experimental conditions. A second rater viewed the operations checklists and scored the implementation of each step. Percent agreement of the implementation steps was calculated by dividing the number of steps observed by the total number of steps × 100. Procedural integrity over six participants did not vary, with an overall integrity of 100%.

Results

Reliability

For 33% of all visits, equally and randomly distributed across the three experimental conditions, a trained independent observer viewed and scored the dependent variable from video recordings. The independent observer could not be blinded to the video ratings because he could see the presence or absence of the iPad during conversations. Target words were classified as present or absent, and the word-for-word results were compared with those of the primary rater. Agreement on the classification of responses per participant ranged from 96% to 100%, with an overall agreement across participants of 99%.

Trainings

Each participant met the 100% mastery criterion for tablet operations at initial training and at the beginning of each subsequent data collection visit. Each participant met the CoChat activity retell criterion for mastery of 100% consistency in providing three accurate details about three sample CoChat stories. All CPs demonstrated initial mastery at using the "5 Ws + H" technique; James' CP required maximal cuing and multiple repetitions of this training.

Phase one: fixed-order condition

The number of target words produced during activity retell by the four participants in the fixed-order condition is shown in Figure 2 and Table 2. The data were evaluated using visual analysis, focusing primarily on overlap between phases, with inspection of changes in level, variability, and trend within and across treatment conditions. Results indicate a higher number of target words in the CoChat condition over the no technology and photo-only conditions for all participants. For three of the participants (Elizabeth, Don, and Warren), visual inspection indicated no-overlap of data (100% non-overlapping data) between CoChat and the other two conditions. The lack of a clear learning effect over all activity retells (i.e., no CoChat trend upwards over the six intervention sessions) indicates that CoChat was an equally useful language support for unstructured, spontaneous conversations across the 3-month interval. For the fourth participant, Alice, 83% of CoChat visits showed no overlap with the photo-only and no technology conditions. Overlap in data is easily explained for visit number three. Alice's photograph was not related to the ensuing conversations, thereby affecting the number of target words produced during the CoChat conversation. (The photo depicted her newly designed neighbourhood entrance sign; the conversations involved details of the neighbour's ill grandson.) Thus, in that entire visit, there was no opportunity for the target words to be useful or relevant during activity retell.

Differences in number of target words selected between the no technology and photo-only conditions were less clear. Elizabeth had the same number of target words for photo-only and no technology during the first two visits, with increasing target words in the last four visits. There was no clear differentiation between no technology and photo-only conditions for Don, Warren, and Alice. For two participants, Elizabeth and Don, there was a slight increasing trend in both the photo-only and no technology conditions across all visits.

Phase two: counterbalanced conditions

The number of target words produced by the three participants in the counterbalanced conditions is shown in Table 3 and Figure 3. Results indicate a higher number of target words in the CoChat condition for two participants (Don, Cathy), with no-overlap of data (100% non-overlapping data) between CoChat and the other two conditions. For James, the results were less clear, so one additional visit was added to James' intervention to determine if continued exposure to the intervention would lead to clearer differentiation among conditions. CoChat was more effective for two of his seven visits (29% non-overlapping data), but in the other five visits, either no technology or photo-only condition was as effective as CoChat for number of target words produced. It is possible to explain these results by the fact that James' CP frequently stated the target words during the activity retell, creating a situation where James was only required to respond *yes* or *no*, and did not need to verbally produce the target words himself. For example, at one visit during an activity retell, James' CP stated, "Oh, so you showed Aimee the new hot tub that we bought from Costco last September and installed in the backyard to help ease your hip pain." This one sentence included 6 of the 10 target words, effectively

