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Prophylaxis and Remediation of Anomia in the Semantic and Logopenic Variants of Primary Progressive Aphasia

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Abstract

This study evaluated the efficacy of phonological and orthographic treatments for anomia in the semantic and logopenic variants of primary progressive aphasia (svPPA and lvPPA). Both treatments were administered for six months. The treatment stimuli consisted of nouns that were consistently named correctly at baseline (prophylaxis items) and/or nouns that were consistently named incorrectly at baseline (remediation items). Oral naming accuracy was measured for trained and untrained picture exemplars, as well as matched items from an untrained condition (UC). Written naming and scene description tasks were also conducted. For all tasks, the change in naming accuracy from baseline to one month post-treatment was compared between UC and each treatment condition. These comparisons indicated that both treatments were effective in the remediation and prophylaxis of anomia in both variants. Furthermore, generalization to untrained exemplars occurred in both subtypes, whereas item generalization occurred in lvPPA, and task generalization was present in svPPA.

Keywords

treatment; primary progressive aphasia; anomia

Introduction

In the clinical syndrome of primary progressive aphasia (PPA), language impairment becomes more severe over time, while other aspects of cognition, such as episodic memory and visuospatial abilities, are relatively unimpaired during the initial stages of the syndrome (Mesulam, 1982; Gorno-Tempini et al., 2011). As described in the consensus diagnostic criteria (Gorno-Tempini et al., 2011), there are three subtypes of PPA: the nonfluent/agrammatic variant (nfvPPA), the semantic variant (svPPA), and the logopenic variant (lvPPA). The latter two subtypes are associated with prominent anomia for nouns that begins early during the illness. In contrast, in the subtype of nfvPPA, anomia for nouns emerges later during the course of the syndrome (Hillis, Oh, & Ken, 2004; Hillis, Tuffiash, & Caramazza, 2002).

svPPA is characterized by impaired confrontation naming and single-word comprehension deficits. Other deficits such as impaired object knowledge, surface dyslexia, or surface dysgraphia may also be present, whereas repetition and speech production are typically spared. svPPA has been associated with bilateral atrophy of the ventrolateral anterior temporal lobe, typically with greater atrophy in the left hemisphere (Gorno-Tempini et al., 2004, 2011; Mummery et al., 2000). In a majority of cases, svPPA has been associated with ubiquitin and TDP-43 positive FTLN (FTLN-U or FTLN-TDP; Hodges et al., 2004; Knibb et al., 2006; Mesulam et al., 2014).

Multiple studies have focused on the treatment of anomia in svPPA, and these studies have typically found that anomia treatment has a positive effect (see reviews by Cathery-Goulart et al., 2013; Croot, Nickels, Laurence, & Manning, 2009; Jokel, Graham, Rochon, & Leonard, 2014). Treatment approaches have included semantic, phonological, and orthographic interventions, as well as hybrid treatments. While treatment is effective in this subtype, anomia treatment effects do not typically generalize to untreated items or untrained tasks (see Jokel et al., 2014).

lvPPA is characterized by impaired single-word retrieval and impaired repetition of sentences and phrases. These deficits may be accompanied by phonological errors in spontaneous speech and/or naming. Single-word comprehension, object knowledge, motor speech, and grammar are typically unimpaired. lvPPA has been associated with atrophy of the left inferior parietal lobe and the left posterior superior temporal lobe (Gorno-Tempini et al., 2004; Josephs et al., 2013; Rohrer et al., 2010). In a majority of cases, lvPPA has been associated with an atypical form of Alzheimer's disease (AD; Mesulam et al., 2008; Mesulam et al., 2014; Rabinovici et al., 2008).

Five studies have focused on the treatment of anomia in a single participant with lvPPA¹ (Beeson et al., 2011; Croot et al., 2014; Henry et al., 2013; Meyer, Snider, Eckmann, & Friedman, 2015; Newhart et al., 2009), and all of these studies have found positive treatment effects. Treatment types have included combined phonological/orthographic (Croot et al., 2014; Newhart et al., 2009), semantic/orthographic (Beeson et al., 2011), and semantic/phonological/orthographic (Henry et al., 2013) interventions, while Meyer, Snider et al. (2015) compared separate phonological and orthographic treatments. Three of these studies found generalization to untreated items (Beeson et al., 2011; Henry, et al., 2013; Newhart et al., 2009), while Meyer, Snider et al. (2015) found cross-language transfer within confrontation naming and naming to definition tasks.

