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“Do you have *mowing the lawn*?” – improvements in word retrieval and grammar following constraint-induced language therapy in primary progressive aphasia

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ABSTRACT

Background: Much recent progress has been made in developing speech–language therapy in primary progressive aphasia (PPA). Several treatment approaches that have shown significant effects with people with aphasia have been adapted and re-evaluated for PPA. Constraint-induced aphasia therapy (CIAT) is a well-evaluated method that has yielded significant language improvements in people with post-stroke aphasia but has not yet been evaluated with people with PPA. Nevertheless, the combination of CIAT features like massed practice and a motivating communicative setting seem likely to make it a suitable tool for improving the speech and language performance of individuals with PPA as well. **Aims:** This study investigates the effectiveness of a modified CIAT protocol on word retrieval, grammatical structure and connected speech in two individuals with non-fluent variant PPA (nfvPPA).

Methods and procedures: Two participants with nfvPPA took part in a 9-day intensive CIAT-based group therapy with additional computer-based home training. Stimuli were 120 photos of people performing daily life activities, which could be described using a simple (e.g., “The man is mowing the lawn”) or reduced (e.g., “mowing the lawn”) sentence structure. During the treatment phase, the participants were required to request picture cards from other group members using spoken language only. The task difficulty was increased hierarchically (shaped) in accordance to each participant’s performance level.

Outcomes and results: Directly after therapy, both participants achieved significant improvements in their noun and verb naming accuracy and their grammatical structure for trained items. Training effects were maintained 2 months after therapy. Moreover, generalisation to different pictures of the same item was found for both participants and one participant also showed improved grammatical structure when describing untrained pictures. No significant generalisation to untrained connected speech samples was observed for either participant.

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Conclusion: This study illustrates that CIAT can be effective in people with PPA. However, further modifications of CIAT should be considered to facilitate generalisation and in order to determine which aspects of the treatment are most important.

Due to ongoing demographic change, clinicians across a range of disciplines have to deal with growing caseloads of individuals with neurodegenerative disease. Therefore, the development of treatment methods and diagnostic instruments for dementia and associated diseases has become an important issue in current medical research. Primary progressive aphasia (PPA) is a type of dementia that is predominantly characterised by speech and language decline (Mesulam, 2001). The prevalence of PPA is currently estimated at 1.1–6 per 100,000 cases (Grossman, 2014). The number of people diagnosed with PPA is increasing, due to new diagnostic technologies and a growing awareness of this disease by physicians. Three different subtypes of PPA can be distinguished, which differ in their core symptoms and in their pattern of atrophy: the semantic variant (svPPA), the logopenic variant (lvPPA) and the non-fluent variant (nfvPPA) (Gorno-Tempini et al., 2011).

The present study focuses on individuals diagnosed with nfvPPA (Gorno-Tempini et al., 2011). This variant is characterised by agrammatic speech production accompanied by speech–sound errors and distortions. For the diagnosis of nfvPPA, at least one of these features needs to be present in an individual with PPA. Additionally, at least two of the following symptoms must be observable: comprehension deficits for grammatically complex sentences, spared comprehension for single words and/or unimpaired object knowledge.

Word-retrieval and grammar treatments in nfvPPA

Word-retrieval difficulties occur across all variants of PPA and have an immense impact on an individual's communicative abilities (Jokel, Graham, Rochon, & Leonard, 2014). As a consequence, most of the therapy studies in PPA have focused on the processing and retrieval of single words (Croot, Nickels, Laurence, & Manning, 2009; Jokel et al., 2014). Although not a defining feature of nfvPPA, anomia is nevertheless a common symptom especially in the late stages of the disease (Gorno-Tempini et al., 2004, 2011; Harciarek, Sitek, & Kertesz, 2014).

Most therapy studies in word retrieval in nfvPPA have targeted noun retrieval and used phonological or semantic approaches (Croot et al., 2009; Jokel et al., 2014). The choice of approach is most commonly based on the patients' main language impairments (Jokel et al., 2014; Nickels, 2002). However, both cueing strategies have been found to be effective in nfvPPA (Henry, Beeson, & Rapcsak, 2008; Jokel et al., 2014). Beside the traditional face-to-face therapy, computer-based programs like MossTalk Words® have been successfully used in the word-retrieval therapy in nfvPPA (Jokel, Cupit, Rochon, & Leonard, 2009; Jokel, Rochon, & Anderson, 2010). Thus, Jokel et al. (2009) suggest computer-based home training as a cost-effective way to increase the amount of individual treatment for people with PPA.

Although verb retrieval is described to be particularly impaired in nfvPPA (Ash et al., 2009; Grossman, 2012), to our knowledge, no behavioural treatment study explicitly targeted the lexical retrieval of verbs in nfvPPA yet. Verbs play an important role in the construction of sentence structures (Marshall, Pring, & Chiat, 1998). Lexical representations of verbs contain information about the argument structure of a sentence and morphological features. If an individual fails to access this crucial information, the construction of a complete and syntactically correct sentence is impaired (Hillis, Tuffiash, & Caramazza, 2002; Marshall et al., 1998; Thompson, Riley, den Ouden, Meltzer-Asscher, & Lukic, 2013).

Indeed, despite the fact that grammatical deficits are a characteristic feature of nfvPPA, a recent review by Thompson and Mack (2014) reported only three intervention studies targeting grammar in PPA. Two of these studies evaluated the effectiveness of repeated transcranial magnetic stimulation without an additional behavioural therapy. Both report significant improvements in verb production when left-hemisphere language areas were stimulated (Cotelli et al., 2012; Finocchiario et al., 2006). In the only behavioural treatment, Schneider, Thompson, and Luring (1996) analysed the effectiveness of a combined verbal and gestural therapy on sentence production of an individual with non-fluent symptoms. The participant learned specific gestures for a selection of nouns, verbs and tense markers and used them in a picture description task. The authors observed a significant treatment effect for trained items. Moreover, following treatment, the participant was able to correctly produce significantly more untrained items in trained tenses. Whether grammatical improvements in PPA could be achieved by a purely verbal therapy approach has not yet been reported.