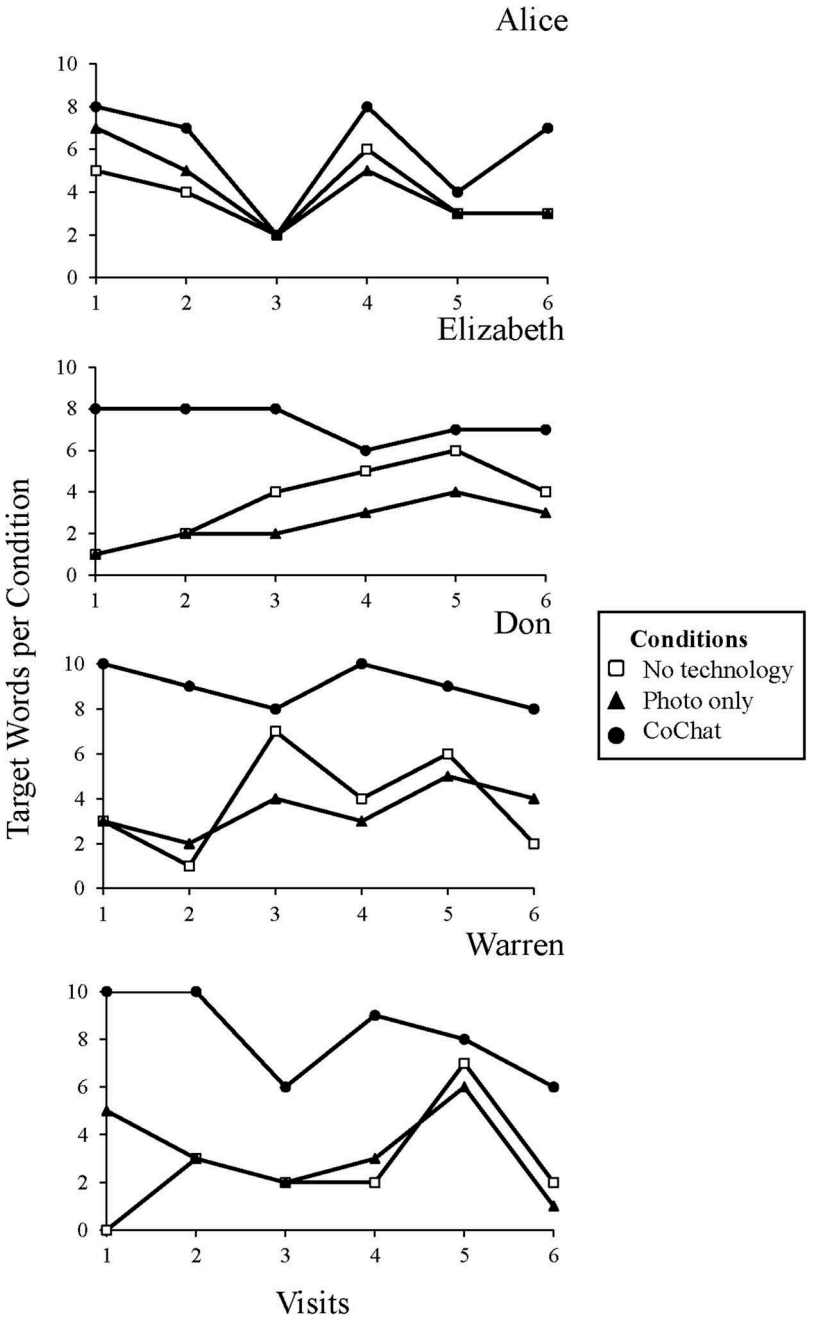

Figure 2. Phase one—Fixed-order conditions. Target words produced during no technology, photo-only, and CoChat conditions across three conversations during each of six visits.

negating James' need to produce them. Although his CP demonstrated mastery with the "5 Ws + H" technique during initial training, at data collection visits she often provided words for him. Even with the extra input from his CP, lexical recall improves in two visits and target word production is maintained in four of the visits with the

Table 2. Phase one—Target word production in fixed-order condition.

	No technology	Photo-only	CoChat
Alice	X- 3.8 Range 2–6	X- 4.2 Range 2–7	X- 6 Range 2–8
Elizabeth	X- 3.5 Range 1–6	X- 2.3 Range 1–4	X- 7.2 Range 6–8
Don	X- 3.8 Range 0–7	X- 3.7 Range 2–5	X- 8.8 Range 8–10
Warren	X- 3.5 Range 1–7	X- 3 Range 1–7	X- 7.5 Range 6–10

Table 3. Phase two—Target word production in counterbalanced order condition.

