

Effects of word prime repetition treatment on anomia

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Abstract

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Repetition priming involving masked primes has been suggested as a method for targeting implicit lexical retrieval processes to facilitate improved word retrieval for individuals with aphasia and anomia. This study was designed to investigate repeated use of explicit repetition priming as an alternative method to implicitly target lexical retrieval in individuals with anomia due to aphasia. A single-subject design was used in a case study with an individual with aphasia. Training involved repeated exposure to identity primes or sham primes paired with pictures. Analyses assessed treatment effects, generalization to untrained items, and effects on broader language skills, immediately and three months post-treatment. The participant improved in naming trained items immediately after treatment. Improvements were greater for primed items than for unprimed items. Generalization within and across semantic categories was mixed. Generalization to broader language skills was noted for overall naming ability and the participant's ability to read aloud. Repetition priming treatment may improve naming and broader language skills for individuals with anomia.

Introduction

Aphasia and Anomia

Aphasia is an acquired receptive and expressive language disorder which typically results from lesions in the left hemisphere of the brain, usually caused by stroke or other focal injury. It manifests as difficulty with expressive and receptive language in the areas of verbal communication, written expression, auditory comprehension, and reading comprehension (Anderson & Shames, 2014). These deficits may be noted across any or all of these domains to varying degrees. The most commonly recognized feature of aphasia is anomia; that is, the difficulty coming up with a given name for an image or object (Nickels, 2002). Communication can be exceedingly difficult for individuals with aphasia when they are unable to retrieve names of objects when speaking. These communication difficulties have a tremendous impact on the individual affected by the disorder as well as on the family and caregivers of those individuals (Code & Herrmann, 2003; DuBay, Laures-Gore, Matheny, Ronski, 2011).

When considering language disorders for the purpose of treating them, it is important to understand how language is believed to be processed. Language retrieval is largely an implicit process; implicit meaning unconscious and automatic. This type of processing differs from explicit processing which includes conscious awareness and attentional processes, (Tyler, 1992). Speakers do not typically require explicit input or cues to generate words and sentences. Language flows with little conscious effort on the part of the speaker. Furthermore, processing of language for comprehension is often implicit in that it is free from conscious control; a native speaker of a language hears their language being spoken and processes it automatically without conscious participation in the process, and without the ability to “turn off” that processing (Tyler,

1992). An example of this implicit nature of language can be seen in the Stroop effect (Stroop, 1935), which provides evidence for the inability to inhibit automatic processing of language when reading. An additional example of implicit linguistic processing has been demonstrated through priming. Priming is the effect of a stimulus (prime) on the participant's response to a subsequent stimulus (target) (Forster, Mohan, & Hector, 2003). For example, if an individual is presented with the word "cat" and asked to decide if a subsequent string of letters is a word or not, they will more quickly recognize "dog" as a real word than "bus". This phenomenon reflects implicit processing in that, when given a prime, an individual is automatically and unconsciously affected in their response to the subsequent stimulus.

Spreading activation, as discussed in the Interactive Activation model (Dell, 1986, Foygel & Dell, 2000) (see Figure 1), is a mechanism that supports these implicit language processes. The model proposed with this theory suggests that the linguistic system contains a connected network of "nodes" (i.e., linguistic units) which represent various linguistic concepts including semantic (meaning), lemma (non-phonological word representations), and phonological (speech sound) units. When formulating a sentence or responding to external stimuli, these nodes are activated and, according to the model, automatically spread activation to similar and related linguistic information.

The model proposes that, to select a word for production, the speaker begins with a concept in their mind of that item. For example, one might have a concept of a tree. From there, activation is spread to a semantic level, where various features of that item are activated. Following the example, the concept of tree would activate semantic information such as plant, leaves, large, green, branches, etc. These semantic features simultaneously activate various non-phonological word level forms called *lemmas*. These activated lemmas are connected to the

activated semantic features. For example, the word representations receiving activation might be tree, forest, or flower. Meanwhile, activation is spread to activated phonological representations (i.e., the sounds that correspond to the words represented by the activated lemma). In this model, there are multidirectional connections (i.e., connections to and from each linguistic level) which interactively spread activation back and forth from to each level within the system. There are no inhibitory connections in the model; therefore, reinforcement of items through the interactive spreading activation mechanism results in summation of activation, generating greater activation for the intended item. Semantic and phonological representations provide reinforcing activation to the lemma, and the most highly activated item within the network can be selected once a threshold for selection is reached. This model suggests sufficient activation within the linguistic system is necessary for word finding. If activation is impaired, there may be deficits in word finding.

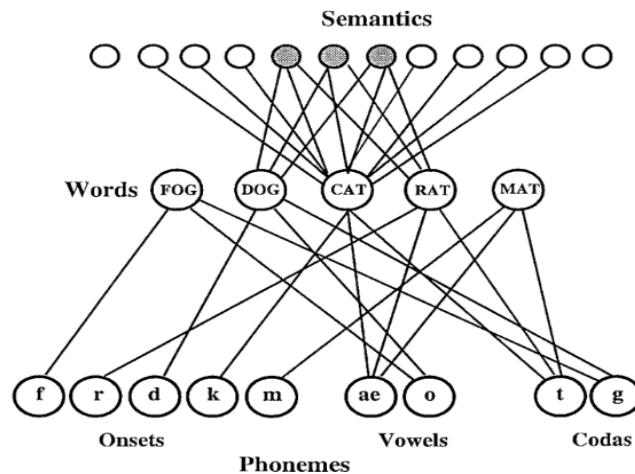


Figure 1: Interactive activation model of lexical retrieval (Foygel & Dell, 2000)

Significant evidence suggests that the underlying impairment in aphasia is not a loss of language, but rather a breakdown in accessing language (Schwartz et al. 1994; McNeil, 1988;

McNeil, Odell, & Tseng, 1991; Miyake, Carpenter, & Just, 1994; Saffran, Schwartz, & Linebarger, 1998; Tseng, McNeil, & Milenkovic, 1993). While aphasia and anomia are described as language impairments, individuals with these disorders are not missing linguistic representations or the underlying mechanism for language comprehension and production. The mechanism for aphasia/anomia is thought to be reduced activation spreading throughout the linguistic system and/or poor maintenance of that activation, not allowing sufficient time for selection (Schwartz, Saffran, Bloch, & Dell, 1994). Evidence suggests that, while individuals with aphasia may have expressive language difficulties, they often retain the ability to implicitly process language (i.e., process language automatically and unconsciously; Hagoort, 1993).

Additional evidence also suggests that individuals with aphasia continue to possess information related to word knowledge even when word finding difficulties are present. For example, individuals with aphasia have been shown to be stimulable for word retrieval when given semantic or phonemic cues (e.g., a related item to the target word or the first letter of the word; Nickels, 2002). Evidence of language impairment in individuals with aphasia has also demonstrated variability within the individuals with the disorder; individuals with aphasia may be able to access a word one day but not the next (McNeil, 1983; Tseng et al., 1993).

Furthermore, aphasia can be transient. When considering the onset of a stroke, individuals may present with severe symptoms and then, through spontaneous recovery, their language can improve significantly and quickly without any intervention (Anderson & Shames, 2014). This suggests that linguistic information remains intact in this population, and that the access to that information is impaired.

Given that breakdowns in word finding result from impaired activation within the linguistic network, if individuals with anomia could have more efficient spreading activation

and/or activation maintenance within their linguistic networks, they may see increased ability to find the words they are searching for. Thus, improving mechanisms of spreading activation and activation maintenance has been the target for many aphasia treatment programs.

