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Prophylactic Treatments for Anomia in the Logopenic Variant of Primary Progressive Aphasia: Cross-Language Transfer

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Abstract

Background—Treatment studies for anomia in PPA have rarely compared multiple treatments in the same individual, and few anomia treatment studies have included participants with the logopenic variant of PPA (lvPPA).

Aims—The goals of this study were to evaluate two types of treatment for anomia in a bilingual participant (ND) with lvPPA, and to examine possible cross-language transfer of treatment effects.

Methods & Procedures—ND is a Norwegian-English bilingual woman with lvPPA who began this study at the age of 69. In the phonological treatment, ND listened to a word while viewing a corresponding picture, and she repeated the word. In the orthographic treatment, ND read a word out loud while viewing the corresponding picture, and she then copied the word. Both treatments were conducted in English, and accuracy for three tasks (oral naming, written naming, and naming to definition) was assessed in English and Norwegian. The treatment occurred over a one-year period, with eight sessions at the laboratory during the first month, followed by monthly laboratory sessions and thrice-weekly home practice sessions during the subsequent 11 months. Post-treatment assessments were conducted at 1 week, 8 months, 1 year, 20 months, and 3 years.

Outcomes & Results—Compared to untrained items, the orthographic treatment resulted in greater English written naming accuracy. This treatment also resulted in cross-language transfer: greater Norwegian oral naming and naming to definition accuracy. The phonological treatment resulted in marginally greater English oral naming accuracy, but it did not have a significant effect on naming accuracy in Norwegian.

Conclusions—These findings suggest that the orthographic treatment was effective in strengthening the orthographic representations of the treated items, which facilitated ND's written naming performance. The pattern of cross-language transfer suggests that the orthographic treatment also strengthened the language-independent semantic representations of the treated items, thereby facilitating access to their Norwegian phonological representations.

Keywords

primary progressive aphasia; anomia; treatment; bilingualism

Primary progressive aphasia (PPA) is a clinical syndrome that involves language impairment that becomes more severe over time (Mesulam, 1982; Gorno-Tempini et al., 2011). In the initial stages of the syndrome, other cognitive domains, such as episodic memory and visuospatial skills, are relatively unimpaired. Logopenic variant PPA (lvPPA) is a subtype of PPA that involves word-finding deficits and difficulty repeating sentences and phrases (Gorno-Tempini et al., 2011). The most common condition underlying lvPPA is an atypical form of Alzheimer's disease (Mesulam et al., 2008).

In a review of 112 cases of PPA, it was found that anomia “is the most common and earliest deficit” associated with the syndrome (Westbury & Bub, 1997; p. 404). Despite this high prevalence, as of this writing, only three anomia treatment studies have focused on lvPPA (Beeson et al., 2011; Henry et al., 2013; Newhart et al., 2009). In the first of these studies, Newhart et al. utilized a cueing hierarchy that involved confrontation naming, written naming, a notebook search, reading, and repetition. The participant showed improvement in oral naming for both trained and untrained items. Maintenance testing was not reported. Beeson et al. tested a semantic treatment that included generative naming (category fluency) tasks and semantic feature elaboration. The participant's category fluency improved for both trained and untrained categories, and the improvement was maintained for both types of categories at 3 weeks post-treatment. This improvement was maintained only for trained categories at 6 months post-treatment. In addition, the participant showed significant improvement on both the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) and the Philadelphia Naming Test (Roach, Schwartz, Martin, Grewal, & Brecher, 1996) at 3 weeks and 6 months post-treatment. Henry et al. tested a treatment that involved semantic, phonological, and orthographic cueing, as well as semantic feature analysis. The participant showed improvement on spoken and written naming tasks and also demonstrated maintenance of the treatment effect at 3 and 6 months. Furthermore, the participant demonstrated generalization to untrained items on the BNT and the Western Aphasia Battery (Kertesz, 1982) object naming subtest at post-treatment and 3 months post-treatment.

Although some of the studies cited above have tested different types of treatment in different individuals, different treatments have rarely been compared in a within-subjects design (one exception is Jokel & Anderson, 2012). Thus, it is often unclear if differences in the observed treatment effects are due to differences in treatment efficacy or individual differences. Furthermore, treatment has often focused on both phonological (e.g., word repetition) and orthographic (e.g., writing the word) tasks. As a result, it is unclear which aspects of the treatment are driving the beneficial effects. In the current study of a person with lvPPA, we addressed these issues by employing a within-subject design that included two types of treatment: a treatment that focused on phonology, and an orthographic treatment that included both reading and writing. Both treatments included picture stimuli.