	No technology	Photo-only	CoChat
Don	X- 4.2 Range 2–6	X- 4.3 Range 3–6	X- 6 Range 2–8
Cathy	X- 5.3 Range 2–8	X- 6 Range 3–8	X- 9.3 Range 8–10
James	X- 3.7 Range 3–5	X- 3.4 Range 2–5	X- 4.6 Range 3–6

support of CoChat. Differences in number of target words produced between the no technology and photo-only conditions for all three participants were consistent with the results in the fixed-order conditions phase.

Pilot phase: maintenance of most effective condition

Since phases 1 and 2 provided a clear demonstration that CoChat was more effective than no technology and photo-only conditions for number of target words produced for five of the six participants, we implemented an additional three visits of the CoChat intervention alone for Don at both 6 and 9 months after phase two intervention to probe for maintenance effect of best condition. The results, shown in Figure 4, demonstrated a continuation of the effect: Don's target word production maintained an average of 7 (range 5–9) across all visits with no decreasing trend, similar to his target word production averages of 6 and 8, respectively, in phases one and two. These pilot data would support a future longitudinal study of CoChat use in daily conversation.

User feedback

Results from the UEQ (Laugwitz et al., 2008), which includes questions about technology use that are presented with a Likert scale of 1–7, were examined. It was determined that two UEQ variables, learnability and supportiveness, were key concepts to explore with CoChat participants. The scores were normalized to a −3 to 3 scale, where 0 is neutral, 3 is the most positive, and −3 would be the most negative rating. Learnability scores ranged from 1 to 3 (mean 2.66) for all participants in phase one and phase two conversations. Supportiveness scores ranged from 1 to 3 (mean 2.62) for all participants in phase one and phase two conversations. When participants and partners were asked which condition was easiest, results were consistent. In phase one fixed-order