Anomia Treatment

Treatments for aphasia and anomia are generally carried out through explicit tasks. For example, one common treatment method for naming deficits is Semantic Feature Analysis (Boyle, 2004), in which a picture stimulus is presented to the individual, who then names the image, analyzes various semantic features related to the word (e.g., group, action, description, location, etc.) and then names the image again. Another explicit treatment method is Phonomotor Treatment which involves training phoneme and phoneme sequence knowledge to strengthen the entire linguistic network and thus improve word-finding abilities in people with aphasia (Kendall et al., 2008). These types of explicit treatments are widely used and have been shown to generate positive outcomes for word-finding in individuals with aphasia (Efstratiadou, Papathanasiou, Holland, Archonti, & Hilari, 2018; Maddy, Capilouto, & McComas, 2014; Kendall, Oelke, Brookshire, & Nadeau, 2015). However, when treatment tasks are largely explicit (e.g., analyzing semantic features) top-down processing from explicit decision making becomes involved and the task no longer mimics natural language processing, which is largely implicit.

If implicit linguistic processes are impaired, it may be worth exploring treatment options that address the impairment through implicit means. Accessing implicit processing has the potential to create more robust treatment outcomes in that it taps into more natural linguistic processes. Perhaps targeting word-finding through the implicit processes of language could

generate treatment gains more efficiently or with less frustration and effort on the part of the client than current treatment methods.

Masked priming

Accessing implicit processes of language can be accomplished through the use of a masked priming paradigm. Masked priming, in particular, aims to isolate implicit processing. With masked priming, actions are taken to eliminate conscious perception of the prime. Masked priming can be accomplished in visual or auditory modalities. Visual masked priming is done by placing a very rapid sequence of symbols (e.g., %%%, @@@, &&&) before and/or after a prime. Furthermore, the exposure duration of the prime is reduced to minimize conscious perception. The visual masks interfere with conscious perception of the quickly presented prime and therefore interfere with the individual's ability to consciously see and explicitly process the prime. Effective masked priming ensures that priming effects are a result of implicit, unconscious processing (Van den Bussche, Van den Noortgate, & Reynvoet, 2009).

Results from previous studies have suggested a potential method for stimulating implicit language processes that, if implemented as a treatment protocol, may strengthen connections within the linguistic network and improve word finding for individuals with anomia (Silkes, Dierkes, & Kendall 2013; Silkes, 2015; 2018). Using masked priming may be advantageous in a treatment paradigm for individuals with aphasia in that it mimics more natural language comprehension and production by capitalizing on implicit language processing to create more robust treatment effects. The reasoning behind using a masked prime to access implicit language processes is that the primes boost activation of the targeted lexical representations so that the target words are more readily accessible when the participant attempts to name them. An

advantage for masking the prime rather than using a visible prime is that it allows the study of linguistic processing without extralinguistic influences, particularly conscious influence on decision making from the frontal lobes (Forster, 1998). Some individuals with aphasia have been shown to have greater difficulty with volitional language (language produced by one's choice) compared to non-volitional language (language that is unconsciously activated for production or comprehension) (Lum & Ellis, 1999). Treatment methods that prevent conscious decision making and volitional processing may be helpful for such individuals in that treatment would not require extensive analysis or reflection and may facilitate automatic spread of activation.

Previous research using masked priming with anomia

Researchers have investigated masked priming and how it may facilitate naming in individuals with aphasia. Avila, Lambon Ralph, Parcet, Geffner, & Gonzalez-Darder, (2001) published a case study of an individual with anomia who demonstrated increased accuracy on a confrontation naming task when masked word primes were presented to this individual prior to naming the images in the task. The authors concluded that the written word prime was either able to activate and reinforce semantic representations of the picture stimuli, or that the primes activated phonological representations from the correspondence between orthography (spelling) and phonology (speech sounds in words) (Avila et al., 2001).

Recently, researchers have taken the concept of masked priming and applied it to a treatment paradigm for individuals with anomia. Silkes (2015; 2018) investigated how the repeated use of masked repetition priming might improve picture naming in individuals with anomia due to aphasia. The goal of the treatment was to stimulate spreading activation through repeated masked priming sequences and, thus, facilitate word retrieval. The treatment involved

repeated exposure to pictures that were primed with either an identity prime (i.e., the name of the subsequent picture) or a sham prime (e.g., XGXGX). Ten participants across the studies had two sessions per treatment day for a total of 12 treatment sessions for each of two semantic categories. In each session, the items were presented four times, with four prime-target exposures presented before naming the target in each trial. Total exposure per session was 16 prime-target exposures and four opportunities to name each target. No feedback was given during treatment sessions.

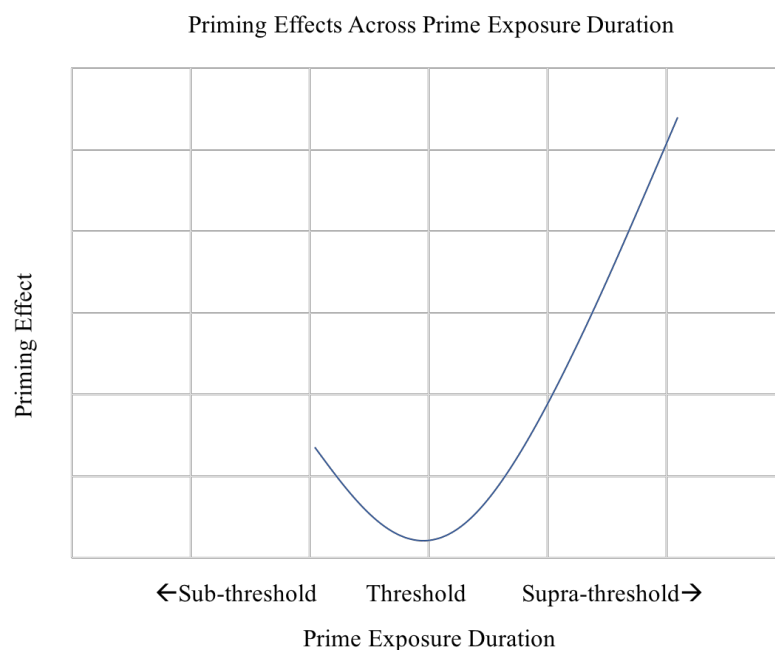
Silkes and colleagues (2015; 2018) found that eight of the ten participants involved saw improvements in their ability to name trained items. This finding suggests that the masked identity primes had an effect beyond the effect that repeated exposure to the images may have had on its own. Overall, the authors concluded that using a masked repetition priming treatment paradigm may improve naming for some individuals with anomia. This conclusion matters to future studies investigating the effects of repetition priming on anomia, and to individuals with anomia in general, in that it provides evidence that a treatment paradigm targeting the implicit language system can improve symptoms of anomia for some individuals.

Limitations/challenges of masked priming treatment

While these results are promising, masked priming has significant limitations when implemented in such a treatment paradigm. First, some participants did not respond to the treatment whatsoever. Furthermore, there was significant variability in results from one participant to another (Silkes, 2015; 2018). For example, some participants did not demonstrate within-category generalization but demonstrated cross-category generalization (i.e., improved naming on items from untrained semantic categories). These results are likely due to a

combination of participant, protocol, and stimulus factors. For example, appropriate prime exposure duration has been shown to be critical for obtaining masked priming effects. Dagenbach, Carr, and Wihlelmsen (1989) proposed that presenting masked primes at near-threshold durations will produce less of a priming effect than if the exposure duration was below the individual's threshold for conscious perception. If one were to graph an individual's priming effects across various prime exposure durations, a J-shaped curve emerges (see Figure 2). Priming effects have been seen at subliminal prime exposure durations and then dip lower near the individual's threshold for conscious perception, curving back up to the greatest priming effects above the individual's threshold for conscious perception.