Maintenance of treatment effects and generalisation to untrained tasks and connected speech are the ultimate treatment goals of language therapy and are especially important given the neurodegenerative nature of PPA (Croot et al., 2009). About 16 of 21 word-retrieval treatment studies reviewed by Jokel et al. (2014) reported positive maintenance effects of trained skills for up to 8 months across all variants. Moreover, the review reported on 10 studies that showed improved word retrieval for untrained items and/or untrained tasks (Jokel et al., 2014). Data suggest that generalisation seems to be most likely when the therapy resulted in learning of strategies (Henry et al., 2008; Jokel et al., 2014; Schneider et al., 1996). Savage and colleagues (2014) reported generalisation effects of word retraining to a video description task in svPPA, but significant generalisation to everyday communication has not yet been reported (Croot et al., 2009, 2015; Jokel et al., 2014). Nonetheless, close relatives of individuals with svPPA have reported the use of trained items in daily conversation (Heredia, Sage, Ralph, & Berthier, 2009; Jokel & Anderson, 2012). Although similar results have not yet been reported in other variants of PPA, these findings suggest that generalisation effects may be achievable. It is possible that a therapy task that encourages natural communication could facilitate generalisation to connected speech. One possible approach, and that chosen in this study, is a group therapy approach (constraint-induced aphasia therapy [CIAT]) where the task encourages the production of connected speech in a more natural communicative setting.

CIAT and its modifications

CIAT is a well-established therapy approach developed for post-stroke aphasia (Pulvermüller et al., 2001). The intervention is based on the theory of learned non-use,

which assumes that functional impairments following brain injury (e.g., speech and language deficits) are caused not only by the damage of brain tissue *per se*, but also by learned avoidance of impaired abilities (Taub, 1977 as cited in Taub, Uswatte, Mark, & Morris, 2006).

In consequence, three main principles apply to the intervention: (1) massed practice, (2) constraints to reduce and deter non-use and (3) behavioural relevance of the therapy contents to encourage use of treatment targets. Massed practice was initially obtained by a treatment intensity of 3 h/day over 10 consecutive weekdays. Constraints were applied on three different dimensions: the treatment material (e.g., high or low word frequency), the rules of the game and shaping (e.g., increasing complexity of utterances required), and reinforcement (e.g., for obeying various rules of the game). The pilot study by Pulvermüller et al. (2001) reported clear benefits of therapy for people with different syndromes and various severities of aphasia. Information about maintenance and generalisation of trained skills was not provided. The therapy was implemented in a card exchange game ("Go Fish"). The participants had to collect matching pairs by requesting cards from their teammates. They were only allowed to use spoken language, while compensatory strategies were constrained. One of the clinicians took part in the game, and a second clinician provided help to the patients, if requested.

In the following years, further research has been conducted replicating these findings under modified conditions (e.g., Barthel, Meinzer, Djundja, & Rockstroh, 2008; Meinzer, Rodriguez, & Rothi, 2012). Meinzer, Djundja, Barthel, Elbert, and Rockstroh (2005) developed one of the first modified CIAT protocols: CIATplus. This approach implemented home practice in addition to the original CIAT protocol, and allowed written cueing during therapy. Both the original and the modified therapy led to significant improvements for all participating patients; however, an advantage for CIATplus was found in maintenance and generalisation to everyday communication. Hence, in our study, we also implemented a home training component.

Other CIAT studies, focusing on specific language domains like sentence or verb processing, have also achieved significant therapy benefits and good maintenance (e.g., Faroqi-Shah & Virion, 2009; Goral & Kempler, 2009; Szaflarski et al., 2008). Kleine-Katthöfer, Jacobs, Huber, Willmes, and Schattka (2012) developed a modified CIAT protocol to improve verb retrieval for patients in the chronic stage of aphasia. The experimental material consisted of photographs from everyday life situations, which could be described using a reduced sentence structure (verb–noun collocations¹; e.g., riding a bike). After 10 days of 90 min training per day, all participants showed significantly improved word retrieval: similar stimuli were therefore used in the present study.

Faroqi-Shah and Virion (2009) are the only researchers so far to report a CIAT modification that targeted grammatical improvements. Morphological constraints (temporal adverbs like "yesterday") were implemented aiming to improve the participants' grammatical completeness and accuracy. However, this approach achieved only minimal improvements, although the authors suggested that perhaps the patients' suitability for the CIAT therapy was not controlled properly (e.g., severity of impairment).

Treatment intensity is thought to be in part responsible for the success of CIAT approaches, but an important question is how frequent treatment needs to be, in order to be considered intensive (Bhagal, Teasell, & Speechley, 2003; Poeck, Huber, &

Willmes, 1989). Multiple studies have modified the amount of CIAT (e.g., Goral & Kempler, 2009; Maher et al., 2006; Szaflarski et al., 2008). Significant improvements have been achieved even when therapy time was reduced considerably (e.g., Kleine-Katthöfer, 2012 [90 min/day over 10 days]; Nickels & Osborne, *in press* [90 min/day, 2× week, for 4 weeks]; Szaflarski et al., 2008 [3 h/day over 5 days]). On the basis of this evidence and in order to reduce the burden on participants, we also implemented a less intense CIAT therapy.

Although CIAT and modified versions of CIAT have been shown to produce significant improvements in patients with post-stroke aphasia, no evidence has yet been reported for people with neurodegenerative language impairments, such as PPA. On the basis of the literature, it seems likely that this impairment-directed language training should lead to significant improvements in PPA, including generalisation to other communicative situations.

Purpose of the study

The present study aimed to evaluate the effectiveness of a CIAT-based therapy approach in two individuals with nvPPA. Our first objective was to improve the participants' word retrieval for nouns and verbs in a picture description task. The second objective was to significantly enhance the grammatical completeness and accuracy of their picture descriptions. Our third and final objective was to examine whether generalisation to connected speech could be achieved.

Method

Participants

Two participants, diagnosed with nvPPA following the consensus criteria by Gorno-Tempini et al. (2011), were included in the study. Inclusion criteria were (1) native English speakers, (2) progressive onset of speech deterioration over the past 2 years or a diagnosis of progressive aphasia, (3) speech and language impairment that affected daily life activities and (4) naming difficulties. Exclusion criteria were (1) major psychiatric disorder and/or profound behavioural problems, (2) mutism, (3) medical conditions restricting participation in high-frequency group therapy and (4) significant impairments of hearing or vision.

Participant ANT

ANT was a 74-year-old female former high school teacher. The deterioration of her speech and language abilities started approximately 4 years prior to the present study. A Pittsburgh compound B Positron Emission Tomography (PiB-PET) scan taken 6 months earlier showed salient bifrontal hypometabolism, which was more extended in the left than in the right hemisphere, and mild left hypometabolism in parietal and temporal regions.