Anomia may be the result of difficulty at the level of accessing semantic representations, difficulty accessing phonological representations, or both types of difficulty. Semantic deficits and semantic paraphasic errors occur in svPPA, suggesting that the first type of difficulty is more likely in this subtype (Hodges, Patterson, & Tyler, 1994; Mesulam et al., 2009; Neary et al., 1998). In contrast, phonemic paraphasic errors are more likely to occur in

¹Three of these studies (Croot et al., 2014; Henry et al., 2013; Newhart et al., 2009) included an additional participant with a different subtype of PPA.

lvPPA (Gorno-Tempini et al., 2008; Henry & Gorno-Tempini, 2010), suggesting that the second type of difficulty is more likely in this subtype.

Two types of treatment for anomia were employed in the current study: a phonological treatment condition (PTC), and an orthographic treatment condition (OTC) that includes reading and writing tasks. In PTC, an auditorily-presented word occurs in conjunction with the corresponding picture, and the word is repeated by the participant. The goal of PTC is to strengthen the phonological representations of the treated words, thereby facilitating their production (see Figure 1a). In OTC, the written word is presented with the corresponding picture, and the word is read out loud and copied by the participant. The goal of OTC is to strengthen the orthographic representations of the treated words, thereby bolstering the alternative, orthographic route to word production (see Figure 1b).

These treatments were utilized in a recent study that involved a Norwegian-English bilingual participant with lvPPA (Meyer, Snider et al., 2015). Both treatments were conducted in English. Compared to an untrained condition, OTC improved the maintenance of English written naming and the oral naming and naming to definition of the corresponding items in Norwegian, whereas PTC had a marginal effect on the maintenance of English oral naming. Based on this pattern of treatment effects, it was argued that OTC strengthened the orthographic representations of trained items in the treated language, and that OTC also strengthened the language-independent semantic representations of treated items, resulting in improved naming in the untrained language. In contrast, PTC appeared to strengthen the phonological representations of treated items. This pattern leads to the prediction that OTC should be more effective than PTC in svPPA. Furthermore, PTC and OTC should both be effective in lvPPA, since each treatment would be expected to facilitate access to phonological representations, either by strengthening these representations, or by bolstering an alternative route to these representations, respectively.

A within-subjects design was utilized in the current study, allowing both treatments to be tested in the same participants. While some studies of anomia treatment in PPA have tested different treatments in different individuals (e.g., Henry et al., 2013; Savage, Ballard, Piguet, & Hodges, 2013), a within-subjects design has rarely been utilized in such studies (one exception is Jokel & Anderson, 2012). As a result, it can be difficult to determine if differences in the observed treatment effects are due to individual differences or disparities in treatment efficacy. In addition, treatment has often focused on both orthographic (e.g., word transcription) and phonological (e.g., word repetition) tasks, making it difficult to determine which aspects of the treatment are producing the positive effects. Both of these issues can be addressed by a within-subjects design that includes separate orthographic and phonological treatments.

Treatment studies for anomia in PPA have typically focused on the remediation of words that could not be named at baseline, rather than the prophylaxis of words that could be named at baseline (see Jokel et al., 2014). However, prophylactic treatment has been found to have positive effects in both svPPA (Jokel, Rochon, & Leonard, 2006; Jokel, Rochon, & Anderson, 2010) and lvPPA (Meyer, Snider et al., 2015). Where feasible, the current study

included both prophylaxis and remediation items for each participant, similar to the studies by Jokel et al. (2006; 2010).

Following a baseline evaluation of language and cognition, PTC and OTC were administered over the course of six months. A post-treatment evaluation began one month after the end of treatment. The one-month delay was included to ensure that any observed treatment effects were not due to the short-term benefits of recent treatment sessions.

Method

Participants

Fourteen participants with svPPA or lvPPA have completed post-treatment testing. Five participants have svPPA, and all of these participants had both prophylaxis and remediation items. All nine of the lvPPA participants had prophylaxis items, and four lvPPA participants had remediation items.

Two participants (SV1 and LV1) participated remotely. These participants showed treatment effects that were similar to those demonstrated by in-person participants (see Meyer, Getz, Brennan, Hu, & Friedman, 2015). For these telerehabilitation participants, the majority of the evaluation sessions and all of the treatment and practice sessions were conducted via videoconferencing.² In addition to the data from these two telerehabilitation participants, some of the data from 10 of the in-person participants were also reported in Meyer, Getz et al. (2015; the exceptions are participants SV5 and LV9).