Figure 2. J-shaped curve of priming effects across exposure duration



The theory behind the resulting J-shaped curve in priming effects is that, at supra-threshold prime exposure durations, the individual can reliably use explicit processing to perceive the prime. Near the threshold for conscious perception, an individual may still rely on

explicit processing in trying to consciously perceive the stimulus, but prime exposure durations near the threshold for conscious perception create little explicit information to use in conscious processing which results in the dip in priming effects. At sub-threshold durations, the individual can rely on implicit processes, thus creating a larger priming effect than near-threshold prime exposure durations. This finding suggests that there is a precise prime exposure duration for which priming effects will be greatest while eliminating conscious processing. To maximize priming effects while minimizing conscious perception, clinicians would need to pinpoint this exact prime exposure duration for each client and program the stimulus delivery paradigm accordingly.

Previous research has given a wide range (10-90 ms) as possible thresholds for conscious perception in masked priming for individuals with aphasia (Silkes & Rogers, 2010; Silkes & Chao, manuscript submitted). Considering that a specific prime exposure duration may be consciously accessible to some individuals with aphasia but not others, it is critical to use perception testing with these individuals to conclude that a stimulus is presented without the participants' ability to gain explicit awareness of task-relevant information. While each participant in Silkes (2015) and Silkes (2018) underwent perceptual testing to determine their threshold for conscious perception of the masked prime, some participants occasionally demonstrated awareness of the prime and what it said. This awareness of the masked primes could suggest perceptual testing as implemented was not accurate or that the individual's threshold for conscious perception of the primes can change. Furthermore, the awareness of primes increased over the course of treatment for some participants. This means it is possible that participants' awareness of primes may have influenced their treatment outcomes and that, for some participants, their threshold for conscious perception of primes decreases over time. Such a

decrease is problematic because it creates uncertainty as to whether participants are gaining task-relevant information during the treatment program. If masking the prime is critical to this paradigm working, a changing threshold for conscious perception of primes does not allow for control of that parameter. Having to assess an individual's threshold for conscious perception and perhaps having to re-assess it throughout treatment may, for one, limit the practicality of implementing treatment in settings where there may not be enough time to run a full assessment of the patient's threshold for conscious perception. Another limitation for clinical implementation is that the equipment needed to perform a masked priming treatment needs precise control of stimulus presentation parameters. It is possible clinicians would not have access to such equipment in their practice and therefore would be limited in their ability to implement a treatment protocol involving masked priming.

Implicit alternatives to masked priming treatment

Masking the prime may not be critical for implementing an implicit treatment program. Considering the challenges presented when limiting conscious perception of primes, it would be useful to consider removing masking and, furthermore, allowing the prime to be explicitly available. The goal of targeting implicit processes to mimic more natural language can still be accomplished using explicit stimuli. While it may be surprising to suggest using explicitly available stimuli in a treatment paradigm targeting implicit processes, it is important to consider the two ways a masked priming treatment implicitly targets the linguistic system. In the masked priming treatment protocols tested so far, implicit processing is targeted in one way by ensuring there is minimal to no conscious perception of the prime. Masking the prime and maintaining the prime below the threshold for conscious perception prevents conscious processes from being

involved in the priming effects seen in primed conditions. This process serves to limit top down processes that may negatively influence the individual's ability to name the objects. The second way the masked priming treatment protocol targeted implicit processes is through the lack of explicit feedback regarding the individual's performance on the task once they have named an item; any improvements in naming ability resulting from the treatment must arise from implicit learning. Implicit learning is automatic and does not require conscious awareness of the learning process (Butler & Berry, 2004). Learning in these types of treatment paradigms would result from repeated exposure of prime-target pairs, and repeated naming attempts strengthening network connections with limited conscious interference from explicit feedback regarding errors (Silkes et al., 2013). Within a treatment paradigm involving explicit stimuli, implicit learning mechanisms can still be recruited to facilitate naming accuracy. Making such a treatment paradigm explicit by removing the mask from the prime and extending the prime exposure duration to make it consciously available would continue to target implicit processing through the mechanism of implicit learning.

If an explicit priming treatment paradigm were successful in improving naming, such parameters would be more practical to implement in a clinical setting. Previous research conducted by Off, Griffin, Spencer, & Rogers (2015) suggests that individuals with anomia may improve naming outcomes from repeated practice of nouns involving implicit learning. Participants were repeatedly exposed to target pictures paired with naming opportunities over a maximum of 15 sessions. After a first naming opportunity, the name of the item was explicitly presented via audio and in writing. Participants were then given a second opportunity to name the picture. No feedback was given so any learning that occurred was due to implicit means. After completing the treatment program, all seven participants showed an overall decrease in

response time and increase in naming accuracy for trained items. These results suggest the potential for implicit learning simply through repetition of stimuli coupled with relevant information (e.g., picture and orthographic representation) in the absence of explicit feedback.

While psycholinguistic models of language are highly useful for thinking about the processes of language comprehension and production, all language processing and production occurs in the brain. Therefore, it is useful to consider the neural mechanisms involved in priming the linguistic system. When implementing a treatment program, the true mechanism of a change in behavior is the strengthening of neural pathways. According to the Global Neuronal Workspace Theory proposed by Dehaene, Changeux, Naccache, Sackur, & Sergent (2006), when gaining conscious access to a stimulus, stronger neural activation is observed when compared to the effects of subliminal stimuli. Furthermore, neural activation may be short-lived with subliminal primes (Dehaene et al., 2006). Differences in activation strength and duration may be critical for word retrieval, as represented in the Interactive Activation model's emphasis on activation strength and decay rate (Dell, 1986). Lexical retrieval depends on spreading activation and activation maintenance to bring the intended item to conscious access. It may be the case that even repeated exposure to a masked prime is not sufficient to cause spreading activation. Dagenbach et al. (1989) state that the more visible a prime is, the greater the priming effects will be. Perhaps a visible prime would generate strong input that would remain active for a longer duration, and, therefore, set up the linguistic network for better lexical retrieval and reinforce the correct target.

Using visible primes would mean that the client would not have to undergo perceptual testing to set their threshold for conscious perception, which would, thus, make individualized customization of such a treatment paradigm more realistic to accomplish. Furthermore, it would

eliminate the need for equipment with precise control of stimulus presentation parameters. Since this treatment paradigm does not involve presenting feedback, it would open up the possibility of developing a treatment program that could be accomplished remotely, using therapy sessions to develop a program that could be used by the patients without constant supervision on the part of the Speech-Language Pathologist (SLP). Such a program may be particularly useful for individuals with limited access to SLP services because of financial, geographic, or health-related reasons.

Current study

The existing evidence suggests that implicit treatment methods may be beneficial for treating individuals with anomia (Silkes et al., 2013; Silkes, 2015; 2018, Off et al., 2015). However, as mentioned above, there are multiple theoretical and practical challenges to implementing masked priming treatment. As also discussed above, further evidence supports allowing for conscious access to primes within repetition priming treatment paradigms. Therefore, the goal of this study is to provide insight into alternative implicit methods for treatment of anomia and to contribute to knowledge regarding how best to implement such treatment. This research also aims to investigate the effects such a treatment paradigm may have on broader measures of language such as language comprehension or reading ability. The current study implemented an implicit treatment method involving repetition priming using visible primes without explicit feedback on participant performance.

Research questions

This study investigated the following research questions addressing the effects of training word retrieval for an individual with aphasia using visible identity primes paired with pictures on picture naming and broader measures of language function. Specifically:

1. Does training word retrieval using visible identity primes paired with pictures lead to improved naming of trained items immediately after treatment?

Hypothesis: Naming of trained items will show improvements in naming accuracy through repeated exposure to visible word primes paired with pictures, by strengthening lexical networks through automatic spreading activation.

2. Does training word retrieval using visible identity primes paired with pictures lead to improved naming of semantically related untrained items immediately after treatment?

Hypothesis: Semantically related untrained words are also predicted to show improvements in naming accuracy resulting from strengthening of lexical networks through automatic spreading activation.

3. Does training word retrieval using visible identity primes paired with pictures lead to improved naming of semantically unrelated untrained items immediately after treatment?