At the beginning of the study, we obtained connected speech samples from an initial conversation and a "Pink Panther" video recount task (for excerpts, see Table 2; for detailed analysis, see Appendix 2). ANT's spontaneous speech in conversation was

effortful and consisted mostly of noun phrases. She occasionally produced verbs when she talked about familiar topics like hobbies and household activities (e.g., “cooking”; “shopping”). Information was generally grammatically unlinked so that the interlocutor had to ask further questions or suggest use of different modalities, like writing, to assist in understanding the content. ANT showed word-finding difficulties in the form of long pauses and fillers like “uh” and “ah”, often expressing her frustration. She maintained her pragmatic skills and used many different strategies, such as writing, gesturing and pointing to communicate. ANT frequently used the automatism “for the” as a starter phrase or to connect information (e.g., “cards for the making”). We observed a similar pattern in her video recount where she produced six content words (type-token ratio (TTR): 100%; 6 nouns) in six phrases. She produced noun phrases (e.g., “the pink man”) which were sometimes connected with the automatism “for the” but remained mostly grammatically unlinked (e.g., “pink man ... for the ... cupboard”). Once again, severe word-finding difficulties were represented by filled and unfilled pauses of about 5 s.

The Comprehensive Aphasia Test (CAT; Swinburn, Porter, & Howard, 2005), conducted at the beginning of this study, revealed moderate to severe word retrieval, repetition and reading difficulties (nine subtests below the 5th percentile for stroke aphasia, see Table 1). ANT’s listening comprehension for words and simple sentence structures as well as her writing skills for the same structures remained relatively preserved. In contrast, her comprehension of syntactically complex sentences was severely impaired (Test of Reception of Grammar-Second Edition (TROG-2), <1st percentile). Her confrontation naming lay at the lower end of the range for healthy controls (Graded Naming Test (GNT) = 25th percentile) or slightly below the cut-off (CAT_{Naming-Nouns}: *T*-score = 61). However, her verb retrieval was disproportionately more impaired (CAT_{Naming-Verbs}: *T*-score = 47). No further cognitive deficits (e.g., semantic and/or visual memory) were detected in the brief CAT examination.

Patient RBI

RBI was a 72-year-old male former stockbroker. He had a 4-year history of language deterioration at the beginning of this study. PET imaging 1 year earlier showed hypometabolism in the left superior temporal lobe and anterior regions of the left temporal lobe. In conversation, RBI’s speech was slowed and showed clear prosodic deficits (e.g., syllable segregation). Word-finding difficulties were observed in the form of fillers like “eh” or “what’s the name for it”. Moreover, grammatical impairments were evident in the form of morphological errors (e.g., “[...] she work with adults [...]”), missing pronouns and determiners (e.g., “the first time I saw [a] neurologist was three years [ago]”) and sentence interruption (e.g., “[...] she was . eh dealt with kids]”). Similar symptoms were observed in the video recount task (for excerpts, see Table 2; for detailed analysis, see Appendix 2). RBI produced 15 phrases and 38 content words (TTR: 85%; 15 nouns, 19 verbs). He used noun and verb phrases but showed difficulties in grammatically linking the contents. Thus, someone naïve to the story would have had difficulties following his description. Moreover, he produced morphological errors (e.g., “he went to the supermarket”), phonological errors (e.g., “he lives [lifts] a lid”) and many filled pauses suggesting word-retrieval deficits (e.g., “eh the pink eh panther [...]”).

At the beginning of the study, RBI’s CAT results for three subtests fell under the 5th percentile for stroke aphasia (see Table 1). Two of which were repetition tasks

Table 1. ANT's and RBI's results in the general assessments CAT, GNT and TROG-2 – pre- vs. post-test.

Test-time Subtest	ANT				RBI			
	Pre-test	T-score	Post-test	T-score	Pre-test	T-score	Post-test	T-score
Comprehensive aphasia test								
Cognition								
Semantic memory	10/10	60	10/10	60	10/10	60	10/10	60
Word fluency	17	60	11	55	22	66	18	61
Recognition memory	10/10	59	10/10	59	8/10	43	8/10	43
Comprehension								
Spoken language								
Words	29/30	60	28/30	58	28/30	58	26/30	53
Sentences	24/32*	56	20/32*	52	30/32	65	30/32	65
Paragraphs	2/4	43	4/4	60	4/4	60	4/4	60
Written language								
Words	29/30	60	30/30	65	30/30	65	30/30	65
Sentences	21/32*	55	21/32*	55	28/32	64	29/32	64
Repetition								
Words	29/32	56	27/32*	53	28/32*	55	31/32	60
Complex words	6/6	62	5/6	55	6/6	62	6/6	62
Non-words	4/10*	49	4/10*	49	2/10*	46	0/10*	38
Sentences	6/12*	48	4/12*	45	12/12	63	12/12	63
Naming								
Objects	42/48*	61	45/48	64	47/48	70	45/48	64
Actions	3/10*	47	4/10*	50	8/10	59	10/10	69
Picture descriptions	5.5*	44	3.5*	43	19*	47	34	51
Reading								
Words	38/48*	54	38/48*	54	46/48	62	47/48	64
Complex words	4/6	57	4/6	57	6/6	67	4/6	57
Function words	4/6	49	2/6*	46	6/6	62	4/6	49
Non-words	3/10*	51	4/10*	52	8/10	61	9/10	64
Writing								
Written Naming	21/21	67	21/21	67	21/21	67	18/21	58
Graded Naming Test (GNT)								
	Pre-test	Percentile	Post-test	Percentile	Pre-test	Percentile	Post-test	Percentile
	18/30	25	19/30	25	20/30	50	20/30	50
Test of Reception of Grammar (TROG-2)								
Total correct	59/80	<1*	52/80	<1*	70/80	10*	73/80	16*
Blocks passed	8/20		7/20		14/20		15/20	

*Score under cut-off: (CAT: mastered by at least 95% of non-aphasic subjects; GNT: 1 SD below mean – mean = 20.4, SD = 4.1; c.f., Warrington, 1997; TROG-2: 1 SD below mean $\hat{=}$ percentile of 16 or less).

Table 2. Examples taken from ANT's and RBI's video recounts in the pre-test and post-test phases.

	Pre-test	Post-test
ANT	eh the pink man ... (6 sec.) for the ... (4 sec.) cupboard ehm or the toy . door ahhh... (4 sec.) the ... (7 sec.) the banana ... cats yes [...]	the fridi fridge the ... (9 sec.) fry fridi ah ... (9 sec.) mouse ... (6 sec.) the shutters no cupboards ... (6 sec) the people ... (22 sec.) the gate [...] the people . for the ...
RBI	eh the pink eh panther finds out there's nothing in the kitchen eh in the fridge . he lives [lifts] a lid and the fly flies eh flies out . so he wents to the eh supermarket and the eh door . door automatic close us on him and he eventually races through with a lady [...]	the pink panther went to the kitchen and found the fridge was empty the cupboards were empty and there was no food in the kitchen . so he went to the supermarket where he was shut out by the automatic doors eh he eh waited till a lady came along and he went . sneaked in behind her eh they he bounded to the eh storeman and with a . he the storeman fell over on the box and he went to the meat section [...] and ehh than ... he eh . no he he's eh the trolly.. hmm something before

(CAT_{word-Rep}: T -score = 55; CAT_{non-word-Rep}: T -score = 46), which provides further evidence for RBI's profound speech–sound deficits. His writing performance as well as his spoken and written language comprehension for single words and simple sentences lay within the range of healthy participants. Nevertheless, RBI's TROG-2 results revealed deficits in his comprehension of syntactically complex sentences (<10th percentile). Despite his word-retrieval deficits in conversation and in the video recount, RBI's confrontation naming performance for nouns and verbs lay within the range of healthy controls (CAT_{Naming-Nouns}: T -score = 70; CAT_{Naming-Verbs}: T -score = 59; GNT: 50th percentile). No cognitive deficits were detected in the brief examination included in the CAT.