Motivation for the two treatments is discussed with reference to the models depicted in Figure 1. In lvPPA, performance on measures of lexical-semantic comprehension is relatively unimpaired (Henry & Gorno-Tempini, 2010), suggesting that semantic representations are intact. Therefore, when an individual with lvPPA makes an error during a confrontation naming task, the difficulty occurs in accessing the word's phonological

representation from its semantic representation. Thus, one possible goal of treatment for anomia in lvPPA could be to strengthen the phonological representation of the word. This might be accomplished by a task that involves repetition of an auditorily-presented word that is presented in conjunction with a corresponding picture (see Figure 1a).

Alternatively, an orthographic treatment that pairs the picture with the written word may be equally effective, because it could bolster a different route to the phonological representation (see Figure 1b). The orthographic treatment that was utilized in the current study involved the oral reading and transcription of a word that was presented with a corresponding picture. The goal of this treatment is to strengthen the orthographic representation of the word, thereby facilitating the participant's access to the orthographic route to word production. Reading deficits are typically mild or absent in PPA (Westbury & Bub, 1997), suggesting that the route between orthography and phonology remains functional, making such an approach tenable. On the other hand, recent examinations of pseudoword reading have indicated that phonological alexia can occur in individuals with lvPPA (Brambati, Ogar, Neuhaus, Miller, & Gorno-Tempini, 2009; Rohrer et al., 2010), suggesting that the route between orthography and phonology may be compromised. If this is correct, then one would not expect an orthographic treatment for anomia to be effective, because phonological representations would be inaccessible via the orthographic route. Another possibility is that the orthographic-phonological route remains largely intact for familiar words (e.g., real words rather than pseudowords). This would increase the likelihood that an orthographic treatment would be effective, since phonological representations would be accessible via the orthographic route.

While treatment was conducted entirely in English, the baseline and post-treatment naming tests were conducted in both English and Norwegian, allowing for an examination of possible cross-language transfer (CLT) of treatment effects from English to Norwegian. CLT has not been examined previously in the PPA treatment literature. However, CLT of anomia treatment effects has been observed in studies involving bilingual participants with post-stroke aphasia, including both CLT from the first-acquired language (L1) to the later-acquired language (L2) and CLT from L2 to L1 (see Ansaldi, Marcotte, Scherer, & Raboyeau, 2008; Faroqi-Shah, Frymark, Mullen, & Wang, 2010; Kiran, Sandberg, Gray, Ascenso, & Kester, 2013; Kohnert, 2009). In a review of treatment studies that involved bilingual participants, Faroqi-Shah et al. did not find any relationships between CLT and the type of aphasia, aphasia severity, or time post-onset. Thus, it appears that the phenomenon of CLT is not limited to specific aphasic subgroups, and it is possible that CLT would occur as a result of language treatment in PPA.

In contrast to the previous treatment studies for anomia in lvPPA (Beeson et al., 2011; Henry et al., 2013; Newhart et al., 2009), the current study focused on the prophylaxis of words that could be named at baseline, rather than the remediation of words that could not be named. If an individual's naming deficit is relatively mild when treatment is initiated, then prophylaxis may be a more appropriate goal than remediation.

Unlike the gradual improvement that is associated with recovery in post-stroke aphasia, PPA involves a progressive decline in language functioning, and treatment occurs within this

context. In the current study, treatment was conducted over the course of one year. It was expected that one year would be a sufficient amount of time for treatment to have a positive effect on naming accuracy for the trained items, and it was expected that accuracy would decline for untrained items during this time period. Post-treatment testing occurred at 1 week, 8 months, 1 year, 20 months, and 3 years.

Method

Case History and Cognitive Profile

ND is a bilingual woman who enrolled in this study at the age of 69. She was diagnosed with lvPPA at the age of 67, following a three-year history of word-finding and spelling difficulties. Prior to diagnosis, a PET scan with CT fusion showed a decrease in metabolic activity within the left temporoparietal cortex.

ND's native language is Norwegian, and she learned English in grade school (beginning at age 7). She completed college in Norway, and she obtained a graduate degree in social work after moving permanently to the United States in the 1960's. When she enrolled in this study, English had been her primary language for approximately forty years, although she regularly speaks Norwegian in telephone conversations with family members. Furthermore, she has typically visited Norway for one month each year and speaks Norwegian during these visits.