Hypothesis: Semantically unrelated untrained items are predicted to not show

improvements in naming accuracy, as previous research has shown cross-category generalization to be limited (Silkes, 2018). However, if semantically unrelated untrained items increase in naming accuracy, it would suggest improvements in broad lexical retrieval mechanisms.

4. Does training word retrieval using visible identity primes paired with pictures lead to improvements in broader language function?

Hypothesis: Participants may improve on measures of broader language function such as the Comprehensive Aphasia Test and Boston Naming Test. Silkes, et al. (2013) demonstrated improvements in broader language function (e.g., auditory comprehension), for some individuals participating in a masked repetition priming treatment study. However, more recent findings (Silkes, 2018) have shown no significant changes in measures of broader language function for participants after masked repetition priming treatment. If improvements in broader language function were to occur, it would provide evidence for strengthening of a general language function including a general lexical retrieval mechanism.

Method

Study design

This research project is a single subject ABA design with one trained and two untrained conditions, with a single participant with aphasia.

Eligibility criteria

The participant will be an adult with aphasia. Diagnoses of aphasia will be based on scores on the Comprehensive Aphasia Test (CAT; Swinburn, Porter, & Howard, 2004) and/or the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) <50/60. The participant will have scores on Raven's Coloured Progressive Matrices test of non-linguistic processing (RCPM; Raven, 1976) within normal limits (minimum score of 23/36) to rule out potential right hemisphere lesions. The participant will not have a significant history of psychiatric disorders, evidence of depression (as measured by a score < 4 on the Depression Intensity Scale Circles; Turner-Stokes, Kalmus, Hirani, & Clegg, 2005), or other neurological disease or injury beyond that which caused aphasia. Lesions will be to the left hemisphere as proven by CT or MRI reports. The participant will show no field cuts or hemi-neglect as assessed by a line bisection test and will have normal or corrected-to-normal vision according to assessment with the Tumbling E eye chart.

Participant characteristics

The participant was a 75-year-old female mild expressive and receptive aphasia who was recruited through the Northwest Aphasia Registry and Repository. She acquired aphasia after experiencing bleeding on the brain during an operation to clip an aneurysm. She was seven years post-onset of aphasia at the time of participation in this research study. Her aphasia was relatively fluent, and she was relatively high-functioning with regard to her expressive and receptive language skills. She spoke in full sentences with instances of anomia. The participant had mild auditory comprehension deficits and had good error recognition. She was frequently able to self-cue for word finding by spelling the target word out loud or in the air with her finger. Her diagnosis of aphasia was based on scores on the Comprehensive Aphasia Test (CAT;

Swinburn, Porter, & Howard, 2004) and the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) (43/60). The participant scored 34/36 on Raven's Coloured Progressive Matrices test of non-linguistic processing (RCPM; Raven, 1976) (minimum score of 23/36) which is sensitive to right hemisphere lesions. The participant did not have a significant history of psychiatric disorders, evidence of depression (as measured by a score of 0 on the Depression Intensity Scale Circles; Turner-Stokes, Kalmus, Hirani, & Clegg, 2005), or other neurological disease or injury beyond that which caused aphasia. Lesions were to the left hemisphere as proven by an MRI report finding a large cortical and subcortical lesion in the distribution of the left middle cerebral artery, including temporal, parietal, and striatocapsular areas. The participant showed no field cuts or hemi-neglect as assessed by a line bisection test and had corrected-to-normal vision according to assessment with the Tumbling E eye chart.

Equipment

Equipment included a personal desktop computer running Microsoft Windows 7 connected to a 20" CRT computer monitor. E-Prime software was used for stimulus delivery (E-Prime Professional version 2.0.10.147, Psychology Software Tools, Pittsburgh, PA, 2003). Additional equipment included a video/audio recording device.

Stimuli

All stimuli were taken from Silkes (2015; 2018). To provide the participant with a variety of categories for treatment targets, picturable nouns from 11 semantic categories were used in the current study. Stimuli within each semantic category were all determined to be logical members of their category by Dr. Silkes and members of the University of Washington Aphasia Research

Laboratory. The stimuli included in each category varied in word length, word frequency, and phonotactic probability. The Subtlex database (Brysbaert & New, 2009), was used to determine word frequencies. Measures of phonotactic probability were acquired through an online probability calculator (Vitevitch & Luce, 2004).

All pictures were color photographs. The pictures had any relevant written information removed (e.g., the words “school bus” or “ambulance” on those vehicles), unless that information was critical for the picture (e.g., letter tiles on a Scrabble board and the names of properties on a Monopoly board). Treatment stimuli were customized for the participant from the lists of words in selected semantic categories based on performance during baseline probes. Items used in treatment were familiar to the participant. Prime words were presented in the center of a computer screen with 30-point, black, Arial font.

Procedures

The participant began with an initial assessment to determine eligibility for the study. Assessment included the CAT and BNT as measures of overall language functioning and lexical retrieval, respectively. The Five Point Test (Regard, Strauss, & Knapp, 1982) was also administered as a baseline control index of non-linguistic cognitive function.

Stimulus selection followed the initial assessment. The participant was given a total of 12 baseline probes across seven days to determine her specific stimulus set and to determine baseline performance before treatment. Baseline naming probes asked the participant to name pictures presented one at a time on a computer screen. The participant was presented with pictures from 11 semantic categories in an effort to find words which she had difficulty naming. Items from all semantic categories were presented randomly in probe lists comprised of 154

items. The participant was readily able to name a significant number of items on probe list 1 and not enough treatment items could be derived from the first list alone. Therefore, a second list of 154 items was used to identify more potential treatment targets. Before treatment began, each treatment item was presented a total of seven times during baseline probes. The participant was asked to report familiarity for each item she did not name. Only items reported as familiar were included in the final stimulus list. Furthermore, the final stimulus list comprised only words that the participant named accurately three times or fewer during baseline probes and not during the final baseline probe session.

Stimulus items were divided across three conditions. The first condition, trained (T), involved the presentation of visible identity primes before presentation of a target image. There was a total of ten stimuli in the T condition. The next condition was untrained–exposed (UE), which contained ten stimuli from the same semantic categories used in the T condition. UE items were seen the same number of times as trained items but did not include a visible identity prime; they were instead preceded by a string of Xs (e.g., XXXXXX) before the target image was presented. The UE condition served as a control condition to differentiate improvements in naming related to repeated exposure to target images alone versus improvements seen when explicit primes were included in trials. The third condition was untrained–unexposed (UU), with a total of 20 items. The UU items were composed of ten items from the same semantic categories used in the T and UE conditions (untrained-unexposed-related; UU-R) and ten items from unrelated semantic categories (untrained-unexposed-unrelated; UU-U). The UU-R items allowed for analysis of within-category generalization, while the UU-U items allowed for analysis of cross-category generalization. UU items were only presented during baseline and post-treatment naming probes. Word lists across the three conditions were balanced for word frequency, number

of letters, number of phonemes, number of syllables, and phonotactic probability. See Table 1 for an outline of stimulus categories across conditions and Appendix A for full list of stimuli used during the protocol. See Table 2 for mean lexical values for stimuli across conditions.