Experimental material

About 120 photographs of everyday life activities (from the website: <http://www.gettyimages.com.au>; Gettyimages®, 1999) were selected for the CIAT card exchange game. Photographs were used in order to facilitate generalisation from the task to real-life objects (Jokel et al., 2014; Meinzer et al., 2005). Each photo showed one to four people carrying out daily activities with a particular object (see Figure 1). Each situation could be described with a simple sentence (subject–verb–object) or using a reduced sentence structure (main verb–object), which allowed the shaping process. The 120 photographs depicted situations involving 60 different object nouns, each of which co-occurred with

Figure 1. Examples of the experimental material: treatment pictures and assessment pictures – “mowing the lawn” (top left): photo by Kenneth E. Zirkel/E+ via Getty Images; “mowing the lawn” (bottom left): photo by Karana E. Kapoor/Cultura via Getty Images; “watering the lawn” (top right): photo by Zen Shui/Frederic Ciron/photoAlto Agency RF Collections via Getty Images; “watering the lawn” (bottom right): photo by VStock/Tetra Images via Getty Image.

two different verbs (e.g., “The man is mowing/watering the lawn.”). Simple and phrasal² verbs were included. Frequency and phonological complexity (number of syllables, phonemes and consonant clusters) for each noun and verb was obtained from the CELEX database (Max Planck Institute for Psycholinguistics, 2001). Based on these features and the participants’ baseline performance, the items were assigned to two matched sets of 60 photographs depicting situations with 30 object nouns and 60 verbs, which were randomly assigned to the training and control conditions. Different depictions of the same situation were used in the assessment and therapy sessions. Thus, a performance change after treatment could be attributed to the patients’ word-retrieval skills rather than their picture recognition skills (Croot et al., 2015; Jokel et al., 2014).

Outcome measures

Standardised assessments

ANT and RBI performed three standardised assessment: the CAT (Swinburn et al., 2005), the GNT (Warrington & McKenna, 1983) and the TROG-2 (Bishop, 2003). We selected these tools to gain an overview on the participants’ general language abilities prior to the therapy and to index any decline in untargeted speech and language domains in the course of the study as a consequence of PPA. In addition, both participants performed a video recount task, in order to determine whether there was any generalisation to connected speech. Participants were asked to recount what happened in a 90s video sequence, a (language-free) Pink Panther cartoon in which the Pink Panther goes to the supermarket and has a series of misadventures. As a measure of meaningful content, we measured the number of propositions. As a measure for syntactic complexity, we analysed the number of phrases and complete phrases. Moreover, we counted number of words, content words, and nouns and calculated TTR. Errors were analysed on the basis of the criteria used for the connected speech evaluation in the Aachen Aphasia Test (Huber, Poeck, Weniger, & Willmes, 1983). Thus, we identified errors in the categories semantics, phonology and morphology/syntax as well as word-finding deficits. These standard language assessments were conducted before and, 2 months later, after the intervention phase.

Treatment-specific assessment

Treatment-specific performance changes were determined using picture description. The participants were asked to describe all 120 stimulus pictures at three time points before and two time points after the intervention, as well as at a follow-up assessment 2 months after the end of the therapy (these are abbreviated as B1, B2, B3 for the three pre-test baselines, P1, P2, P3 for the post-test assessments and FU for the Follow-up; see Figure 2). Every test session was recorded and transcribed. The participants’ responses were evaluated for naming accuracy as well as grammatical performance. In the analysis of naming accuracy, the production of nouns and verbs in every picture description was coded as correct (producing target word or synonym) or incorrect. Moreover, each picture description response was scored as grammatically correct (producing all parts of the sentence or reduced sentence structure; correct word order and correct morphology) or incorrect.

Due to ANT’s severe grammatical impairment, for her, the intervention targeted the production of reduced (verb-object; e.g., mowing the lawn), rather than complete, sentence structures (subject-verb-object; e.g., the man is mowing the lawn). Thus, not

Figure 2. Design of the treatment study (B1 = Pre-test Baseline 1, B2 = Pre-test Baseline 2, B3 = Pre-test Baseline 3, P1 = Post-test 1, P2 = Post-test 2, P3 = Post-test 3, FU = Follow-up).

only complete sentences but also grammatically complete, reduced sentence structures were coded as correct for ANT. In contrast, only complete simple sentences were coded as grammatically correct for RBI.

Data analysis

Weighted statistics (WEST; Howard, Best, & Nickels, 2015) were used to analyse the participants' performance changes between every time point. This method was specifically developed to analyse nominal data in single case studies with multiple test times. Two different measures were calculated: Trend (WEST-Trend) and Rate of Change (WEST-Rate of Change (ROC)). WEST-Trend gives information about the overall change in performance across the whole study period. WEST-rate of change was used to evaluate whether the rate of change in performance during the CIAT-treatment phase was significantly different from the change during the CIAT-free phase. Both the WEST-Trend and the WEST-Rate of change analyses must show improved performance at statistically significant levels to allow the conclusion that there has been a positive effect of the CIAT group treatment. Two sampled *t*-tests were used to compare differences in the rate of change between trained and untrained item sets. Moreover, the McNemar test for paired dichotomous items was used to evaluate specific performance changes between individual test times (e.g., B3 vs. P1). A significance level of $p < .05$ (one-tailed) was applied to all statistical tests.

Intervention

As in the traditional CIAT approach, the intervention presented in this study was performed in a group setting over two consecutive weeks. The number of therapy days was reduced to 9 instead of the traditional 10 days (Pulvermüller et al., 2001) because one of the participants was unavailable on one day. Each CIAT session took about 60 min and used a card game format. Every participant received 10 picture cards at the beginning of each game. They needed to request picture cards from their teammates, aiming to collect as many matching pairs as possible (Meinzer et al., 2012). A student speech pathologist was involved as a third player to increase the number of players and model the required picture description structure. Barriers were built on the table in order to prevent the participants from using compensatory communication strategies like writing, pointing or drawing. Due to ANT's severe expressive

difficulties, she was allowed to use writing as a self-cueing strategy, but not for communication purposes.