Demographic information for all participants is presented in Tables 1 and 2. The inclusion criteria were a clinical diagnosis of PPA, English fluency since childhood, at least 10 years of education, age of at least 40 years, and no history of other neurological or psychiatric disorders.

Subtyping was based on the international criteria (Gorno-Tempini et al., 2011). Two neurologists and one clinical neuropsychologist independently reviewed each participant's baseline assessment results and medical history, including the results of prior language and neuropsychological testing. The subtype raters also viewed videos of the participant performing language tasks, including the Cookie Theft narrative (Goodglass, Kaplan, & Barresi, 2001) and the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001). When videos were unavailable, the raters listened to audio recordings. Disagreements between the raters were resolved through additional review of these materials and discussion between the raters.

Stimuli

For each participant, up to 120 items were selected from a set of 294 nouns. For each selected item, there were three different picture exemplars. Oral naming accuracy for

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²Other than the remote delivery of these sessions, the only procedural differences involved minor technical changes. Instead of E-Prime, custom stimulus presentation software was utilized for the telerehabilitation participants. For the practice sessions, the telerehabilitation participant's laptop was used to present the visual stimuli, instead of training cards. In the OTC, the participant copied each word onto a signature pad, rather than a sheet of paper.

Exemplar 1 was tested twice during the baseline evaluation, and this exemplar was utilized during treatment. Oral naming accuracy for Exemplar 2 was tested once at baseline. Exemplar 2 was not utilized during treatment, but it was used to assess stimulus generalization during post-treatment testing. Exemplar 3 was only used as a foil during treatment. Exemplar sets 1 and 2 have high name agreement, as determined by norming conducted with unimpaired controls. For Exemplar 1, the unimpaired group consisted of 24 individuals with a mean age of 52.3 ($SD = 7.0$) and mean education of 15.4 years ($SD = 2.4$). For Exemplar 2, the unimpaired group consisted of 24 individuals with a mean age of 51.4 ($SD = 7.5$) and mean education of 15.9 years ($SD = 2.1$).

Each selected item was either named correctly by the participant during all three of the baseline oral naming tests (Prophylaxis Items), or it was named incorrectly during all three of these tests (Remediation Items). All of the selected words were read and repeated accurately at baseline. The selected items were divided into three sets and were matched across sets for frequency (Baayen, Piepenbrock, & Gulikers, 1995), semantic category, and number of syllables, phonemes, and letters.

Participants typically had 40 items per treatment condition, resulting in 80 trained items per session. For five participants (SV2, LV4, LV7, LV8, and LV9), filler items were included in order to reach 40 items per condition. The fillers were selected from the items that could not be matched across conditions, and they were not included in the statistical analyses. See Table 3 for the number of critical items per condition for each participant.

Procedure

Timeline—Following the baseline evaluation, treatment took place during the next six months. In the first month of treatment, there were two sessions per week. Each session lasted about 45 minutes and included both types of treatment. After the participant had become familiar with the treatment tasks during the first month, the home practice period began. During this five-month period, shorter (10 to 15 minutes) practice sessions occurred at home three times per week. One treatment session also occurred each month, in order to check in with the participant and verify that he or she was performing the treatment tasks correctly. Thus, participants completed 13 treatment sessions and about 60 practice sessions. The post-treatment evaluation began one month after the end of all treatment and practice sessions.

Baseline evaluation—The baseline evaluation occurred over the course of six sessions, with one or two sessions per week. During these sessions, participants completed a battery of language and cognitive tests, including the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), the BNT, the 3-Picture version of the Pyramids and Palm Trees test (P&PT; Howard & Patterson, 1992), Word-Picture Matching (Rogers & Friedman, 2008), subject and object Wh-questions from the Northwestern Anagram Test (NAT; Weintraub et al., 2008), selected subtests from the Boston Diagnostic Aphasia Examination (BDAE; Goodglass et al., 2001), repetition of 5-syllable pseudowords, and the reading and spelling of irregular and regular words. The latter repetition, reading, and spelling tasks were

developed at the Center for Aphasia Research and Rehabilitation at Georgetown University Medical Center. The baseline assessment results are presented in Tables 1 and 2.

Individualized treatment words were selected as described above. After stimulus selection, accuracy for the selected items was also tested in two other ways: written confrontation naming and naming during scene description. In the first task, the participant was asked to print the name of each Exemplar 1 picture. In the second task, the participant was asked to describe a visual scene. Each scene contained one of the selected items.