Table 1. Stimulus categories across conditions:

<i>Trained (T)</i>	<i>Untrained-exposed (UE)</i>	<i>Untrained-unexposed (UU)</i>
Occupations (3 items)	Occupations (3 items)	Occupations (2 items)
Toys (3 items)	Toys (3 items)	Toys (3 items)
Sports and Games (4 items)	Sports and Games (4 items)	Sports and Games (5 items)
		Household items (3 items)
		Instruments (3 items)
		Tools (4 items)

Table 2. Mean lexical values across conditions:

<i>Lexical value category</i>	<i>Trained (T)</i>	<i>Untrained-exposed (UE)</i>	<i>Untrained-unexposed (UU)</i>	<i>One-way ANOVA</i>
Frequency	5.774849	2.494202	1.914863	$F = 1.04$ $p = 0.36$
Number of Phonemes	6.2	6.6	6.6	$F = 0.18$ $p = 0.84$
Number of Syllables	2.7	2.5	2.85	$F = 0.80$ $p = 0.46$
Number of letters	7.8	7.2	8.2	$F = 0.56$ $p = 0.58$
Phoneme probability	0.24306	0.30289	0.151265	$F = 0.89$ $p = 0.42$
Biphone probability	0.01242	0.02191	-0.0857	$F = 1.05$ $p = 0.36$

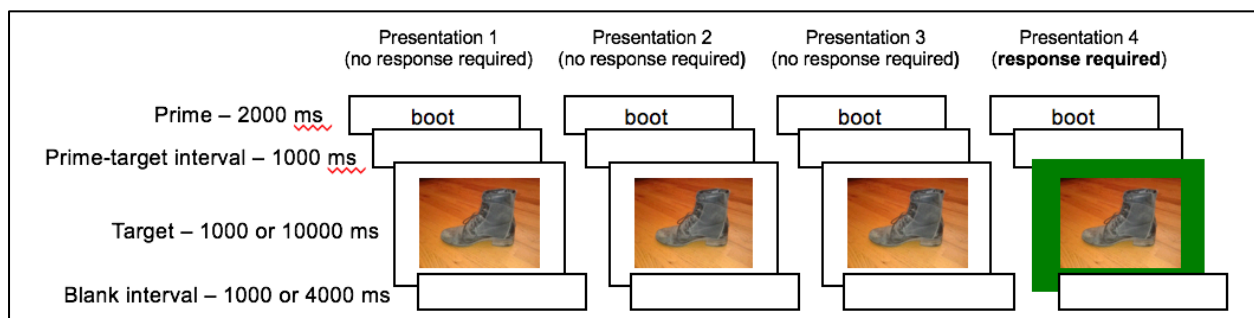
Treatment sessions

The participant took part in two sessions per day, approximately three days a week, for a total of 12 sessions lasting around an hour each. A break lasting a minimum of one hour was

given between sessions. Treatment sessions took place in a quiet room and the participant was seated at a comfortable distance from the computer screen on which she watched the treatment session stimuli. The participant was given frequent opportunities for breaks during the sessions.

Each treatment trial involved four presentations of the visible identity prime (2000 ms each), a 1000 ms blank screen, and the target picture (1000 ms for the first three presentation, 10000 ms for the final presentation), with an opportunity to name the picture during the final presentation (see Figure 3). The participant was instructed only to name the picture on the fourth presentation, when the picture was presented with a green frame around it. There were 16 total prime-picture exposures per session and four chances to name the picture. Participants had ten seconds to name the image; after the ten-second window, the picture disappeared and there was a four-second pause before the next prime-picture sequence began. Feedback regarding the accuracy of naming attempts was not provided throughout the treatment protocol.

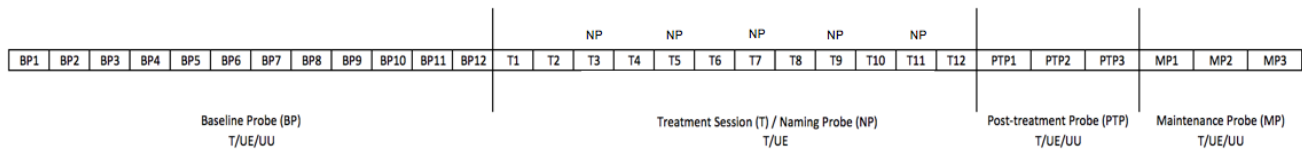
Figure 3. The sequence of visual stimuli in a single treatment trial.



Naming probes were administered at the beginning of every third treatment session and included all T and UE items. A total of three post-treatment probes were conducted the week immediately after treatment was completed. Post-treatment probes included all target items used in T, UE, and UU conditions. Maintenance probes were conducted three months following

completion of post-treatment probes and also included all target items used in T, UE, and UU conditions. See Figure 4 for an outline of the treatment schedule. The primary outcome measure for these probes was accuracy of responses.

Figure 4. Treatment and naming probe schedule outline.



The CAT and BNT were administered again following treatment and at maintenance testing to compare scores with pre-treatment functioning. This served to highlight changes in overall language ability. The Five Point Test was also re-administered post-treatment and at maintenance testing to assess any changes in non-linguistic cognitive function.

To gain basic knowledge related to the participant’s experience participating in such a treatment protocol, qualitative questions were asked in an interview style at specific points during the treatment protocol. Two questions addressed how the participant felt about naming pictures during the session and how she was approaching the treatment. These questions were asked following the initial treatment session probes and the final treatment session probes. Four questions addressed the participant’s overall perception of the treatment method and strategies she may have used to name pictures during treatment sessions. These questions were asked only following the final treatment session probe. Responses were audio recorded for later transcription. Please refer to the *results* section to see the specific qualitative questions used.

Data processing & analysis

Response accuracy was scored by the experimenter during all naming probes and treatment sessions. Any uncertainties were verified using audio recording. Responses given by participants were considered correct if the target word was produced at any time while the final picture presentation was on the screen (ten seconds). Words that were distorted were considered correct if that distortion did not cross phonemic boundaries. Inflectional changes to the target response (e.g., *dogs* for *dog*) were considered correct responses because inflectional morphemes (e.g., plural -s) do not change the grammatical category of the noun. Derivational changes to target words, (e.g., *skiing* for *skis*), were counted as incorrect responses because derivational morphemes (e.g., -ing, -ly) change the grammatical category of the word. This distinction was made because the goal of treatment was to train retrieval of nouns; if other parts of speech were retrieved and counted as correct responses, the outcome measure would not have measured improvement in noun retrieval.

Effect sizes immediately post-treatment were calculated using the mean accuracy and standard deviation from the accuracy seen during the seven baseline probe stimulus presentations as well as the mean probe accuracy from the three post-treatment probes, with the following formula: $[d = (\text{Mean}_{\text{post-treatment}} - \text{Mean}_{\text{baseline}}) / \text{SD}_{\text{baseline}}]$ (Busk and Serlin, 1992).

Maintenance effects were calculated by comparing the participant's performance on the initial seven baseline probe stimulus presentations and performance on the three maintenance probes administered three months after treatment. Within-category generalization effects for exposed and unexposed items were calculated by comparing baseline naming performance on UE and UU-R items with naming performance on those items during post-treatment probes. Cross-category generalization effects were calculated by comparing initial naming performance

on UU-U items during baseline probes and performance naming UU-U items on the three post-treatment probes. Effect sizes > 2.6 were considered to be small, > 3.9 were medium, and > 5.8 were large (Beeson & Robey, 2006).

Responses to qualitative questions presented throughout the treatment sessions were transcribed verbatim from audio recordings by the experimenter. Summary statements were generated from the participant's responses are reported below.

Reliability

All probe responses were scored for accuracy in real time during administration. The author and a trained research assistant rescored 25% of all probe responses (695 stimuli) using an audio/video recording. The research assistant was instructed in the scoring criteria outlined in the *Data Processing & Analysis* section of this paper. To ensure reliability of the data, an inter-rater reliability analysis for probes was calculated using Cohen's kappa. This compared the initial scoring with that of the second trained listener. Intra-rater reliability was also calculated by using the initial online scoring by the experimenters who had conducted probe sessions and comparing scores to the re-scoring by the same individual. This ensured that the experimenters were consistent in their own scoring judgments. Per Cohen's kappa, inter-rater reliability was determined to be $k = 0.94$ and intra-rater reliability was determined to be $k = 0.97$, both indicating high reliability.