Shaping was applied to the material and the dialogue structure over a series of approximately nine games within each session. Initially, the stimulus cards used were those depicting different objects and actions (e.g., “mowing the lawn” vs. “mopping the floor”). Thus, even a single noun or verb was sufficient to distinguish the picture cards. Cards depicting different actions performed with the same object were introduced within the game as the therapy progressed (e.g., “watering the lawn” and “mowing the lawn”, see [Figure 1](#)), providing distractor items and requiring more precise language and complex structures. Every card request started with the participant addressing a co-player (e.g., John). The length of the target request was extended from a single word (e.g., making the request “John. Mowing?”), through restricted structures (e.g., “John, ‘mowing the lawn?’”) to complete simple sentence structures (e.g., “John Do you have ‘The man is mowing the lawn?’”). If a grammatically incorrect target structure was produced, the clinician modelled the grammatically correct structure (e.g., [RBI] following “man is mowing the lawn” the clinician would model “the man is mowing the lawn”/ [ANT] “lawn mowing” modelled as “mowing the lawn”). The clinician ensured that the participant produced the target structure correctly before the game was continued.

The shaping of the response structure began with a simple “yes” or “no” and was extended over the course of the study to require a complete simple sentence structure (e.g., “No, I don’t have ‘mowing the lawn.’”). This adaptation was applied individually for each participant (full overview of individual shaping steps, see [Appendix 1](#)). In this study, only participant RBI was able to produce complete sentence structures to describe the target pictures during the therapy. ANT described the pictures in reduced sentences but used the starting question “Do you have...?” to produce a complete sentence frame by the end of the treatment (e.g., Question: “RBI. Do you have: mowing the lawn?”; Response: “Yes, I do.”). The participants reached a new shaping step as soon as their spontaneous responses in the previous game were at least 90% correct.

If a participant failed to name an item spontaneously during the therapy, the clinician provided help following a specific phonological cueing hierarchy. First, the initial sound of the target verb was given. Second, the initial syllable of the verb was provided. In a third step, the clinician named the whole verb, this was followed by the first syllable of the object noun and the verb. If the participant was still unable to produce the requested picture description, he/she was asked to repeat the whole object–verb phrase modelled by the clinician.

A software application (henceforth “app”) was developed to provide an additional home training programme on a tablet computer. The target pictures appeared in randomised order on the screen. The participant was required to describe the picture. If they were unable to do so, they pressed one of four buttons to receive an auditory cue. Buttons labelled 1–4 were displayed underneath the picture. Pressing each button in turn produced a hierarchical series of cues. The first cue provided the initial phoneme of the verb and the final cue contained the complete target response, allowing the participants to check their answer and/or repeat the sentence, minimising errors during learning. For each participant’s primary therapy goals, individual cues were developed. During the baseline, ANT showed severe verb retrieval deficits, thus, her cues in the home training targeted primarily the verb retrieval. ANT received the first sound of a

verb as a first cue (e.g., “m”), the first syllable as a second (e.g., “mo”), the whole verb as a third (e.g., “mowing”) and the whole verb–noun collocation as a fourth cue (e.g., “mowing the lawn”). Participant RBI showed moderate verb retrieval deficits but frequently omitted function words during the baseline. Therefore, his home training cues were different. The first cue provided the first sound of the verb and the second cue already gave the whole verb. The third cue consisted of an extended verb–noun collocation (e.g., “is mowing the lawn”) and the last cue provided the whole sentence frame (e.g., “The man is mowing the lawn”). Each home training session took about 30 min and was performed daily. The participants started the home training on the first day of the CIAT intervention and continued the training at least until the follow-up testing 2 months after the therapy.

ANT had just one regular speech therapy session during the study period. Her speech pathologist targeted only non-verbal communication, so that no impact should be expected on our results. RBI did not receive any other speech therapy during the study period.

Results

Participant RBI attended every therapy and assessment session, while ANT was unavailable for the second post-test (P2). For this reason, the line connecting P1 and P3 for ANT’s performance in the picture description task is illustrated with a dashed format.

There was no significant change in any of the standardised assessment subtests (CAT, TROG-2 or Graded Naming Test) comparing pre- and post-intervention assessments (see Table 1).

Noun and verb retrieval accuracy

ANT

ANT’s noun and verb retrieval showed highly significant improvement over the course of the study (see Figure 3; over all test items and test time points: Nouns: $p_{WEST-Trend} < .001$, Verbs: $p_{WEST-Trend} < .001$). However, when treated and untreated sets were examined individually, this was only significant for the treated sets (untrained noun: $p_{WEST-Trend} = .32$, trained noun: $p_{WEST-Trend} < .001$; untrained verb: $p_{WEST-Trend} = .71$, trained verb: $p_{WEST-Trend} < .001$). In order to evaluate whether this positive performance change was intervention related, the rate of change was compared between phases with and without treatment. A highly significant therapy effect was found for trained items (nouns and verbs: $p_{WEST-ROC} < .001$), while there was no significant change for untrained items (untrained nouns: $p_{WEST-ROC} = .878$, untrained verbs: $p_{WEST-ROC} = .942$). Moreover, treated items showed significantly greater improvement than untreated items (nouns and verbs; $t(119) > 3.63$; $p < .001$). ANT showed her best word retrieval directly after the therapy (P1). Her performance had declined at the 2-month follow-up assessment, but nevertheless treated items showed significantly higher naming than the highest pre-test performance (nouns: McNemar’s $p_{B2 \text{ vs. } FU} < .01$, verbs: McNemar’s $p_{B2 \text{ vs. } FU} < .001$).

RBI

Despite RBI’s high pre-test accuracy, there was a highly significant improvement in his noun and verb retrieval across the course of the study (see Figure 4; nouns: p_{WEST-

Figure 3. ANT's retrieval of nouns (panel A) and verbs (panel B) in the picture description task before and after treatment (B1= Pre-test Baseline 1, B2 = Pre-test Baseline 2, B3 = Pre-test Baseline 3, P1 = Post-test 1, P2 = Post-test 2, P3 = Post-test 3, FU = Follow-up).

$Trend < .001$; verbs: $p_{WEST-Trend} < .001$). However, when treated and untreated sets were examined individually, this was only significant for the treated sets (untreated nouns: $p_{WEST-Trend} = .86$, treated nouns: $p_{WEST-Trend} < .001$; untreated verbs: $p_{WEST-Trend} = .86$, trained verbs: $p_{WEST-Trend} < .001$). Comparing the rate of change of phases with and without therapy, significant differences were found for treated items (nouns and verbs: $p_{WEST-ROC} < .01$), but not untreated items (nouns: $p_{WEST-ROC} = .335$, verbs: $p_{WEST-ROC} = .260$). However, the difference between the two conditions did not reach significance (nouns: $t(119) = 1.282$; $p = 0.101$; verbs: $t(119) = 1.080$; $p = 0.141$) although the treated verbs did show significantly greater improvement across the course of the study (WEST-Trend) than the untreated verbs ($t(119) = 2.761$; $p = .003$). The comparison between RBI's highest baseline performance and the follow-up showed good maintenance for at least 2 months after the end of the CIAT therapy phase (nouns: McNemar's, $p_{B3 \text{ vs. } FU} < .01$; verbs: McNemar's, $p_{B3 \text{ vs. } FU} < .001$).