Orthographic treatment condition (OTC)—In OTC, E-Prime (Psychology Software Tools) was used to present stimuli in the following sequence: 1) Picture alone, 1.5 seconds. 2) The written word under the picture, in one of 15 fonts, 1.5 seconds. 3) The word alone, 1.5 seconds. 4) The picture-word combination (PWC) appeared again, and the participant was asked to read the word aloud. 5) A beep then signaled the participant to copy the word onto a response sheet. 6) Two recognition slides were presented in succession, with the words “Did you see this?” and either the correct PWC or a foil. Instructions specified that both the identical exemplar of the picture and the word in the identical font had to be present for a “Yes” response. The participant responded by saying “Yes” or “No.” The foil used for each PWC was one of the following: 1) The correct picture paired with the written word in a second, incorrect font; 2) An incorrect exemplar of the picture paired with the correct font; or 3) The incorrect exemplar of the picture with the second, incorrect font. To perform this task correctly, visual aspects of both the picture and the word must be encoded (i.e., this task cannot be done verbally). The purpose of this task is to ensure that the participant is focusing on both the picture and the written word.

Phonological treatment condition (PTC)—This treatment was similar in design to the OTC. However, the picture was not accompanied by its written name. Instead, it was accompanied by a string of symbols (e.g., #\$\$\$) in a specific font. The symbol string, though unrelated to the picture, was included in this condition so that the participant would perform the same task as in the OTC, thereby keeping the conditions well matched for activity and engagement. The participant was asked to look at the picture and string of symbols on the screen as the pre-recorded name was presented auditorily, and then to repeat the name.

The participant was then given a yes/no recognition task analogous to the one given in the OTC: the task and foil options were the same, the symbols appeared in one of 15 distinctive fonts, and the participant was asked to remember both the symbols and the picture. The symbols themselves, like the words in the OTC, did not change in the foils; only the font was changed.

Spaced retrieval learning—A spaced retrieval paradigm was incorporated into the design at the stage of the recognition slides (#6 above) to increase the likelihood of long-term retention (e.g., Fridriksson, Holland, Beeson, & Morrow, 2005). There were three levels of spacing. First, in level 1, each PWC or picture-symbol combination (PSC) was presented alone, followed immediately by the yes-no recognition test. If a recognition accuracy of 90% was reached in both treatments, then the participant advanced to level 2, in

which the number of events (trials or tests) between the PWC or PSC and its recognition test was increased by one. Here, the participant was presented with two PWC or PSC trials in a row, and then their recognition tests were presented in the same order. Similarly, if the participant reached 90% accuracy on level 2, then he or she advanced to the next level, in which four trials were followed by four recognition tests.

Home practice sessions—The home practice sessions were similar to the treatment sessions, except that the recognition tests were omitted. Each participant used training cards to perform these tasks with a caregiver three times per week. During the five-month home practice period, one treatment session was also conducted each month.

Each card in the OTC had one picture on the front. The back of the card had the same picture with the corresponding written word. The participant looked at the picture on the front, turned the card over, read aloud the name of the picture, and then copied the name on a response sheet.

Each card in the PTC had one picture on the front, while the back had the same picture with the associated symbol string. The participant looked at the picture on the front, and then looked at the picture and symbols on the back. The caregiver then spoke the name of the picture, which the participant repeated.

The caregiver also ensured that the participant practiced the two sets appropriately and kept a practice session log. The experimenters collected the cards and session log at the end of the six-month treatment period.

Post-treatment evaluation—Post-treatment testing began one month after the end of treatment. During this evaluation, treatment effects were measured, and the language and cognitive battery was re-administered. No testing was conducted between the baseline and post-treatment evaluations.

Data analysis—Naming accuracy was analyzed separately for prophylaxis and remediation items. For each participant, the change in naming accuracy from baseline to post-treatment was calculated for each type of item (prophylaxis or remediation) within each treatment condition (UC, PTC, or OTC). For each combination of PPA subtype and task, a one-way repeated-measures analysis of variance (ANOVA) was used to examine the effect of treatment condition. The Greenhouse-Geisser correction was utilized when Mauchly's Test indicated that sphericity was not present.