During the baseline evaluation sessions, several tests of cognition and language were administered (see Tables 1 and 2), including the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975); the Test of Nonverbal Intelligence (Brown, Sherbenou, & Johnsen, 1997); Raven's Coloured Progressive Matrices (Raven, Court, & Raven, 1995); Digit and Spatial Span subtests from the Wechsler Memory Scale (The Psychological Corporation, 1997); the 3 Pictures and 3 Words subtests of the Pyramids and Palm Trees Test, which examines semantic processing (Howard & Patterson, 1992); the BNT; and the Boston Diagnostic Aphasia Examination (BDAE; Goodglass, Kaplan, & Barresi, 2001). The MMSE, BNT, and selected BDAE subtests were also administered in Norwegian. These tests and subtests were translated by an experienced Norwegian translator (the third author).

Baseline testing indicated that general cognitive functioning, nonverbal reasoning, short-term memory, and semantic processing were unimpaired, whereas naming performance was clinically impaired in both languages. ND's performance on the BDAE indicated difficulty with tasks involving sentence repetition, spelling of common irregular words, and written picture naming.

Materials and Procedure

During baseline testing, ND was asked to name 160 English nouns on three occasions. The same 160 nouns were represented by two different sets of 160 clip-art pictures: the Exemplar 1 set, which was tested twice, and the Exemplar 2 set, which was tested once. The Exemplar 1 set contained the images that were utilized during treatment, whereas the Exemplar 2 images were not seen during treatment.

During different days of the baseline assessment, two additional tasks were conducted: in the written naming task, ND was asked to print the name of each picture in the Exemplar 1 set; in the naming to definition task, a written definition for each of the 160 items was presented on the screen, and the definition was read out loud by the experimenter. ND was asked to name the corresponding word.

The five baseline tasks (naming Exemplar 1 on two occasions, naming Exemplar 2, written naming of Exemplar 1, and naming to definition) were also conducted in Norwegian. For the naming to definition task, an experienced Norwegian translator was videotaped while speaking each definition in Norwegian, and this video was shown to ND.

For the ten baseline tasks (five in English and five in Norwegian), the items were presented in the same pseudo-randomized order each time, with the exception of the naming to definition task, which utilized a different pseudo-randomized order. However, there was an interval of at least five days between each baseline task.

Sixty nouns with consistently correct oral naming for both exemplars in both languages were identified, and these nouns were then assigned to one of three conditions – orthographic treatment, phonological treatment, or untrained items. The selected nouns were matched across conditions for frequency in each language (Baayen, Piepenbrock, & van Rijn, 1993; Guevara, 2010), as well as the number of syllables, phonemes, and letters within each language (see Table 3 for the mean stimulus characteristics in each language and the Appendix for a list of stimuli).¹

Written naming and naming to definition accuracy were not deliberately matched across the three conditions prior to treatment. However, the chi-square test (or a twotailed Fisher's exact test, when the minimum expected cell count was less than 5) did not indicate a significant difference between any of the conditions at baseline for Written Naming in English (Phonological vs. Untrained: $\chi^2(1, N = 40) = 1.03, p = .31$; Orthographic vs. Untrained: $\chi^2(1, N = 40) = .44, p = .51$; Orthographic vs. Phonological: $\chi^2(1, N = 40) = .13, p = .72$) or Norwegian (Phonological vs. Untrained: $p = 1$, Fisher's exact test; Orthographic vs. Untrained: $p = 1$, Fisher's exact test; Orthographic vs. Phonological: $p = 1$, Fisher's exact test); nor for Naming to Definition in English (Phonological vs. Untrained: $p = 1$, Fisher's exact test; Orthographic vs. Untrained: $p = .34$, Fisher's exact test; Orthographic vs. Phonological: $p = .66$, Fisher's exact test) or Norwegian (Phonological vs. Untrained: $p = 1$, Fisher's exact test; Orthographic vs. Untrained: $p = 1$, Fisher's exact test; Orthographic vs. Phonological: $p = 1$, Fisher's exact test).

Treatment Timeline—Treatment took place over the course of one year. In the first month, ND visited the laboratory for two treatment sessions per week. Each session included both types of treatment. During the subsequent 11 months, ND visited the laboratory for one session per month, and she completed home practice three times per week.