Grammatical structure production

ANT

Due to ANT's severe grammatical impairment, she was trained on reduced sentence structures (e.g., "mowing the lawn"). Prior to the intervention phase, fewer than 30% of all

Figure 4. RBI's retrieval of nouns (panel A) and verbs (panel B) in the picture description task before and after treatment (B1= Pre-test Baseline 1, B2 = Pre-test Baseline 2, B3 = Pre-test Baseline 3, P1 = Post-test 1, P2 = Post-test 2, P3 = Post-test 3, FU = Follow-up).

Figure 5. ANT's grammatical performance for reduced sentence structures in the picture description task before and after treatment (B1= Pre-test Baseline 1, B2 = Pre-test Baseline 2, B3 = Pre-test Baseline 3, P1 = Post-test 1, P2 = Post-test 2, P3 = Post-test 3, FU = Follow-up).

picture descriptions resulted in even a reduced sentence structure (see Figure 5). Correct simple sentence structures were not observed at all. She mainly produced single content words (e.g., “pilot” for *flying the plane*; “watering” for *cleaning the window*) and noun phrases (e.g., “shutters for the window” for *opening the window*). As in her connected speech, ANT used the automatism “for the” to link two words (e.g., “scissors for the paper”). Moreover, her word order in the picture descriptions was often incorrect (e.g., “eggs for the cracking”; “drink water and girl”). After therapy, we found significant improvements in the grammatical structure of trained and untrained item sets across the course of the study (both trained and untrained: $p_{WEST-Trend} < .001$). Comparing the rate of change in phases with and without therapy, significant differences were only found for treated items ($p_{WEST-ROC} < .001$). After therapy, she described more than 90% of the pictures from the trained set with a correct reduced sentence structure. However, there was no significant therapy-related improvement in grammaticality of untrained picture descriptions ($p_{WEST-ROC} = .740$). She described between 30% and 50% of all untrained pictures using a correct reduced sentence. The remaining responses consisted of noun phrases (e.g., waiter for the salad), single words, or were characterised by word order errors (e.g., “bike fixing”). Comparing the extent of improvement in the trained and untrained sets revealed a significant difference ($t(119) = 5.715$; $p < .001$). Thus, no clear evidence for generalisation was found.

RBI

RBI's therapy goal was to produce complete simple sentence structures. During baseline, he described between 10% and 20% of all pictures in complete simple sentences (see Figure 6). His two most common errors were the omission of the initial article (omitted in $\approx 54\%$ of all picture descriptions in B1–B3) and the omission of the auxiliary verb (omitted in $\approx 31\%$ of all picture descriptions in B1–B3). The number of correct and complete sentences produced improved significantly following the therapy phase. RBI showed significant improvement across the course of the study in production of simple sentences for both the trained and untrained item sets (trained and untrained: $p_{WEST-Trend} < .001$). In contrast to ANT, the intervention-related rate of change revealed

Figure 6. RBI's grammatical performance for simple sentence structures in the picture description task before and after treatment (B1= Pre-test Baseline 1, B2 = Pre-test Baseline 2, B3 = Pre-test Baseline 3, P1 = Post-test 1, P2 = Post-test 2, P3 = Post-test 3, FU = Follow-up).

highly significant differences across phases for both item sets ($p_{WEST-ROC} < .001$). Moreover, the comparison of improvement in trained and untrained item sets did not show a significant difference ($t(119) = -0.606$; $p = .272$). These results suggest generalisation of the benefits of treatment to untrained picture descriptions.

RBI reached his peak performance of about 85% correct sentence production at the second post-test (P2). This dropped significantly (McNemar's $p_{P2vs.P3} < .001$) to about 45% grammatically correct picture description in the third post-test and increased again at the 2-month follow-up testing (about 75% correct, McNemar's $p_{P3vs.FU} < .001$). This performance fluctuation was observed equally for trained and untrained picture descriptions. These changes were mostly related to omissions of the initial determiner (the word "the"). While this error appeared in only about 3% of all picture descriptions in the second post-test, it increased to about 34% in the third post-test but decreased again in the 2-month follow-up. For unknown reasons, RBI seemed to be especially focused on his grammatical accuracy and the production of "the" during the second post-test. One possible explanation might be the absence of his wife between the second and the third post-test. We observed that RBI received a lot of corrective feedback from his wife during home training and in daily conversation. Thus, her absence might have resulted in a less effective home training or reduced RBI's awareness for grammatical errors at P3. The importance of communicative partners in the therapy process and especially for the maintenance of improvements has been underlined in the previous literature (e.g., Jokel et al., 2014; Meinzer et al., 2005), and (the lack of) his wife's support during some of the home training might have been reflected in RBI's performance.

Generalisation to connected speech

ANT

Connected speech samples were obtained from a video recount task before and after the therapy phase (for excerpts, see Table 1; for detailed analysis, see Appendix 2).

ANT's limited syntactic skills resulted in her using only noun phrases to describe the video in the pre- and post-test. At the end of the study, she produced two more content

words but used one of them repeatedly (TTR: 89%; 8 nouns). The words “banana(s)” and “supermarket” were excluded from the analysis because they appeared as written words in the video sequence. ANT did not produce any verbs in either the pre- or the post-test. The information still remained grammatically unlinked, so that someone naïve to the video would not be able to understand what was happening. Moreover, ANT showed severe word-finding difficulties represented in filled and unfilled pauses. The length of pauses even increased from an average of 5 s in the pre-test to about 9.5 s in the post-test. Overall, no significant changes were observed from pre- to post-test.

RBI

In comparison to RBI's pre-test performance, his post-test video recount started very fluently and was grammatically correct. This time, he produced 21 phrases and 50 content words (TTR: 76%; 25 nouns, 19 verbs) in total. RBI's TTR decreased from pre- to post-test (TTR_{pre}:85% vs. TTR_{post}:76%). The increased number of content words can thus be partly explained by multiple repetitions of the same word (e.g., “section” and “storeman” mentioned 3x). In contrast to the pre-test, RBI confused the chronological order of major events in the video. In consequence, his speech flow became more interrupted and hesitant as the recount progressed (e.g., “he eh . no he he's eh the trolly.. hmm something before”). Thus, numerous word-finding difficulties, represented by filled pauses of about 2 s, and sentence interruptions occurred. Despite the improvements observed at the beginning of the recount task, no significant changes were observed in the overall measures from pre- to post-test.