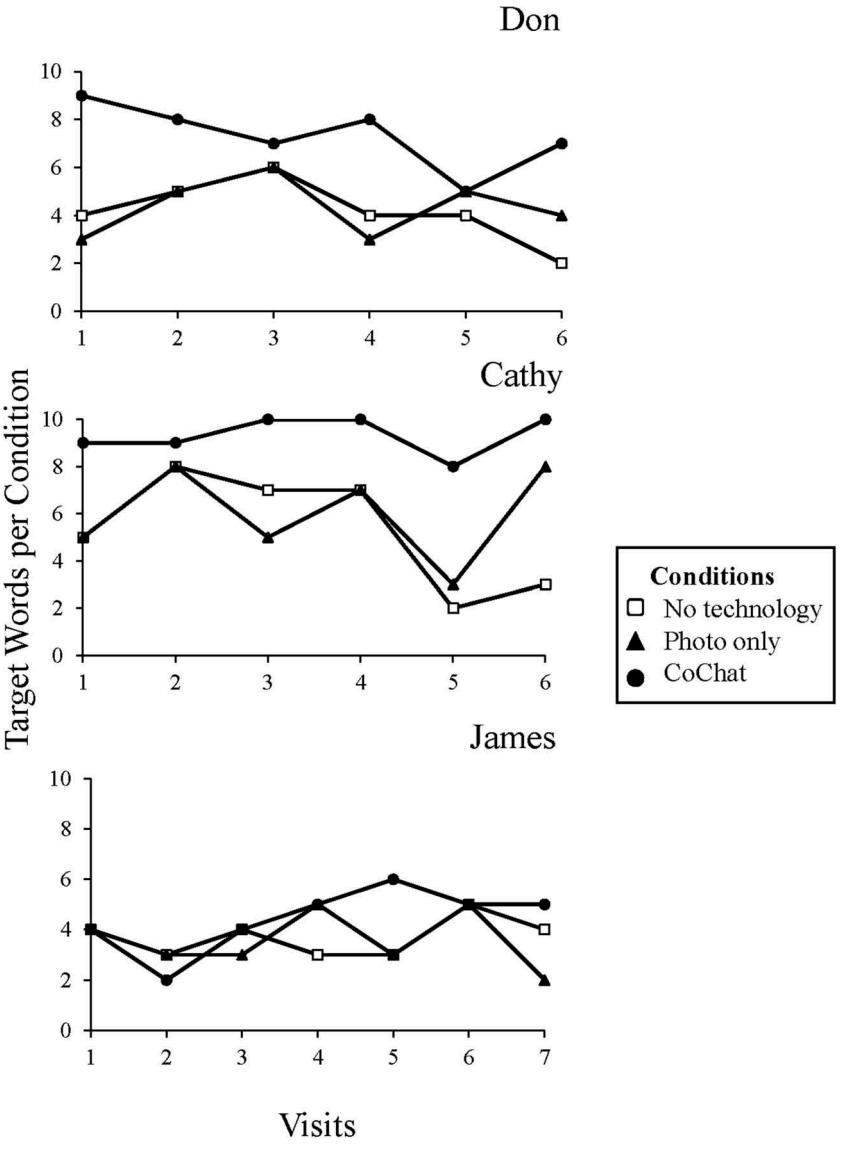

Figure 3. Phase two—Counterbalanced conditions. Target words produced during no technology, photo-only, and CoChat conditions across three conversations in each of six visits. James participated in one additional visit.

conditions, CoChat conversations were reported as easiest 71% of the time (17 of 24 conditions); photo-only was 25% (6 of 24 conditions), and no technology was 4% (1 of 24 conditions). In phase two, CoChat conversations were reported as easiest 69% (13 of 19 conditions); photo-only was 15.5% (3 of 19 conditions), and no technology was 15.5% (3 of 19 conditions). Participants stated that CoChat provided assistance and boosted confidence for conversation, "It helps, especially with the right words." They commented, "The words really help to direct and focus my storytelling." CPs related that use of CoChat created conversations which were richer than their typical (unsupported)

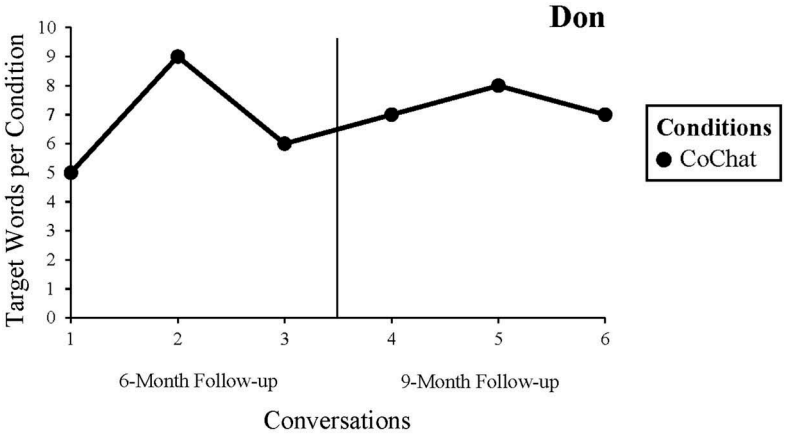

Figure 4. Pilot phase three—Maintenance of best condition. Number of target words produced during the CoChat condition alone for 6- and 9-month follow-up visits for Don. Each visit included one conversation using CoChat.

interactions, with more meaningful information conveyed. They remarked, "He talked longer and started to add more detail." CPs also reported that pre-intervention training was beneficial and helped them support their loved ones during conversations.

Discussion

In this study, the effect of intervention with a newly developed AAC app developed for research that relies on just-in-time photo capturing and social network annotation was compared to less supported conditions in an activity retell task. Overall results, for both fixed-order and counterbalanced experimental conditions, indicated that CoChat's VSD with a 10-word co-constructed external lexicon led to improved word retrieval in a natural conversational context for individuals with PPA. Participants were satisfied with the intervention and found conversations to be easier when using this technology. This study provides evidence that compensatory strategies, such as the CoChat app, provide necessary support for lexical retrieval during natural conversations about personally relevant topics. There is *Strong Evidence* in five out of six participants that sharing new information with CPs was richer, in terms of target words produced, when CoChat was available. For a majority of conversations in both study phases, participants and partners reported that conversations were easiest when CoChat was used.