Stimulus Selection

The participant came in for 12 total baseline probe sessions. The first five sessions used stimuli list 1 and the next two sessions used the remaining items from list 1 (items that had not

been correctly named three times up to that point), as well as all stimuli from list 2. The final five baseline sessions included only items from stimuli list 2. Each selected item was presented in a total of seven baseline probes. Stimuli were separated into Treated (T), Untreated – Exposed (UE), and Untreated - Unexposed (UE) categories according to the semantic category parameters outlined above.

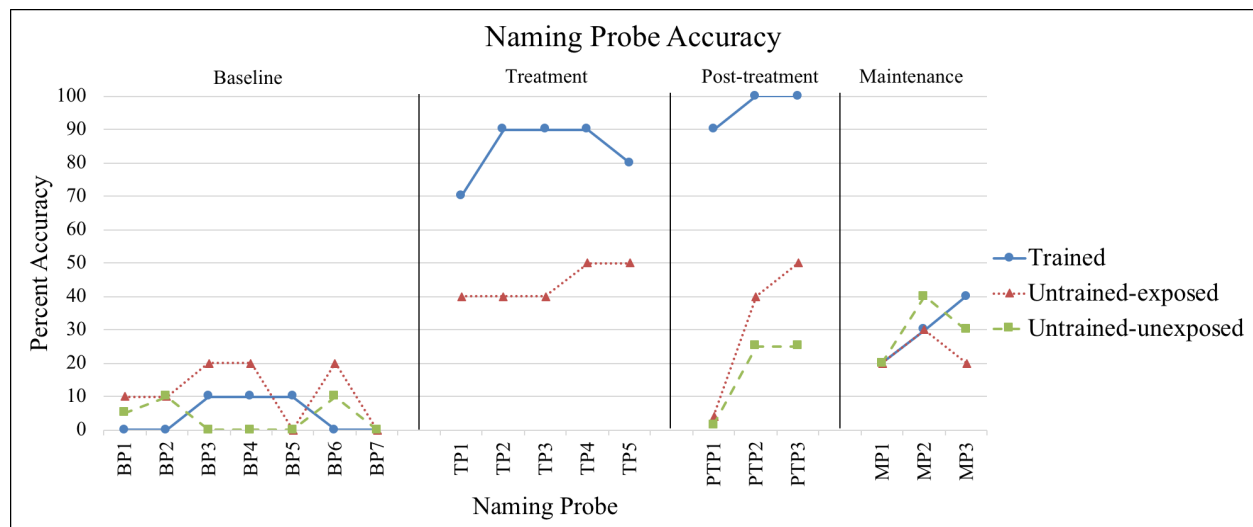
Results

Effect sizes for naming probes immediately post-treatment were 17.28 (large) for the T condition, 3.55 (small) for the UE condition, and 3.80 (small) for the UU condition (see Table 3 for summary of effect sizes across treatment and Figure 5 for naming probe accuracy across baseline, treatment, post-treatment, and maintenance sessions). The UU condition was broken down into related (UU-R) and unrelated (UU-U) items to assess for within category and cross category generalization. This revealed an effect size of 1.83 (none) for UU-R items and 2.84 (small) for UU-U items. At maintenance testing, effect sizes for naming probes were 4.81 (medium) for the T condition, 1.32 (none) for the UE condition, and 4.86 (medium) for the UU condition. When broken into UU-R and UU-U items, the effect size for UU-R items was 2.71 (small) and the effect size for UU-U items was 3.27 (small).

Table 3. Effect sizes post-treatment and at maintenance testing

Condition	Post-treatment effect size	Maintenance testing effect size
<i>Trained (T)</i>	17.28 (large)	4.81 (medium)
<i>Untrained-exposed (UE)</i>	3.55 (small)	1.32 (none)
<i>Untrained-unexposed overall (UU)</i>	3.80 (small)	4.86 (medium)
<i>Untrained-unexposed-related (UU-R)</i>	1.83 (none)	2.71 (small)
<i>Untrained-unexposed-unrelated (UU-U)</i>	2.84 (small)	3.27 (small)

Figure 5: Naming Probe Accuracy



During baseline naming probes, participant errors were often semantically related items or real items that were phonological similar to the target. Errors also frequently included nonwords that involved significant phonological components of the target. Many naming attempts involved self-cuing by spelling the target word out loud (e.g., “h-u-l-a-h-o-o-p; hula hoop”). The participant demonstrated occasional perseverations from previous items but recognized errors immediately. In addition, responses for inaccurate target words were largely consistent across sessions (e.g., *roller skate rink* for *roller derby*). CAT scores showed some

improvements in reading subtests when comparing performance during baseline testing to immediately post-treatment and maintenance testing three months after treatment. BNT scores were 43, 51, and 49 respectively (see Table 4 for summary of participant test data). Comparing the average number of accurate and unique designs produced on the Five Point Test during baseline probes with the average number of accurate and unique designs produced during final probes revealed no significant difference. Comparison of average Five Point Test scores during baseline probes with average scores during maintenance testing also revealed no significant difference.

Table 4. Participant Test Data

Assessment	Baseline	Post-treatment	Maintenance
<i>Boston Naming Test</i>	43/60	51/60	49/60
<i>Comprehensive Aphasia Test</i>			
Line Bisection	0	0	0
Semantic memory	10/10	10/10	10/10
Word fluency -Animals	13	12	11
Word Fluency – S	3	5	5
Word Fluency - Total	16	17	16
Recognition memory	10/10	10/10	10/10
Gesture object use	12/12	12/12	12/12
Arithmetic	5/6	5/6	5/6
<i>COGNITIVE TOTAL</i>	37/38	37/38	36/27
Comprehension of spoken words	28/30	28/30	28/30
Comprehension of spoken sentences	26/32	22/32	29/32
Comprehension of spoken paragraphs	4/4	4/4	4/4
<i>COMPREHENSION SPOKEN TOTAL</i>	58/66	54/66	61/66
Comprehension of written words	28/30	28/30	30/30
Comprehension of written sentences	27/32	24/32	30/32
<i>COMPREHENSION WRITTEN TOTAL</i>	55/62	52/62	60/62
Repetition of words	30/32	30/32	30/32
Repetition of complex words	4/6	6/6	3/6
Repetition of nonwords	6/10	4/10	4/10
Repetition of digit strings	6/14	8/14	8/14
Repetition of sentences	10/12	8/12	8/12
<i>REPETITION TOTAL</i>	56/74	56/74	53/74
Naming objects	43/48	44/48	42/48
Naming actions	10/10	10/10	10/10
<i>NAMING TOTAL</i>	69	71	69
<i>SPOKEN PICTURE DESCRIPTION</i>	203.5	133.5	129.5
Reading words	43/48	48/48	44/48
Reading complex words	1/6	2/6	6/6
Reading function words	6/6	6/6	6/6
Reading nonwords	4/10	10/10	8/10
<i>READING TOTAL</i>	54/70	66/70	64/70

Qualitative results

Qualitative questions addressed the participant's perception of the treatment paradigm as well as her approach to naming stimuli in treatment sessions. The first question was asked during the initial naming probe session as well as during the final naming probe session. The question asked the participant to, "*Describe what is happening in your head when you see the word, the picture, and then try to name it.*" The participant reported in the initial session that she could, "physically feel the brain working hard." She stated she became aware of how before her injury she could name things without effort. She also stated, "Ultimately, it becomes like a headache after doing several of these." In addition, she highlighted that when she received a prime that she recognized, she felt relief that she would be able to name the target. She mentioned, however, that for some word primes she only recognized a few letters initially, stating, "Some words are not recognized at all you see maybe one or two letters look familiar, three maybe but the rest of it doesn't look familiar." In these instances, she would have to, "sound [the word] out" to help her name the target. In the final probe session, she stated that sometimes she would recognize the word instantly when seeing the prime and that sometimes she would cue herself by spelling the word in her head. This is consistent with observed participant behavior of spelling target words out loud or writing them in the air throughout the treatment sessions.