Discussion

The first objective of this study was to analyse whether a modified CIAT protocol with additional individual home training improved the noun and verb retrieval of two participants with PPA in a picture description task. As a result of the therapy, ANT and RBI showed significant improvement in naming of trained object nouns and verbs depicted in action photographs. Moreover, this improved naming was found using different depictions of the targets. In contrast, verb and noun retrieval for untreated items in the picture description tasks and in the CAT and GNT did not show treatment-related improvements. Our second objective was to enhance the ability of the participants to produce grammatical structure. Again, highly significant treatment effects were found for trained items for both participants. Moreover, RBI showed generalisation to improved grammatical structure for untrained items. Our third objective was to increase grammatical structure in connected speech. However, no treatment-related generalisation was observed in the participants' connected speech samples or in any of the general assessments.

Modifications to the CIAT protocol

The importance of high treatment intensity is one of the most discussed features of the CIAT approach. Pulvermüller et al. (2001) suggested a therapy frequency of 30 h over 10 treatment days. Based on previous successful CIAT modifications (Goral & Kempler, 2009; Szaflarski et al., 2008) and intensive therapy approaches in PPA (Henry et al., 2008), we

decided to perform 90 min of treatment (60 min CIAT group + 30 min home training) per day over 9 days in 2 consecutive weeks. Prior to the study, RBI and ANT received speech therapy once to twice a month. Thus, the CIAT protocol constituted a dramatic increase of their usual therapy time. This relatively high treatment intensity could have played a key role, especially in the observed grammatical improvements of both participants. Unlike in word retrieval, the production of grammatically correct picture descriptions was not supported by a hierarchical cueing strategy. Thus, the massed practice of correct sentence structures might have increased the participants' awareness of grammatical features (e.g., RBI: use of auxiliaries and determiners, ANT: word order) and resulted in significant improvements in the picture description task.

In addition, we believe that the communicative setting of the treatment could have been an important factor in these gains. Group therapy has yielded good outcomes in post-stroke aphasia (Elman & Bernstein-Ellis, 1999; Holland & Ross, 1999; Pulvermüller et al., 2001), but only one study has reported the results of group therapy with people with PPA to date. Four individuals with svPPA and nfvPPA achieved significant improvements in their narrative skills in an intervention promoting "strategic television viewing" (Cartwright & Elliott, 2009). The content and important vocabulary of each episode of a popular television show were introduced, summarised and discussed in order to enable the participants to understand and recount the plot as completely as possible. As a result, all of the participants significantly improved their narrative skills. Like Cartwright and Elliott's (2009) participants, ANT and RBI both reported that they appreciated the opportunity to communicate with others on an equal level and were especially motivated when they could help other group members. We believe that the exchange of experiences is an especially important feature of the communicative group setting for people with PPA just as it is in post-stroke aphasia (Attard, Lanyon, Togher, & Rose, 2015; Masoud, Arnold, Schilikowski, Simon, & Simon, 2009).

A third important CIAT feature is *shaping* (Barthel et al., 2008; Meinzer et al., 2012). In this study, shaping was applied to the required dialogue structure and the experimental material (Meinzer et al., 2005; Pulvermüller et al., 2001). The therapy demand was increased gradually and only when a participant successfully reached about 90% accuracy at a particular level. Thus, the performance limits of ANT and RBI were stretched without overwhelming them (Meinzer et al., 2012). Avoiding failure and its associated negative feelings is one of the most important aspects when shaping is applied (Barthel et al., 2008). ANT was allowed to use writing as a self-cueing strategy during therapy, in order to reduce frustration that may have inhibited her therapy success. As the therapy progressed, ANT was encouraged to use as little writing as possible. In this way, the reduction of written self-cueing was used as an additional shaping step for ANT.

Our results show that a modified CIAT intervention can lead to significant improvements in subjects with PPA. However, the effectiveness of each individual CIAT feature (massed practice, group setting and shaping) could not be assessed given the design of the study reported here. For future studies, it would be very interesting to manipulate these different features to determine which of these CIAT features contribute most to the therapy success to inform further therapy approaches in PPA.

A novel aspect of this study, compared with most previous impairment-directed treatment studies in PPA, is that reduced and complete simple sentence structures were trained, rather than just training single word naming. The participants had to retrieve nouns and

verbs simultaneously and insert them into grammatical frames to describe the pictures. Many of the verb-object structures used in our material often appear together in daily conversation (e.g., driving the car, kicking the ball). Thus, the verbs and nouns can serve as semantic cues for each other, which may facilitate the selection and/or retrieval of words (Kleine-Katthöfer et al., 2012; Schlenck, Schlenck, & Springer, 1995). In addition, a phonological cueing hierarchy was provided if ANT or RBI failed to describe the picture spontaneously. The home training included a similar hierarchy.

We assume that the combination of the impairment-directed cueing approach and the indirect semantic cueing were factors that positively influenced the therapy outcome. Both phonological and semantic cueing have previously proved to be effective in nfvPPA (Henry et al., 2008; Jokel et al., 2014). Moreover, some studies on word-retrieval disorders in post-stroke aphasia have described semantic cues as being effective, even if the impairment is primarily phonological (Abel, Willmes, & Huber, 2007; Raymer & Ellsworth, 2002). Additionally, studies on individuals with Broca's aphasia showed significant word-retrieval improvements following a treatment with combined phonological and semantic cueing (Kleine-Katthöfer, 2012; Wambaugh, Cameron, Kalinjak-Fliszar, Nessler, & Wright, 2004). Our results suggest that these mechanisms can be equally effective in individuals with nfvPPA.

Maintenance and generalisation of therapy effects

Maintenance of therapy gains is one of the most important therapy goals but may not be possible given the neurodegenerative nature of PPA. Some authors argue that even the maintenance of a patient's pre-test performance level might be considered a therapy achievement (Croot et al., 2009; Henry et al., 2008; Jokel et al., 2014). Both the participants in the present study maintained improved performance compared to pre-therapy levels until the 2-month follow-up. Jokel et al. (2014) argued that continuous training is especially important to maintain trained skills in PPA. ANT and RBI continued the home training after the group therapy sessions ended. Follow-up testing showed no further significant improvement. This suggests that the participants' word-retrieval and grammatical improvements were more likely to be caused by the modified CIAT than by the computer-based home training alone. However, ANT and RBI's performance did not decline after the end of the CIAT intervention. Thus, we suggest that the home training contributed strongly to the participants' maintenance of post-treatment levels of performance. Due to organisational restrictions, we were only able to perform one follow-up testing. An additional follow-up testing after a period without any home training would have been interesting to evaluate the effectiveness of the computer-based home training in more detail. Nevertheless, our results support the claim of Jokel et al. (2009) that computer-based home training programs could be very helpful for increasing the usual therapy intensity and facilitate maintenance in a cost-effective and efficient way.