¹The items were not matched across conditions for semantic category. However, ND's performance on Pyramids and Palm Trees suggests that her semantic processing remained intact over time (see Table 1).

Orthographic Treatment—All treatment sessions were conducted in English. In the orthographic treatment, E-Prime (Psychology Software Tools) was used to present stimuli on a computer screen 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 together again, and the participant was asked to read the word aloud, 3 seconds. 5) A beep then signaled ND to copy the word onto a sheet of paper. 6) Two recognition slides were presented in succession, with the words “Did you see this exact combination?” 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 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. ND pressed a key corresponding to either “yes” or “no” and her answers were recorded by E-Prime. 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—This treatment was similar in design to the orthographic treatment. However, the picture was not accompanied by its written name. Rather, 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 ND would perform the same task as in the orthographic condition, thereby keeping the conditions well matched for activity and engagement. ND 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. ND was then given a yes/no recognition task analogous to the one given in the orthographic treatment: the task and foil options were the same, the symbols appeared in one of 15 distinctive fonts, and she had to remember both the symbols and the picture. The symbols themselves, like the words in the orthographic treatment, 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). First, in level 1, each PWC or picture-symbol combination (PSC) was presented alone, followed immediately by the yes-no recognition test. When a recognition accuracy of 90% was reached, ND moved to level 2, in which the spacing between the PWC or PSC and its recognition test was increased by one. Here, ND was presented with two PWC or PSC trials in a row, and then their recognition tests were presented, in the same order. However, when recognition accuracy fell below 90%, ND returned to level 1.

Home Practice—ND was given two stacks of index cards for the home practice sessions. Each card in the orthographic treatment set had one picture on the front. The back of the card had the same picture with the corresponding written word. During home practice with

this set, ND looked at the picture on the front, turned the card over, read aloud the name of the picture, and then transcribed the name on a response sheet.

Each card in the phonological treatment set had one picture on the front, while the back had the same picture with the associated symbol string. ND looked at the picture on the front, and then looked at the picture and symbols on the back. Her caregiver then spoke the name of the picture, which ND repeated. Her caregiver also ensured that she practiced the two sets appropriately and kept a home practice treatment log. The cards and treatment log were collected by the experimenters at the end of the one-year treatment period.

Post-treatment Testing—A post-treatment assessment began one week after the completion of treatment. The assessment included the tests of oral naming, written naming, and naming to definition that were administered during the baseline evaluation, each conducted during a separate session. Additional testing was performed at 8 months, 1 year, 20 months, and 3 years post-treatment. Standardized tests of language and cognition were also administered during these evaluations (see Tables 1 and 2). The naming to definition task was not administered at 8 months post-treatment.

Data Analysis—In order to decrease the familywise error rate and increase statistical power, the accuracy data from 1 week post-treatment through 20 months post-treatment were summed for each combination of language, task, and condition (e.g., for English oral naming within the orthographic condition, the total number of correct responses and the total number of incorrect responses were calculated). Chi-square analyses of the summed naming accuracy data were then used to determine if the proportion of correct items was significantly different between conditions. Because of the long interval between 20 months and 3 years post-treatment, the final time point was analyzed separately from the other post-treatment time points. For all analyses, if the minimum expected cell count was less than five, a two-tailed Fisher's exact test was utilized instead of the chi-square test.

Results

Language and Cognition Tests

ND's semantic processing (P&PT), spatial short-term memory, and nonverbal reasoning (TONI, RCPM) remained intact over time (see Table 1). In contrast, ND's digit span score was at the first percentile at 3 years post-treatment, indicating that her verbal short-term memory, which was in the low average range at baseline and post-treatment, had become impaired by the end of the study. Confrontation naming, which was impaired at baseline, continued to decline over time (see Table 1, BNT scores). ND's performance on BDAE subtests measuring auditory comprehension, sentence repetition, sentence reading, comprehension of written paragraphs, and spelling also declined over time (see Table 2).² Other aspects of language remained relatively intact.

²Two items from the BDAE Written Picture Naming subtest (hanger and giraffe) were included in the untrained condition and the orthographic condition, respectively.

Treatment Results

The accuracy data for the treated and untreated items are presented in Figures 2 – 7. Data from the English oral naming, written naming, and naming to definition tasks are plotted in Figures 2, 3, and 4, respectively. Data from the Norwegian tasks are plotted in Figures 5 – 7.