The results from phase one intervention using fixed-order conditions provide *Strong Evidence* of an effect for the CoChat condition on target word use as compared to either no technology or photo-only condition for three participants (Elizabeth, Don, and Warren) and *Moderate Evidence* of an effect for one participant (Alice) (What Words Clearinghouse, 2014). It may be argued that in phase one, the best performance (CoChat) was due to a practice or interaction effect because this condition was always in the final conversational position. Activity retells with no technology or photo-only always preceded the conversation with the CoChat app. The fixed-order was intentional so that participants could not benefit from picture or word support (photo-only or

CoChat condition) before they were asked to retell an activity with no support (no technology condition). People with mild PPA do not have significant memory impairments, and may recall words from previous conditions if provided with the cues.

The results from phase two intervention where the conditions were counterbalanced showed *Strong Evidence* of an effect for two participants (Don and Cathy) and *Moderate Evidence* for one participant (James) (What Words Clearinghouse, 2014). The superior target word production observed in the CoChat condition for all three participants is due to intervention alone and not from practice. James had only a moderate effect of target word production but his results did not deteriorate. He maintained lexical retrieval skills across all CoChat conversations. It is critical to note that in studies involving individuals with neurodegenerative disease, an outcome of no change or a slowing of deterioration can also indicate that the intervention has had an effect (Croot et al., 2009). James conversation partner's interaction style of providing him with words during conversation limited his target word productions during data collection visits. It is also possible that he experienced changes in cognitive skills, attention, or motivation over the course of this study, causing the AAC tool to be less effective. There is a need for a longitudinal study that examines these factors for individuals with PPA.

Don's behaviour in the pilot study, phase three, demonstrated that presenting relevant, personalized word cues via CoChat's lexical display has positive effects on conversation over time. The pilot phase was only implemented with one participant because the others were not available. It is promising to note that Don could retain the learned behaviour of relying on the CoChat display to support lexical recall even 6 months after phase two intervention. It is possible to explain why Don's first maintenance visit produced lower results. During that first visit, the RA did not retrain the participant on how to use CoChat. In the other visits, an initial training was conducted before the conversation. This highlights the importance of training. It is not enough to just present a display and expect people with neurodegenerative language impairments to use the tools (Fried-Oken, Rowland, et al., 2012). Systematic instruction is critical for an individual to effectively use compensatory strategies and tools. Additional data collection is needed before more analysis can be discussed about the long-term effects of the CoChat intervention.

CoChat's lexical display presents a shared reference for CPs that provides clear support for natural conversation. Individuals with language limitations benefit significantly from access to photos of meaningful events in their lives to communicate with others. Photos that are personally relevant and highly contextualized and surrounded by text, called VSDs, increased expressive modality units and perceived helpfulness for five individuals with severe aphasia during a story retell task (Beukelman, Hux, Dietz, McKelvey, & Weissling, 2015; McKelvey, Dietz & Beukelman, 2010). They suggest that the picture + text may have elicited stronger activation of the visual sketchpad and episodic long-term memory (Baddeley, 2000), thus reducing attentional demands and increasing communication and language resources for the story retell task. Results from CoChat intervention strengthen these results, suggesting that VSDs with lexical displays play an important role in conversational support for individuals with chronic and progressive aphasia where language loss is a significant challenge to verbal participation.

Some might argue that presenting the written words on the tablet supports single-word reading aloud. Even if participants just read the target words, these data provide evidence that the written word in a just-in-time application is, in fact, beneficial in activity retells for individuals with PPA. We did not observe single-word oral reading in any of the six participants during the CoChat use. Dyads validated that having the support of these relevant words made the CoChat condition to easiest and most enjoyable condition for spontaneous conversations.

Individuals with PPA present a unique challenge. They are losing their language while initially retaining cognitive abilities. Although surface dyslexia is one of the clinical features that can be seen in svPPA, and phonological dyslexia a potential feature in lvPPA, these were not characteristics identified in our six participants at language assessment or in clinical observation. Many people with PPA can read single words late in the disease process, and can use these words as cues for lexical retrieval. This preserved reading ability must be optimized with AAC tools so that communication participation can be maintained during language loss. As stressed by Croot et al. (2009), it is time to identify outcomes that go beyond word recall in traditional therapy settings. Activity/participation interventions that are rigorously investigated and documented, such as this CoChat SCRD, are critically needed to have a greater impact on everyday communication outside the clinic.