Results

svPPA

Oral Naming, Prophylaxis Items—The change in naming accuracy for each task and condition is plotted in Figure 2. The effect of treatment condition was significant for the oral naming of Exemplar 1 [$F(2, 8) = 10.23, p = .006$] and Exemplar 2 [$F(2, 8) = 29.57, p < .001$]. Compared to UC, the decline in naming accuracy for each exemplar was significantly smaller in each treatment condition [PTC, Exemplar 1: $t(4) = 4.86, p = .008$; PTC, Exemplar

2: $t(4) = 10.75, p < .001$; OTC, Exemplar 1: $t(4) = 3.53, p = .024$; OTC, Exemplar 2: $t(4) = 5.50, p = .005$]. The decline in naming accuracy for each exemplar was not significantly different between PTC and OTC [Exemplar 1: $t(4) = 1.28, p = .271$; Exemplar 2: $t(4) = -0.25, p = .815$].

Written Naming, Prophylaxis Items—The effect of treatment condition was significant for written naming [$F(2, 8) = 6.09, p = .025$]. Compared to UC, the decline in written naming accuracy was significantly smaller in OTC [$t(4) = 5.52, p = .005$], but the decline in naming accuracy was not significantly different in PTC [$t(4) = 2.08, p = .106$]. The change in naming accuracy was not significantly different between PTC and OTC [$t(4) = 0.47, p = .664$].

Scene Description, Prophylaxis Items—The effect of treatment condition was significant for the scene description task [$F(2, 8) = 6.05, p = .025$]. Compared to UC, the decline in naming accuracy was significantly smaller in OTC [$t(4) = 3.35, p = .029$] and marginally smaller in PTC [$t(4) = 2.25, p = .088$]. The change in naming accuracy was not significantly different between PTC and OTC [$t(4) = 0.65, p = .551$].

Oral Naming, Remediation Items—The change in naming accuracy for each task and condition is plotted in Figure 3. The effect of treatment condition was significant for the oral naming of Exemplar 1 [$F(2, 8) = 11.49, p = .004$] and Exemplar 2 [$F(2, 8) = 12.99, p = .003$]. Compared to UC, the increase in naming accuracy for each exemplar was significantly greater in each treatment condition [PTC, Exemplar 1: $t(4) = 3.60, p = .023$; PTC, Exemplar 2: $t(4) = 6.90, p = .002$; OTC, Exemplar 1: $t(4) = 4.34, p = .012$; OTC, Exemplar 2: $t(4) = 3.97, p = .017$]. The increase in naming accuracy for each exemplar was not significantly different between PTC and OTC [Exemplar 1: $t(4) = 1.04, p = .355$; Exemplar 2: $t(4) = 1.41, p = .230$].

Written Naming, Remediation Items—The effect of treatment condition was significant for written naming [$F(2, 8) = 6.05, p = .025$]. Compared to UC, the increase in written naming accuracy was significantly greater in each treatment condition [PTC: $t(4) = 3.25, p = .031$; OTC: $t(4) = 3.13, p = .035$]. The increase in naming accuracy was not significantly different between PTC and OTC [$t(4) = -1.35, p = .249$].

Scene Description, Remediation Items—The effect of treatment condition was significant for the scene description task [$F(2, 8) = 8.16, p = .012$]. Compared to UC, the increase in naming accuracy was significantly greater in each treatment condition [PTC: $t(4) = 3.36, p = .028$; OTC: $t(4) = 3.30, p = .030$]. The increase in naming accuracy was not significantly different between PTC and OTC [$t(4) = -1.67, p = .170$].

Summary—For prophylaxis items, each treatment resulted in a significantly smaller decline in oral naming accuracy, and these treatment effects generalized to untrained picture exemplars. In the written naming and scene description tasks, the OTC resulted in a significantly smaller decline in naming accuracy in both tasks, while the PTC resulted in a marginally smaller decline in the scene description task. For remediation items, each

treatment resulted in a significantly larger increase in naming accuracy for all exemplars and tasks.

IvPPA

Oral Naming, Prophylaxis Items—The change in naming accuracy for each task and condition is plotted in Figure 4. For oral naming, the effect of treatment condition was not significant for Exemplar 1 [$F(2, 16) = 2.38, p = .125$], but it was significant for Exemplar 2 [$F(2, 16) = 5.15, p = .019$]. For Exemplar 2, compared to UC, the decline in naming accuracy was significantly smaller in PTC [$t(8) = 3.16, p = .013$] and OTC [$t(8) = 2.36, p = .046$]. Compared to PTC, the decline in naming accuracy for Exemplar 2 did not differ in OTC [$t(8) = -0.01, p = .991$].