There were no significant differences between any conditions for any task in either language at 3 years post-treatment. The results presented below all refer to the summed accuracy data from 1 week post-treatment through 20-months post-treatment.

English Language Results

Oral naming: There was no significant difference in oral naming accuracy between the orthographic and untrained conditions or between the orthographic and phonological conditions. Accuracy in the phonological condition was marginally higher than accuracy in the untrained condition ($\chi^2(1, N = 160) = 2.93, p = .087$).

Written naming: Accuracy was significantly higher in the orthographic condition than in the untrained condition, $\chi^2(1, N = 160) = 6.83, p = .009$. Accuracy was also higher in the orthographic condition compared to the phonological condition, $\chi^2(1, N = 160) = 9.45, p = .002$. Accuracy was not significantly different in the phonological and untrained conditions.

Naming to definition—There were no significant differences in naming to definition accuracy between any of the three conditions.

Norwegian Language Results

Oral naming: Compared to the untrained condition, accuracy was significantly higher in the orthographic condition, $\chi^2(1, N = 160) = 5.63, p = .018$. Compared to the phonological condition, accuracy in the orthographic condition was marginally higher, $\chi^2(1, N = 160) = 3.41, p = .065$. Accuracy in the phonological and untrained conditions did not differ.

Written naming: There were no significant differences in written naming accuracy between any of the three conditions.

Naming to definition: Accuracy in the orthographic condition was significantly higher than accuracy in the untrained condition ($\chi^2(1, N = 120) = 4.39, p = .036$) and was marginally higher than accuracy in the phonological condition, $\chi^2(1, N = 120) = 3.00, p = .083$. Accuracy in the phonological and untrained conditions did not differ.

Discussion

The goals of this study were to compare the efficacy of orthographic (reading and writing) and phonological (repetition) treatments for anomia in lvPPA, and to determine if cross-language transfer (CLT) of treatment effects occurs in lvPPA. Given the pattern of relatively unimpaired lexical-semantic comprehension and real word reading that is present in lvPPA (Henry & Gorno-Tempini, 2010), it was expected that the orthographic treatment would be at least as effective as the phonological treatment. Unexpectedly, the orthographic treatment did not have a significant beneficial effect on English oral naming accuracy, while the

phonological treatment resulted in English oral naming accuracy that was marginally greater than accuracy in the untrained condition. However, orthographic training did have a significant beneficial effect on written naming accuracy in English, indicating that this treatment was effective in strengthening the orthographic representations of the trained items (see Figure 1b). Thus, it appears that strengthened orthographic representations did not facilitate oral naming in English. One interpretation of these findings is that phonological representations are inaccessible via the orthographic route in lvPPA (Brambati et al., 2009; Rohrer et al., 2010). Alternatively, the increased strength of the orthographic representation may simply not be sufficient to boost the strength of the impoverished phonological representation.

While no CLT effects resulted from the phonological treatment, the orthographic treatment had a significant positive effect on both Norwegian oral naming and Norwegian naming to definition. These findings suggest that orthographic training in English may have strengthened the treated word's language-independent semantic representation (see Figure 8). A stronger semantic representation could have facilitated access to the treated word's Norwegian phonological representation, resulting in higher accuracy on the oral naming and naming to definition tasks. Although one would expect the orthographic treatment to also facilitate performance within the English oral naming and naming to definition tasks, ND's oral naming ability declined more slowly in English, making it difficult to observe treatment effects. This explanation is supported by ND's more rapidly declining Norwegian BNT accuracy (see Table 1).

Semantic-level CLT effects have been found previously (Edmonds & Kiran, 2006; Kiran et al., 2013). For example, Kiran et al. (2013) utilized a semantic feature analysis treatment with 17 Spanish-English bilingual participants with post-stroke aphasia, and 14 participants showed improved naming accuracy for the trained items. Out of these 14 participants, two also showed improvement for the same items in the untrained language, three showed improvement for semantically-related items in the untrained language, and three showed improved naming accuracy for both the same items and semantically-related items in the untrained language. These findings, and the findings of the current study, are consistent with the hypothesis that semantic representations are shared across languages (Kroll & Stewart, 1994; Kroll, Van Hell, Tokowicz, & Green, 2010).