One AAC technique that relies on just-in-time written word cues provided by conversation partners is called written choice communication (Garrett & Beukelman, 1995). With this technique, the person with aphasia and conversational partner identify a common topic, and the partner writes down two to five word or phrase choices that would potentially help the person with aphasia respond to questions. The written choice strategy provides linguistic support on a turn-by-turn basis to accommodate language processing and lexical retrieval challenges. It offers written cues to bypass the word finding impairment. In real time, partners can scaffold the communication event. As stated by Garrett and Beukelman (1995), the written choice technique may provide a means for successful verbal exchanges despite persistence of verbal impairment, thus strengthening participation in a natural setting. With this technique, however, writing down keywords requires significant input and knowledge from the conversational partner. If the partner is not familiar with the information that the person with PPA wants to share, written choice technique will not be successful. The partner must be present to write down words. CoChat may be considered a context-aware, technology-based version of written choice technique, where there is automated input from a familiar social network to describe a picture and present keywords in real time. CoChat combines the written choice technique with the power of personalized, highly contextualized VSDs so that language concepts are embedded within a photograph during naturally occurring events (Wilkinson & Light, 2011). The co-constructed external lexicon that results from just-in-time photo capturing with an intelligent NLP engine supports lexical retrieval by individuals with PPA in natural conversational settings.

One value of the CoChat concept is the innovative use of social media for lexical support. Most adults who rely on AAC use social media primarily for maintaining connections and providing networks for communication opportunities (Caron & Light, 2015). Most research on social media and AAC is exploratory in nature, asking users what platforms they prefer and about their experiences with the various platforms (Helmsley,

Balandin, Palmer, & Dann, 2017). Social media as a tool for language support is a novel concept that has not been discussed previously. CoChat, as an application that would rely on social media and allow the user to obtain language support for natural conversation, literacy learning, or lexical retrieval provides a new avenue for treatment (Caron & Light, 2015; Hynan et al., 2014). The present study demonstrated that this model of communication support is acceptable for natural conversation by people with PPA, and can be integrated into daily communication functions. This new application could eventually be integrated into AAC technologies, creating a novel use of social media for language assistance. The technologies and facilitating factors that support effective communication using social media need to be established, and products need to be developed and implemented. This study, and future work on intelligent, context-aware AAC technologies that include social media supports for persons with degenerative language disorders will be innovative and must be supported by other disciplinary fields, including human–computer interaction, NLP, and software development (Hemsley et al., 2017; Paterson, 2017).

Limitations

This report is an initial attempt to design and evaluate a new NLP-based application for individuals with PPA. A simulated social network was used for proof of concept. The photos were captured in real time and sent to the AAC laboratory for annotation. In a natural situation, an available social media application would have been used and the photos would have been sent to actual family members, friends, and familiar partners. Additionally, the pilot phase only presented data on one participant to show proof of concept. More subjects, even with an SCRD, are needed to determine the effect of long-term CoChat use.

Future studies

This SCRD is a small study that demonstrated feasibility of an innovative language support. Future research is needed with larger groups of participants to determine if CoChat or a similar just-in-time language support is effective over time and with individuals who present with the three variants of PPA. Analysis of conversation with targeted words to examine the quality and meaningfulness of word choice could highlight differences in the behavioural manifestations and treatment for the PPA variants. An examination of generalization effects with AAC supports is needed now that evidence is available on the value of just-in-time VSDs with personalized vocabulary. Additionally, with a longitudinal experimental design, we will learn about what language supports and treatment paradigms maintain lexical retrieval and conversational participation as individuals continue to lose language and eventually cognitive skills.

Conclusions

This alternating treatments experimental design with six participants and their CPs demonstrates that the use of CoChat, an iOS app that captures photos for just-in-time annotation through a simulated social media, is a powerful AAC compensatory strategy to support conversational participation in adults with mild-to-moderate PPA.

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Appendix A.

CoChat app operations: proficiency demonstration sheet

Participant # _____

Levels of cueing: least amount of support to most
Independent: participant requires no reinstruction.
Verbal instructions: state, "You need to press the "___" to make it "___". Please press "___". RA is repeating the verbal instructions and restating the item they want pressed.