Written Naming, Prophylaxis Items—The effect of treatment condition was not significant for written naming [$F(1.1, 9.1) = 0.92, p = .376$].

Scene Description, Prophylaxis Items—The effect of treatment condition was not significant for the scene description task [$F(2, 16) = 1.27, p = .308$].

Oral Naming, Remediation Items—The change in naming accuracy for each task and condition is plotted in Figure 5. For oral naming, the effect of treatment condition was significant for Exemplar 1 [$F(2, 6) = 6.19, p = .035$], but it was not significant for Exemplar 2 [$F(2, 6) = 2.80, p = .138$]. For Exemplar 1, compared to UC, the increase in naming accuracy was marginally greater in PTC [$t(3) = 3.03, p = .056$], but it did not differ in OTC [$t(3) = 1.49, p = .233$]. Compared to OTC, the increase in naming accuracy in PTC was marginally greater for Exemplar 1 [$t(3) = 2.96, p = .060$].

In order to examine the apparent increase in oral naming accuracy in UC, the effect of time point was examined. From baseline to post-treatment, there was a significant increase in oral naming accuracy for Exemplar 1 [$F(1, 3) = 65.05, p = .004$] and Exemplar 2 [$F(1, 3) = 24.37, p = .016$]. The increase in oral naming accuracy was significant or marginally significant within every condition [Exemplar 1: UC: $t(3) = 2.78, p = .069$; PTC: $t(3) = 5.75, p = .010$; OTC: $t(3) = 3.62, p = .036$; Exemplar 2: UC: $t(3) = 5.18, p = .014$; PTC: $t(3) = 3.59, p = .037$; OTC: $t(3) = 3.78, p = .032$].

Written Naming, Remediation Items—The effect of treatment condition was significant for written naming [$F(2, 6) = 5.18, p = .049$]. Compared to UC, the increase in written naming accuracy was significantly greater in OTC [$t(3) = 3.60, p = .037$], but the change in naming accuracy was not significantly different in PTC [$t(3) = 2.23, p = .113$]. The change in naming accuracy was not significantly different in PTC and OTC [$t(3) = -1.30, p = .286$].

Scene Description, Remediation Items—The effect of treatment condition was not significant for the scene description task [$F(2, 6) = 1.26, p = .350$].

Summary—For prophylaxis items, the decline in naming accuracy for Exemplar 2 was significantly smaller in both treatment conditions, compared to UC. For remediation items,

compared to UC, the increase in oral naming accuracy for Exemplar 1 was marginally greater in PTC. Moreover, the increase in oral naming accuracy from baseline to post-treatment was significant or marginally significant for both exemplars, within every condition. In addition, the increase in written naming accuracy was significantly greater in OTC, compared to UC.

Discussion

The goal of the current study was to examine the efficacy of two treatments for anomia in svPPA and lvPPA. Following a baseline evaluation of language and cognition, a phonological treatment condition (PTC) and an orthographic treatment condition (OTC) were administered over the course of six months. One month after the end of treatment, naming accuracy was measured, and the change in naming accuracy was compared between the treated items and items from the matched untrained condition (UC). Based on previous findings (Meyer, Snider et al., 2015), it was predicted that OTC would be more effective in svPPA, while PTC and OTC were both expected to be effective in lvPPA.

In svPPA, both treatments were effective in the prophylaxis and remediation of anomia, compared to UC. For remediation items, both treatments resulted in significantly greater oral and written naming accuracy, and the treatment effects generalized to untrained picture exemplars (Exemplar 2). The treatment effects also generalized to untrained tasks, including scene description in both treatment conditions, as well as written naming, which was an untrained task in PTC. For prophylaxis items, both treatments resulted in a significantly smaller decrease in oral naming accuracy for trained and untrained exemplars, but only OTC resulted in a significantly smaller change in naming accuracy within the written naming and scene description tasks. Therefore, orthographic treatment may be more effective in the prophylaxis of anomia in svPPA. On the other hand, PTC resulted in a marginally smaller decrease in naming accuracy within the scene description task, and there were no significant differences between PTC and OTC.

A number of studies have examined generalization of anomia treatment effects in svPPA, and generalization does not typically occur (see Jokel et al., 2014). However, generalization to alternative exemplars of trained items has been observed (Green Heredia, Sage, Lambon Ralph, & Berthier, 2009; Jokel et al., 2010), and generalization to untrained items was found in one study (Henry et al., 2013). Furthermore, Jokel and Anderson (2012) found generalization to a category fluency task, while Savage, Piguet, and Hodges (2014) found generalization to several untrained tasks, including video description, comprehension of verbal instructions, and word-picture matching. The current study provides additional evidence that stimulus and task generalization can occur in svPPA. Moreover, significant generalization effects were present in both treatment conditions, suggesting that phonological and orthographic treatments can both strengthen semantic representations (cf. Meyer, Snider et al., 2015).