In the current study, many of the stimulus words were English-Norwegian cognates (see the Appendix for examples). The presence of cognate nouns has been shown to positively affect naming performance in bilingual individuals with post-stroke aphasia (Detry, Pillon, & de Partz, 2005; Roberts & Deslauriers, 1999). In the CLT literature, this effect has not received a great deal of attention. In one treatment study that examined this effect, the participant was a Spanish-English bilingual man with nonfluent aphasia (Kohnert, 2004). The treatment stimuli consisted of Spanish-English cognates such as *rosa* (rose) and non-cognates such as *escoba* (broom), while the test stimuli consisted of a different set of cognates and non-cognates. It was found that CLT from treated Spanish words to tested English words occurred for cognates but not for non-cognates. In a more recent treatment study, Kurland and Falcon (2011) examined the effect of cognates on the naming performance of a Spanish-English bilingual woman with nonfluent aphasia. In contrast to the findings of Kohnert

(2004), naming accuracy during the treatment and post-treatment phases of the study was typically greater for non-cognates than for cognates. This effect may have been caused by phonological interference from the non-target language.

In the present study, 40 of the 60 English words were cognates in Norwegian, and an additional 3 words were partial cognates.³ The distribution of these 43 words was roughly equivalent across the three conditions (orthographic treatment = 14 words, or 70%; phonological treatment = 14 words; untrained condition = 15 words, or 75%). Thus, it is unlikely that the greater naming accuracy that was observed in the orthographic treatment condition is related to the number of cognates in this condition. However, the lack of a CLT effect in the Norwegian written naming task appears to be related to the high proportion of cognates in this study, which seems to have facilitated performance in the untrained condition. For example, in the untrained condition written naming accuracy for cognates declined from 87% at baseline to 67% at post-treatment, while written naming accuracy for non-cognates declined from 100% to 20%. In contrast, the initial decline in written naming accuracy in the orthographic condition was similar for cognates and noncognates: accuracy for cognates declined from 86% at baseline to 64% at post-treatment, while accuracy for non-cognates declined from 83% to 67%.

On the other hand, English orthography appeared to interfere with Norwegian written naming for some cognate words. For example, ND spelled the Norwegian word *sjiraff* as “giraff.” This type of Norwegian writing error occurred more often in the orthographic condition: across all time points, there were 9 interference errors in the orthographic condition, 6 interference errors in the phonological condition, and 6 interference errors in the untrained condition.

It is possible that one aspect of the phonological treatment contributed to its relative lack of efficacy. In this treatment condition, the picture stimulus was presented with a string of symbols. The symbol string was included in order to match this condition with the orthographic condition, which included a written word stimulus. However, the irrelevant symbol string may have been distracting to the participant, and treatment efficacy may have been reduced as a result.

The goal of treatment studies for anomia in PPA has typically been the remediation of naming for items that cannot be named at baseline, rather than the prophylaxis of items that can be named at baseline (although both were examined by Jokel, Rochon, & Leonard, 2006). In contrast, the current study focused solely on prophylaxis. Future work will examine the effect of orthographic and phonological treatments on the naming of words that require remediation, in addition to the prophylaxis of words that can be named at baseline. One possibility is that a prophylaxis approach to treatment could be more effective than a

³These classifications were made by an experienced English-Norwegian translator and a native Norwegian speaker. A few of the cognates within each condition were phonologically identical across languages, orthographically identical, or both. In the untrained condition, piknik and sokk were phonologically identical, while turban and vase were orthographically identical. In the phonological condition, sigarett was phonologically identical, while bacon, piano, and radio were orthographically identical, and vest was both phonologically and orthographically identical. In the orthographic condition, pipe and tunnel were orthographically identical, while ring was both phonologically and orthographically identical.

remediation approach, because the recovery of words that cannot be produced could be more difficult than the enhancement of words that can be produced.

Treatment studies for anomia in PPA have typically included only one or two participants (but cf. Jokel & Anderson, 2012; Savage, Ballard, Piguet, & Hodges, 2013; Senaha, Brucki, & Nitrini, 2010). As a result, the level of generalizability of positive treatment effects to other individuals remains unclear. Furthermore, no treatment studies involving bilingual or multilingual individuals with PPA have been reported previously, although the language deficits of these individuals have been described in the literature (Druks & Weekes, 2013; Filley et al., 2006; Hernandez et al., 2008; Kambanaros & Grohmann, 2012; Larner, 2012; Liu, Yip, Fan, & Meguro, 2012; Machado, Rodrigues, Simoes, Santana, & Soares-Fernandes, 2010; Zanini, Angeli, & Tavano, 2011). The current study is a valuable contribution, as it expands the PPA literature to include a Norwegian-English bilingual individual, and it is the first study to examine cross-language transfer of treatment effects in bilingual PPA.