The second question was also asked during the initial and final naming probe sessions. The question asked, "*Do you feel it was easier to name the pictures this time versus the first time you saw them?*" The participant stated at the initial naming probe session that she felt the words were easier to name than the first time she saw them. In the final naming probe session, the participant stated, "Yes, it has gotten easier to name them since then."

The remaining questions were asked only during the final naming probe session. These questions included:

“Did you use any strategies or methods to help you name the pictures? If so, what did you use?” When considering the strategies, she used to name images during treatment sessions, she stated, “Spelling is the primary thing.” She would think of the first letter or letters of the target word to cue herself to name it. This was also apparent to the experimenter as the participant would say letters out loud herself and spell in the air with her finger.

“How did you feel about this approach overall? How did it work for you?” The participant stated, “When you gave me the word, I liked that a lot. With the Xs, frustration is definitely there.”

“Do you think the length of the sessions was too long, too short, or just right? Why?” The participant focused on individual trials when thinking about the overall length of sessions and stated, “In the beginning, it was a good time between the name and you sit there ‘till finally you can say it. In the beginning, it was perfect. Now that I have done it so much it could be sped up a little bit.” However, she also recognized that she was still having trouble naming some items and, therefore, would want the allotted time to try to name those items.

“Is there anything you would change about this approach? If so, what would you change?” The participant responded by saying, “I want all the answers” (i.e., primes) and by expressing that it was frustrating to try to name items when not given the prime.

Discussion

The single case presented in this investigation provides initial evidence to support the use of explicit repetition priming within a protocol that uses implicit learning to improve word retrieval in an individual with aphasia and anomia. The participant's naming ability improved significantly for trained items immediately post-treatment as well as at maintenance testing. The nonlinguistic control measure (Five Point Test) showed non-significant change across the study, suggesting any changes in naming accuracy across the duration of the study were not likely a result of overall improvements in cognitive functioning.

For this participant, in agreement with the hypothesized outcome, repeated exposure to explicit word primes paired with images (T condition) showed greater overall improvements than repeated exposure to picture stimuli alone (UE condition). Also in accordance with the hypothesized outcome, there were small improvements noted in the UU condition overall. Interestingly, and not in agreement with the hypothesized outcome, the participant showed statistically significant improvements only for semantically unrelated (UU-U) stimuli immediately post-treatment. This indicated cross-category generalization in the absence of within-category generalization. The finding that there was no within-category generalization was surprising in that, according to the spreading activation model of lexical processing, it would be expected that items from the treated semantic categories would be most readily strengthened by increased network activation and would therefore see greater generalization effects than those items unrelated to the trained words. Interestingly, however, similar results were found in Silkes et al. (2013) with use of a masked repetition priming treatment paradigm.

One potential explanation for the presence of cross-category generalization in the absence of within-category generalization can be an overall improvement in the linguistic network.

However, it would be difficult to determine, if that were the case, why unrelated items benefited over related items. An alternative explanation could be a protocol factor that may have an influence on participant performance. In this case, a protocol factor to consider is whether treatment stimuli are blocked by semantic category or mixed. Silkes et al. (2013) argued that lack of within-category generalization in a masked repetition priming paradigm may have occurred because stimuli were blocked by semantic category during training rather than being presented randomly. Previous research has shown the potential for training of items within one semantic category to cause interference (Schnur, Schwartz, Brecher, & Hodgson, 2006) and therefore reduce potential for strengthening lexical representations. In this study, however, stimuli were mixed in an attempt to prevent such within-category interference. It is possible, however, that mixing semantic categories during training reduced the potential for within-category generalization immediately following treatment. Prior research investigating contextual priming found that semantically blocking stimuli in training can lead to improved outcomes for trained items as well as improved outcomes for generalization to semantically-related untrained items (Renvall, Laine, Laakso, & Martin, 2003).

It could be, for the participant in the current study, that mixing the semantic categories actually reduced the ability for robust activation of the linguistic network to strengthen activation of a single semantic category. Perhaps random presentation of stimuli from all semantic categories created the need for decay of activation within a given category to select the item from the next semantic category, leading to less robust spreading activation to semantically related nodes. The overall linguistic mechanism may have been strengthened through mixed semantic presentation resulting from repeated instances of increased activation of varying semantic networks across the lexical system. However, without activation of a more focused semantic

network for an extended period of time, as would occur with semantically blocked stimuli, the trained semantic categories themselves may not have had sufficient activation to create long-term network improvements within the semantic category. If this explanation were to be true, it could explain the presence of cross-category generalization without within-category generalization in the current treatment paradigm. Given these similar results across the current study and Silkes et al. (2013) with varying protocol factors in each study, future research should investigate differences in treatment effects when implicit or explicit priming treatment paradigms involve both semantically blocked and mixed treatment conditions to determine if one method tends to lead to greater within-category generalization.

This result of cross-category generalization post-treatment is questionably meaningful, however, due to the fact that this small effect size for improved naming of semantically unrelated items occurred in a single individual participating in this paradigm. In addition, it is important to consider the small number of stimuli used for this comparison. A larger pool of stimulus items as well as a larger pool of participants would be necessary for determining the within- and cross-category generalization effects of an explicit repetition priming treatment protocol. If a pattern of cross-category generalization in the absence of within-category generalization were to be seen repeatedly with future participants, it would be worth exploring further.

Similar to results from the previous study involving anomia treatment using a masked repetition priming paradigm (Silkes, 2015; 2018), this participant became more consistent in her naming responses across the course of the experiment; that is, she became increasingly closer to the target with her responses when an explicit word prime was provided (e.g., no response – “kalioscope” – “kaleidoscope”). Over the course of the training sessions, all items that included an explicit prime were eventually recognized and accurately named. In contrast, when an explicit

word prime was not present, the participant sometimes became more consistent with an incorrect naming response to a target picture (e.g., consistently saying “roller skate rink” for “roller derby”).

As mentioned, prior literature has suggested learning can occur in anomia treatment without feedback (Off et al., 2015). Similarly, naming accuracy for UE items in the current study showed a small effect size post-treatment, providing further evidence that exposure to a picture stimulus with repeated naming attempts in the absence of feedback has the potential to improve naming accuracy for those items in individuals with anomia. However, given the large effect size for improved naming accuracy for primed items, it seems that, while repeated exposure to target images can lead to improvements in naming accuracy, the presence of the prime adds to the repeated exposure and has the potential to maximize treatment outcomes.

In this participant’s case, the improvements for trained stimuli may be related to individual participant factors. It has been suggested in previous research (Silkes, 2015; 2018) that a participant’s language profile, presence of perseveration, error awareness, and reading ability may impact their response to masked priming protocol. In the case of an explicit priming protocol, all of these factors have the potential to impact response to treatment as well. The participant in the current study had moderately intact reading and spelling ability at baseline, the latter of which she often used to cue herself for word retrieval. This may have influenced her ability to gain useful information from the explicit primes in that she was visually perceiving the orthography of each word prime. It is also important to mention, however, that although single word reading, and spelling were moderately intact for this participant, she, at times, produced incorrect naming responses to stimuli involving an explicit word prime.

Although reading ability might seem like an obviously beneficial skill for individuals participating in an explicit priming protocol, previous research has suggested that individuals with severe acquired alexia can demonstrate intact single-word processing for implicit tasks (Mimura et al., 1996; Revonsuo, 1995). It may be the case that even individuals with severe acquired alexia could have single-word processing for explicit word primes as well, whether that be implicit or explicit in nature. Interestingly though, one participant from the Silkes (2018) masked priming treatment study had intact single word comprehension, but was unable to read words aloud. This participant did not respond to treatment, which suggests that his ability to gain semantic information from words he would not have been able to read out loud may not have been adequate for creating robust spreading activation to compensate for the lack of phonological information gained from the masked prime. This result suggests that perhaps participants require the ability to read words out loud to benefit from masked priming treatment. Given that the single participant in the current study had relatively intact ability to read single words out loud, limited conclusions can be made with regard to how variations in reading ability may change outcomes for treatment in an explicit repetition priming paradigm. More research related to the role of reading and spelling ability on response to explicit word priming is necessary to understand how such a participant factor may influence treatment outcomes.