In lvPPA, there was evidence that both treatments were effective. For prophylaxis items, compared to UC, both treatments resulted in a significantly smaller decline in naming accuracy for untrained picture exemplars (Exemplar 2). In contrast, for trained exemplars

(Exemplar 1), the effect of treatment condition was not significant. This pattern of significant effects for untrained picture exemplars, but not trained exemplars, may be the result of a testing effect. During post-treatment testing, seven of the lvPPA participants were tested on Exemplar 1 before Exemplar 2 (the exceptions were LV6 and LV9). By providing retrieval practice, the initial testing session may have facilitated phonological access for treated items during the subsequent testing session (see Roediger & Butler, 2011).

A different pattern of results occurred for remediation items in lvPPA. Compared to UC, the increase in oral naming accuracy was marginally greater for Exemplar 1 in PTC, while the increase for Exemplar 1 was not marginally or significantly different in OTC, and the effect of treatment condition was not significant for Exemplar 2. However, from baseline to post-treatment there were marginal or significant increases in naming accuracy for both exemplars within all three conditions. Thus, it appears that one or both of the treatments had effects that generalized to untreated items. This type of generalization effect has been found previously in lvPPA (Beeson et al., 2011; Henry et al., 2013; Newhart et al., 2009), and it may be related to a general improvement in phonological access (Newhart et al., 2009). Another possibility is that the increase in accuracy for untreated items is not a treatment effect, and that it resulted from variability in phonological access in lvPPA. However, this possibility seems unlikely, given that the remediation items were selected from the items that were named incorrectly on three occasions during baseline testing.

In conclusion, the findings of this study indicate that phonological and orthographic treatments are both effective in the remediation and prophylaxis of anomia in svPPA and lvPPA. In each treatment condition, both groups showed stimulus generalization, and the svPPA group also demonstrated task generalization. These findings suggest that both treatments strengthened semantic representations. Furthermore, the lvPPA group showed item generalization, suggesting that at least one of the treatments improved access to untreated items. It remains to be seen if these treatment effects will be maintained following post-treatment intervals that are longer than one month, or if clearer differences in treatment efficacy will be observed at later time points. In an attempt to address these issues, we will conduct follow-up evaluations at 8 months and 15 months post-treatment.

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Figure 1.

The blue ovals depict internal representations, while the red rectangles depict external stimuli and outputs. Bold arrows identify the stimuli that were paired during treatment, blue arrows represent the pathways that are normally activated during confrontation naming, red arrows represent additional pathways that were activated during treatment, and shaded blue ovals depict the representations that are intended to be strengthened by treatment.

Figure 2.

Effects of prophylaxis treatment in svPPA. For this figure and those that follow, the change in naming accuracy from baseline to one-month post-treatment is plotted in percentage points, and the bars represent the standard error.

Figure 3.
Effects of remediation treatment in svPPA.

Figure 4.
Effects of prophylaxis treatment in IvPPA.

Figure 5. Effects of remediation treatment in lvPPA. Participants LV1, LV3, LV5, and LV7 had remediation items.

Table 1

Demographic Information and Baseline Assessment Results for Participants with svPPA

	<u>SV1</u>	<u>SV2</u>	<u>SV3</u>	<u>SV4</u>	<u>SV5</u>	<u>M(SD)</u>
Age at Baseline	68	71	61	59	69	65.6 (5.3)
Education (years)	16	20	16	18	16	17.2 (1.8)
Sex	F	M	M	F	M	
MoCA/30	1	20	19	12	20	14.4 (8.2)
Boston Naming Test/60	10	14	11	6	5	9.2 (3.7)
P&PT, 3 Pictures/52	22	38	45	17	41	32.6 (12.3)
Word-Picture Matching/48	39	43	43	15	33	34.6 (11.7)
Northwestern Anagram Test/10	0	4	9	6	9	5.6 (3.8)
BDAE Articulatory Agility/7	7	7	7	7	7	7 (0)
BDAE Phrase Length/7	6	7	7	7	7	6.8 (0.4)
BDAE Embedded Sentences/10	1	9	10	4	8	6.4 (3.8)
BDAE Sentence Repetition/10	3	10	10	2	9	6.8 (4.0)
Pseudoword Repetition/10	4	4	10	6	10	6.8 (3.0)
Reading HF Irregular Words/10	9	10	10	6	10	9 (1.7)
Reading LF Irregular Words/10	7	7	6	1	3	4.8 (2.7)
Reading HF Regular Words/10	8	10	10	9	10	9.4 (0.9)
Reading LF Regular Words/10	9	10	10	9	10	9.6 (0.5)
Spelling HF Irregular Words/10	NA	NA	7	NA	10	8.5 (2.1)
Spelling LF Irregular Words/10	NA	NA	1	NA	3	2 (1.4)
Spelling HF Regular Words/10	NA	NA	8	NA	10	9 (1.4)
Spelling LF Regular Words/10	NA	NA	8	NA	9	8.5 (0.7)