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Appendix

Appendix Noun Stimuli

Untrained		Phonological		Orthographic	
English	Norwegian	English	Norwegian	English	Norwegian
basket	kurv	angel	engel	alphabet	alfabet
bell	bjelle	bacon	bacon	balcony	balkong
belt	belte	calendar	kalender	bandage	bandasje
clock	klokke	candy	sukkertøy	bicycle	sykkel
devil	djevel	cannon	kanon	broom	kost
hanger	kleshenger	cigarette	sigarett	camel	kamel
nun	nonne	circus	sirkus	carrot	gulrot
octopus	blekksprut	clown	klovn	dentist	tannlege
picnic	piknik	drum	tromme	elephant	elefant
pocket	lomme	fork	gaffel	envelope	konvolutt
potato	potet	garlic	hvitløk	giraffe	sjiraff
pyramid	pyramide	lobster	hummer	moon	mane
sock	sokk	pencil	blyant	pear	pære
spoon	skje	piano	piano	pipe	Pipe
strawberry	jordbær	radio	radio	ring	ring
tomato	tomat	salad	salat	sandwich	brødskeive
turban	turban	toe	tå	shoe	sko
vase	vase	vest	vest	tunnel	tunnel

Untrained		Phonological		Orthographic	
English	Norwegian	English	Norwegian	English	Norwegian
walrus	hvalross	violin	fiolin	umbrella	paraply
witch	heks	wallet	pengebok	valcano	vulkan

Note. Cognates appear in bold. Partial cognates appear in bold and italics.

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Figure 1.

The blue ovals depict internal representations, while the red rectangles depict external stimuli and outputs. Within each subfigure, the bold arrow identifies the stimuli that were paired during treatment, the blue arrows represent the pathways that are normally activated during confrontation naming, the red arrows represent additional pathways that were activated during treatment, and the shaded blue oval depicts the representation that is thought to be strengthened by treatment.

Figure 2.
English oral naming accuracy. Tx = treatment.

Figure 3.
English written naming accuracy. Tx = treatment

Figure 4.
English naming to definition accuracy. Tx = treatment.

Figure 5.
Norwegian oral naming accuracy. Tx = treatment.

Figure 6.
Norwegian written naming accuracy. Tx = treatment.

Figure 7.
Norwegian naming to definition accuracy. Tx = treatment.

Figure 8.

A model of cross-language transfer (CLT) for the orthographic treatment. The blue ovals depict internal representations, the red rectangles depict external stimuli and outputs, and the blue arrows represent pathways that are activated during one or more of the three tasks. The shaded blue ovals depict the representations that are thought to be strengthened by the orthographic treatment.

Table 1

Cognitive Assessment Results

Measure	Baseline	Post Tx	8 Mo. Post Tx	1 Year Post Tx	20 Mo. Post Tx	3 Years Post Tx
MMSE in English/30	29 (50)	27 (27)	NA	26 (13)	26 (13)	20 (<1)
MMSE in Norwegian/30	28 (16)	27 (27)	NA	26 (13)	NA	15 (<1)
TONI/45	16 (19)	NA	21 (45)	18 (30)	NA	13 (19)
RCPM (A and B)/24	17 (15)	19 (28)	NA	16 (4)	NA	18 (17)
WMS Digit Span/30	10 (9)	9 (9)	NA	NA	NA	5 (1)
WMS Spatial Span/32	11 (16)	11 (25)	NA	NA	NA	9 (16)
BNT in English/60	45 (1)	33 (<1)	NA	25 (<1)	23 (<1)	6 (<1)
BNT in Norwegian/60	43 (<1)	22 (<1)	NA	18 (<1)	22 (<1)	7 (<1)
P&PT/52						
3 Pictures	49	49	NA	51	50	51
3 Words	50	NA	50	NA	49	NA

Note. Percentile ranks are in parentheses. Bold text denotes clinically significant impairment. Span scores include forward and backward tasks. Tx = treatment, MMSE = Mini-Mental State Examination, TONI = Test of Nonverbal Intelligence, RCPM = Raven's Coloured Progressive Matrices, WMS = Wechsler Memory Scale, BNT = Boston Naming Test, P&PT = Pyramids and Palm Trees, NA = not administered. Boston Naming Task norms: Heaton, Avitable, Grant, and Matthews (1999). MMSE norms: Crum, Anthony, Bassett, and Folstein (1993). RCPM norms: Smits, Smit, van den Heuvel, and Jonker (1997).