Both participants showed generalisation to different depictions of trained items. This suggests significantly improved language skills rather than a learned picture-name (or phrase) association (Croot et al., 2015; Jokel et al., 2014). Moreover, RBI's grammatical improvements generalised to picture descriptions for untreated items. Generalisation to new material and tasks is most commonly reported when the therapy targets the training of general strategies and not only specific language skills (Croot et al., 2009; Schneider et al.,

1996). In contrast to word retrieval, grammatical features like the use of an initial determiner or an auxiliary verb are not item-specific. Generalisation is likely to have been facilitated because the same grammatical structure was required for trained and untrained items.

Similar to previous intervention studies in PPA, no statistically reliable generalisation was found to a more demanding connected speech task (Croot et al., 2015; Henry et al., 2008; Jokel et al., 2014). Both Webster, Whitworth, and Morris (2015) and Croot and colleagues (2015) recently discussed some of the difficulties of evaluating transfer to connected speech. We used a video recount task to gain a general overview of the participants' pre- and post-test connected speech. We were interested in whether the participants would change their description strategy (e.g., ANT: production of verb-noun collocations instead of single words) but we did not observe any significant changes. In RBI's case, the beginning of his video description appeared to be remarkably improved, no significant changes were found in the quantitative measures. It is possible that RBI's main difficulties in the recount task were in selecting and organising relevant information and the conceptualisation of a coherent narrative (e.g., Cairns, 2006). Further examination of his "thinking for speaking" abilities would be necessary to test our hypothesis (c.f., Marshall, Pring, & Chiat, 1993).

The overall results of the CAT, GNT and TROG-2 also did not show any evidence for a significant change, indicating minimal decline in the participants' language abilities over the period of the study. Since the improvement in grammatical skills was one objective of this study, we looked for positive changes in the TROG-2 score, but would only expect to see these if our CIAT treatment of simple sentences and verb-noun collocations generalised to receptive grammatical processing abilities. Our findings indicate that the training of these very basic grammatical skills was not specific enough to improve the comprehension of grammatically complex sentences.

While there was no quantitative evidence of generalisation in ANT's case, there were nevertheless several positive indicators. First, she used one of the treatment items ("shutters") in her post-test video description that she did not use at the pre-test. In addition, she was observed to use therapy items in her daily conversation. For example, ANT offered to drive the clinician to the nearby train station. On one visit prior to therapy, it took ANT several minutes to communicate this information using non-specific gestures and showing her car keys. In contrast, after the intervention, she produced the treatment phrase "driving the car" to make her offer. On another occasion, she explained her plan for the day using the trained phrase "doing the washing". It is also possible that ANT learned the verb-noun collocations as *gestalts* rather than as grammatical structures.³ Heredia et al. (2009) reported similar anecdotes about their participant with svPPA. Neither ANT nor the participant reported by Heredia et al. were using trained items in experimentally controlled connected speech or communicative tasks, but these anecdotes suggest that generalisation of items from impairment-directed therapy to communicative situations might be possible.

Conclusion

Both participants in the present study achieved significant improvements in their naming accuracy and completeness and accuracy of grammatical structures for new depictions of trained items. Moreover, RBI was able to generalise his grammatical improvements to

untrained picture descriptions. This suggests that CIAT could be an effective treatment approach in nfvPPA; additionally, implementing supplementary continuous home training may be especially beneficial for maintenance of treatment gains in PPA. We suggest that features like the intensive treatment frequency, the impairment-directed therapy approach in combination with the indirect semantic cueing of grammatical structure provided by the materials and the motivating character of group therapy might have contributed to our positive therapy outcomes. Nevertheless, further research is necessary to extract the features that contributed most to treatment gains from this CIAT approach.

No significant generalisation was found to RBI's and ANT's naming of untrained items or to their performance in a video recount. This is in line with previous findings regarding word-retrieval therapy in PPA (Croot et al., 2009, 2015; Jokel et al., 2014). Thus, the communicative aspects of the presented CIAT were not sufficient to facilitate generalisation of trained word-retrieval skills to this spontaneous speech task.

In sum, the therapy effects found here support the fact that significant treatment and maintenance effects can be achieved by a modified form of constraint-induced language therapy with people with PPA. Moreover, we presented further evidence that generalisation of grammatical skills might be possible in at least some individuals with nfvPPA. Further research on a larger sample will be essential to establish the reliability of these findings.

Notes

1. Collocations are defined as verb–noun compounds that are strongly semantically related and often occur together in spoken language (Schlenck et al., 1995).
2. A phrasal verb is a verb composed of a verb and an adverb or a preposition. In our study they were all of the preposition form (e.g., throwing away, trying on).
3. We would like to thank the anonymous reviewer for this suggestion.

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Appendix 1: Individual shaping steps applied to dialogue structure
(-II-: structure remains, new components)

Shaping step	Request structure	Request example	Answer structure	Answer example
1	addressing + one word naming (noun)	John. "Lawn"?	one word	Yes/No
2	+ one word naming (verb)	John "Mowing"?	-II-	Yes/No
3	+ reduced sentence structure	John. "Mowing the lawn"	-II-	Yes/No
4	+ "Do you have"	John. Do you have "mowing the lawn"?	+ "I do"/"I don't"	Yes, I do./No, I don't.
5	+ complete sentence frame	John. Do you have "The man is mowing the lawn"?	-II-	Yes, I do./No, I don't.
6	-II-	John. Do you have "The man is mowing the lawn"?	+ repetition of requested picture description	Yes, I do/No, I don't have "mowing the lawn"/"The man is mowing the lawn".

Appendix 2: ANT's and RBI's pre- and post-test results of the video recount task

	ANT		RBI	
	Pre-test	Post-test	Pre-test	Post-test
Content				
Propositions	3	3	7	10
Phrases				
Phrases	6	7	15	21
Complete phrases	0	0	12	18
Words				
Words	23	22	107	143
Content Words	6	8	38	50
Type token ratio (TRR)	100%	89%	85%	76%
Nouns	5	8	15	25
Nouns (TRR)	100%	89%	87%	76%
Verbs	–	–	19	19
Verbs (TRR)	–	–	84%	79%
Errors				
Word finding difficulties	8	8	16	12
Semantic errors	2	1	2	1
Phonological Errors	–	–	5	1
Syntactical errors	Noun phrases only	Noun phrases only	10	7