Gains in naming accuracy were maintained for the T category three months post-treatment. However, many stimuli were not readily named at maintenance testing and the effect size was reduced from large to medium. A possible explanation for the reduction in the effect size seen at maintenance could be personal relevance of the stimuli. Personal relevance of stimuli has been shown to be a factor in maintenance of treatment gains for individuals with aphasia (McKelvey, Hux, Dietz, & Beukelman, 2010). As the stimuli were initially selected as those

challenging for the participant to name (possibly due to lack of personal relevance), this lack of maintenance for some conditions may be related to trained stimuli having had little relevance to the participant in functional communication both before and after treatment. Interestingly, improvements noted in the UE condition were not maintained three months after treatment. This finding could have occurred due to the lack of explicit prime presentation in this condition resulting in a less robust activation of the lexical network and therefore a less robust representation at maintenance testing. However, in conflict with that possibility, maintenance testing found maintenance of UU-U items. Additionally, while there was no effect size for UU-R items at post-treatment testing, maintenance testing revealed a small effect size for UU-R items. This suggests within- and cross-category generalization occurred at maintenance testing for unexposed items. If lack of prime exposure was the cause of lack of maintenance, UU-U and UU-R condition effects should not have been maintained. Furthermore, UU-R items should not have seen an improvement from post-treatment testing. A more likely explanation for the lack of maintenance of UE items with maintenance and improvement for UU items would be specific item effects. It could be, with random selection of the stimuli, that the items in the UE condition were particularly difficult for this participant to name. This difficulty may be related to reduced spreading activation and/or increased decay rate for those items in comparison to items selected for the UU condition. Again, it is important to recognize the limited number of stimuli used in each condition as well as the inability to draw conclusive information on both generalization and maintenance patterns due to the nature of a single subject design with a single case. Should this treatment paradigm be used in further research, a greater number of stimuli per condition may be useful for determining generalization and maintenance effects.

Interestingly, this participant made notable improvements in broader language measures of the CAT and the BNT post-treatment and at maintenance testing. Her naming performance was improved by greater than 5 points on the BNT, suggesting the potential for treatment to generalize to naming performance in other contexts (Sachs et al., 2012). In addition, the participant showed a significant improvement in her ability to read words as evidenced by overall improvement on scores on the CAT reading subtests. Most notably was the participant's improvement in non-word reading post-treatment. This suggests that perhaps repeated exposure to word primes for limited exposure durations facilitated improvement of orthographic to phonologic correspondence which strengthened the participant's overall reading ability. Prior research by Ablinger and Domahs (2009) provides evidence for short-duration exposure to written words to improve single word reading. Ablinger and Domahs (2009) reported a case study on an individual with severe alexia who was provided limited exposure (between 800 and 1300 ms) to written words and was asked to read them out loud. Feedback was given regarding reading errors. Both reading speed and accuracy were improved following intervention for trained and untrained words. In the case of the current explicit repetition priming paradigm, the presence of the repeated explicit prime in the trained condition may have provided information for the participant to recognize errors in production of the prime word during naming attempts. However, due to the differing linguistic profiles of the participants (e.g., relatively intact reading versus severe alexia), as well as the differences in protocol factors, conclusions cannot easily be drawn as to what mechanism may have resulted in improved naming for the current study's participant. Further research is needed regarding the potential effects of explicit repetition priming on reading ability.

Qualitative results from this study served to gain a sense of what this treatment paradigm feels like from a client perspective. When asked how she felt about the approach overall, the participant spoke favorably about the primed condition, likely because the explicit primes helped her to find the target word with less frustration. In contrast, she reported significant effort and frustration when she was not given a prime before the target image. This was likely due to the lesser degree of spreading activation caused by the picture stimulus alone compared to the primed condition. When asked how she perceived the length of the sessions, it appeared by her response that the treatment sessions felt too long. This was because many individual trials (those for words she had already mastered) felt long. For other items, those that were not so readily named, the participant clearly stated she appreciated the time allotted to name the items. This is likely due to increased activation in the lexical network over time leading to increased success and speed when naming the item. In a clinical treatment protocol, words that have reached mastery would be rotated out for new items. Therefore, it is possible individuals participating in treatment would not feel that some of the individual trials are too long. When asked what she would change about the treatment protocol, the only change she requested was to have all of the target images involve the explicit prime. This may have been related to the participant's report of frustration with unprimed trials. The unprimed condition was a necessity for the purposes of this research protocol. If this protocol were to be implemented as a clinical treatment, an unprimed control condition would not be included. Individuals given this protocol as a treatment method would, therefore, not experience frustration from the absence of a prime before the target image.

Conclusion

These initial findings suggest that repeated exposure to explicit word primes and their target images paired with naming opportunities in the absence of explicit feedback may have positive effects on naming accuracy for trained items, and to some extent to untrained items. However, generalization to semantically related and/or semantically unrelated stimuli may be limited. Furthermore, these findings suggest further investigation is necessary to determine what factors may be involved in producing greater maintenance of treatment gains. These results also suggest that such a treatment protocol may have the potential to strengthen the linguistic network and improve overall naming ability. Furthermore, this protocol may have the potential to benefit other aspects of language such as reading ability.

Future studies involving explicit repetition priming should include a larger sample size and should investigate how participant characteristics such as reading and spelling ability may affect response to an explicit repetition word priming treatment paradigm. Furthermore, it will be necessary to assess varying protocol factors such as semantically blocked vs random presentation of stimuli to determine the most effective methods for generating treatment gains, generalization, and maintenance.

If a treatment paradigm using explicit repetition priming were to be used in the future, research must be conducted regarding optimal treatment dosage as well as how differing treatment delivery systems (i.e., computer, tablet, website, application, etc.) may affect treatment outcomes. In a real-life clinical setting, clinicians would not have access to the E-Prime software used in this experiment. An application or some type of program would have to be created to implement such a treatment protocol. Furthermore, the application or program would have to be easily customizable so that a clinician may insert picture/word pairs that are specific to a client's

individual needs. Research would also need to be conducted regarding when a word/picture pair should be considered mastered, as there may be a level of mastery that improves the likelihood for maintenance.

Additionally, it would be important to investigate whether any improvements in naming accuracy are carried over to unfamiliar images of the stimulus items and/or to real life objects. Future research should also include a reliability coder for qualitative questions and include more in-depth qualitative analysis to gain information related to the client's perspective on the process as well as any perceived outcomes from treatment. Finally, given previous research using masked primes having yielded similar results regarding improvement in naming of trained items (Silkes, 2015; 2018), it would be important to assess how individuals compare in improving naming ability when exposed to explicit vs implicit primes.

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Appendix

Appendix A: *Stimulus List*

Trained Exposed	Untrained Exposed	Untrained Unexposed	Semantic Category
Astronaut	Barber	Mechanic	Occupations
Referee	DJ	Pediatrician	Occupations
Roofer	Welder	Air hockey	Occupations
Frisbee	Gymnastics	Bullfighting	Sports and games
Kickball	Lacrosse	Javelin	Sports and games
Operation	Roller derby	Monopoly	Sports and games
Shotput	Skateboarding	Rugby	Sports and games
Hula hoop	Pogo stick	T-ball	Toys
Kaleidoscope	Puzzle	Roller skates	Toys
Yo-yo	Slinky	Walkie talkie	Toys
		Chandelier	Household items
		Hammock	Household items
		Ottoman	Household items
		Maracas	Instruments
		Recorder	Instruments
		Triangle	Instruments
		Chainsaw	Tools
		Dolly	Tools
		Gavel	Tools
		Lawnmower	Tools