Table 2

Boston Diagnostic Aphasia Examination (BDAAE) Results

Measure	Baseline		Post Tx		1 Year Post Tx		20 Mo. Post Tx		3 Years Post Tx	
	ENG	NOR	ENG	NOR	ENG	NOR	ENG	NOR	ENG	NOR
Fluency										
Phrase Length/7	7	NA	7	NA	7	NA	NA	NA	7	NA
Melodic Line /7	7	NA	7	NA	7	NA	NA	NA	7	NA
Grammatical Form/7	7	NA	7	NA	7	NA	NA	NA	6	NA
Auditory Comprehension										
Basic Word Discrimination/37	37	NA	37	NA	36	NA	35	NA	31	NA
Commands/15	14	NA	15	NA	14	NA	11	NA	9	NA
Complex Ideational Material/12	11	11	9	9	9	9	8	10	7	9
Automatic Sequences/8	8	NA	6	NA	7	NA	4	NA	5	NA
Repetition										
Words/10	9	NA	9	NA	9	NA	9	NA	8	NA
Sentences/10	8	NA	6	NA	2	6	4	6	4	3
Naming										
Responsive Naming/20	20	NA	17	NA	14	NA	13	NA	12	NA
Special Categories/12	12	NA	12	NA	12	NA	11	NA	11	NA
Reading										
Matching Cases and Scripts/8	8	NA	8	NA	8	NA	NA	NA	8	NA
Number Matching/12	12	NA	12	NA	11	NA	NA	NA	12	NA
Picture-Word Match/10	10	NA	10	NA	8	NA	NA	NA	9	NA
Lexical Decision/5	5	NA	5	NA	5	NA	NA	NA	5	NA
Homophone Matching/5	5	NA	5	NA	5	NA	NA	NA	5	NA
Free Grammatical Morphemes/10	10	NA	10	NA	10	NA	NA	NA	10	NA
Basic Oral Word Reading/30	30	30	30	30	30	NA	NA	NA	27	27
Oral Sentence Reading/10	10	10	10	9	7	NA	NA	NA	7	4
Oral Sentence Comprehension/5	5	5	5	5	5	NA	NA	NA	5	5
Sentence/Paragraph Comp./10	9	NA	9	NA	10	NA	NA	NA	7	NA
Writing										
Form/18	18	NA	17	NA	16	NA	NA	NA	18	NA

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Measure	Baseline		Post Tx		1 Year Post Tx		20 Mo. Post Tx		3 Years Post Tx	
	ENG	NOR	ENG	NOR	ENG	NOR	ENG	NOR	ENG	NOR
Letter Choice/27	27	NA	27	NA	26	NA	NA	NA	24	NA
Motor Facility/18	18	NA	18	NA	18	NA	NA	NA	18	NA
Primer Words/6	6	NA	6	NA	6	NA	NA	NA	5	NA
Regular Phonics/5	5	NA	5	NA	4	NA	NA	NA	1	NA
Common Irregular Words/5	3	NA	2	NA	1	NA	2	NA	0	NA
Written Picture Naming/12	9	NA	6	NA	4	NA	4	NA	2	NA
Narrative Writing/11	11	NA	9	NA	8	NA	8	NA	PR	NA

Note. Tx = treatment, ENG = English, NOR = Norwegian, NA = not administered, PR = participant refused.

Table 3

Mean Stimulus Characteristics

	English			Norwegian		
	<u>Untrained</u>	<u>Phonological</u>	<u>Orthographic</u>	<u>Untrained</u>	<u>Phonological</u>	<u>Orthographic</u>
Frequency	21.2	20.0	21.8	10.9	8.6	9.9
Syllables	1.9	2.0	2.1	2.0	2.3	2.2
Phonemes	5.0	5.2	5.4	5.3	5.5	5.6
Letters	5.6	5.5	6.2	6.0	5.9	6.1

Note. Frequency = frequency per million.