Note. MoCA = Montreal Cognitive Assessment, P&PT = Pyramids and Palm Trees, BDAE = Boston Diagnostic Aphasia Examination, HF = high frequency, LF = low frequency, NA = not administered.

Table 2

Demographic Information and Baseline Assessment Results for Participants with IvPPA

	<u>LV1</u>	<u>LV2</u>	<u>LV3</u>	<u>LV4</u>	<u>LV5</u>	<u>LV6</u>	<u>LV7</u>	<u>LV8</u>	<u>LV9</u>	<u>M (SD)</u>
Age at Baseline	69	66	71	88	73	68	67	67	71	71.1 (6.7)
Education (years)	18	18	18	16	18	18	14	18	16	17.1 (1.5)
Sex	F	F	F	M	F	M	F	F	F	
MoCA/30	12	20	16	5	21	18	12	20	11	15 (5.4)
Boston Naming Test/60	15	46	18	33	31	34	14	37	24	28 (10.9)
P&PT, 3 Pictures/52	49	51	40	35	50	51	48	49	49	46.9 (5.6)
Word-Picture Matching/48	44	48	43	45	48	48	47	48	48	46.6 (2.0)
Northwestern Anagram Test/10	6	9	9	5	7	5	7	5	5	6.4 (1.7)
BDAE Articulatory Agility/7	7	7	7	5	7	7	6	6	7	6.6 (0.7)
BDAE Phrase Length/7	7	7	7	7	7	7	7	7	7	7 (0)
BDAE Embedded Sentences/10	4	10	10	7	10	6	3	5	6	6.8 (2.7)
BDAE Sentence Repetition/10	3	7	8	4	6	7	2	4	6	5.2 (2.0)
Pseudoword Repetition/10	7	9	NA	9	NA	0	0	8	7	5.7 (4.0)
Reading HF Irregular Words/10	10	NA	10	10	10	10	8	10	9	9.6 (0.7)
Reading LF Irregular Words/10	8	NA	9	10	8	9	6	5	10	8.1 (1.8)
Reading HF Regular Words/10	10	NA	10	10	10	10	10	10	10	10 (0)
Reading LF Regular Words/10	8	NA	10	10	10	10	10	10	10	9.8 (0.7)
Spelling HF Irregular Words/10	7	NA	7	7	10	8	NA	10	7	8 (1.4)
Spelling LF Irregular Words/10	2	NA	4	5	10	8	NA	9	3	5.9 (3.1)
Spelling HF Regular Words/10	10	NA	10	9	10	10	NA	10	10	9.9 (0.4)
Spelling LF Regular Words/10	9	NA	9	8	10	6	NA	9	9	8.6 (1.3)

Note. MoCA = Montreal Cognitive Assessment, P&PT = Pyramids and Palm Trees, BDAE = Boston Diagnostic Aphasia Examination, HF = high frequency, LF = low frequency, NA = not administered.

Table 3

Number of Critical Items per Treatment Condition

	<u>Prophylaxis</u>	<u>Remediation</u>	<u>Total per Condition</u>
SV1	10	30	40
SV2	8	31	39
SV3	19	21	40
SV4	12	28	40
SV5	9	31	40
LV1	26	14	40
LV2	40	0	40
LV3	20	20	40
LV4	33	0	33
LV5	23	17	40
LV6	40	0	40
LV7	18	11	29
LV8	34	0	34
LV9	34	0	34

Note. Treatment Condition refers to UC, PTC, or OTC. For five participants (SV2, LV4, LV7, LV8, and LV9), filler items were included in order to reach a total of 40 items per condition.