General iPad mastery: (+/–)	Initial training	S1	S2	S3	S4	S5	S6	S7	S8
Demonstrate touch with pad of finger Demonstrate light, single touches.									
	Levels of Cueing								
Date:	Initial training	S1	S2	S3	S4	S5	S6	S7	S8
To get the app working, first Press Home button Press Arrow to slide open Press CoChat app icon Find your initials to choose your participant set (cued by RA) *Now we're going to practice taking a new picture*: Press 'New Photo' Press anywhere to take photograph *hold iPad in landscape orientation with the home button on right side* Press and hold unwanted photo and press delete. Press the BACK button									

Direct model with tactile and verbal cues: RA verbally repeats the instruction and physically touches the desired location on the iPad. "So, in order to get the iPad to "____",
I have to press with the pad of my finger on the "_____"."

Based on Sohlberg, M. M. and Turkstra, L. S. (2011).

Appendix B.

Using photos or CoChat app in conversation: mastery demonstration sheet

Participant # _____ **Date**: _____

RA states, "We are using pictures and pictures with words to tell a story. Today we will practice with three different examples."

Photo only

RA states, "Take a moment to look at this photograph. This may help you tell your story. Communicate at least 3 details about this picture to me."

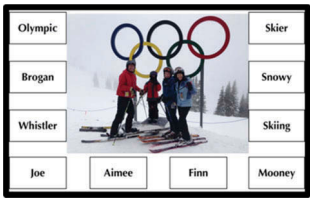
	Ice cream	Birthday	Skiing
Participant communicates a minimum of three accurate details.			

CoChat app

RA States, "*T*ake a moment to look at this app with a photograph and words. There are ten words around the picture. First, let's make sure you see some of the words." RA asks participant to point to one word each on left, right and underneath photo, after stating the word.

CoChat app

RA states, "Take another moment to look at the photograph and all of the words. This may help you tell your story. Now, communicate at least 3 details about this picture for me."



	Ice cream	Birthday	Skiing
Participant communicates a minimum of three accurate details.			

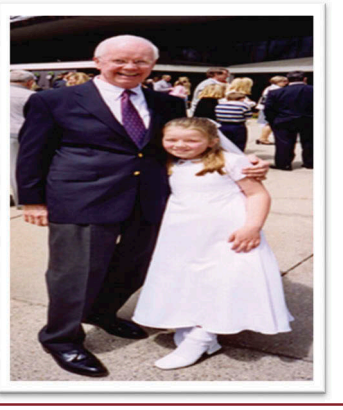
	Ice cream	Birthday	Skiing
Participant communicates a minimum of three accurate details.			

Appendix C.

CoChat app: rules for labelling photographs (second researcher)

Imagine that a member of your social network has difficulty finding words during conversation. They post a picture on a social media website for your viewing and comments. Please write 10 comments to describe the photo. Your comments provide them vocabulary.

- Describe the picture in using the five Ws: **who, what, when, where, why.**
- Use comments, NOT questions (the tone is to be informative; not conversational).
- Use **complete sentences**, not individual words or fragments, with a period at the end.
- Use a word representing a **socially relevant event** (e.g., birthday, wedding).
- Use a **noun** labelling a person or object depicted in photograph (e.g., minister or dress).
- Use a **verb** relating to the action taking place in the photograph (e.g., pouring).
- Use **proper nouns** (e.g., SeaRay, Aimee), but NOT the name of the participant.
- Name the **setting** (e.g., specific name, Dawson Park, or generic term, park).



Good examples	Poor examples	Good examples	Poor examples
Mike and your **dad** on a **boat** ride on a **lake**. (nouns, setting)	What lake are you on?	**Grandpa Jerry** and **Jessica** look happy(proper nouns)	They look happy (no specific nouns)
They are celebrating Mike's **birthday**. (socially relevant)	Rocking it!(vague)	**First Communion St Mary's** church (proper noun/ setting)	What a great day! (vague)
Mike loves **driving** the boat. (verb)	Great day!	Jessica's **dress** and white **shoes** fancy(nouns)	How cute (no nouns)
A perfect **Michigan** summer day on the lake. (proper noun/ setting)	The hat looks good	Jessica is growing taller everyday (verb)	
It's **Fourth of July** weekend too. (socially relevant)	Is it sunny?(question)		

Based on work by McKelvey et al. (2010).