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Abstract

Background: Although aphasia rehabilitation has been shown to be efficacious, many questions remain regarding how best to deliver treatment to maximize functional gains for persons with aphasia. Treatment delivery variables, such as intensity and dosage, are likely to influence both behavioral and structural changes during anomia treatment. While numerous protocols have concluded that treatment intensity positively impacts functional outcomes, few studies to date have examined the role that dose plays in patient outcomes for anomia treatment.

Aims: This study sought to investigate how manipulating dose of repeated confrontation naming within sessions influences naming in persons with aphasia. Repeated practice of confrontation naming, without feedback, was hypothesized to improve trained but not untrained words, to be persistent after withdrawal, and to be sensitive to the number of trials (i.e., dose) within sessions.

Methods and Procedures: A single-subject ABA design with replication across seven participants with aphasia was used to investigate the influence of repeated confrontation naming attempts on the acquisition and maintenance of trained pictures relative to untrained pictures. Training involved repeated attempts to name pictures, along with repeated exposure to pictures of objects (nouns) and their names, without feedback. The primary independent variable was within session dose; the dependent variable was naming accuracy.

Outcomes and Results: Naming accuracy improved for all participants for trained pictures across both acquisition and maintenance phases per visual inspection; such positive effects were not observed for untrained pictures. Effect size calculations indicate that three of seven participants demonstrated considerable change for trained items, while one of seven participants demonstrated meaningful change for untrained items. The high-dose condition elicited small

effect sizes for one participant, and large effect sizes for two of seven participants, while the low-dose condition elicited small and medium effect sizes for two of seven participants.

Conclusions: Participants across a variety of aphasia severity levels responded positively to two doses of repeated confrontation naming practice, without feedback, across phases of this naming protocol. Results are in line with principles of neuroplasticity and demonstrate that repeated practice, without feedback, can produce significant and persistent changes in naming ability for some persons with aphasia.

Key Words: aphasia, anomia, picture naming, dose, intensity, repetition priming

The impact of dose on naming accuracy with persons with aphasia

Introduction

Aphasia is an acquired impairment of language, typically resulting from a focal brain lesion that impacts neural networks mediating speaking, listening, reading, and writing skills. Many questions remain to be answered about how to deliver aphasia treatment to optimize patient outcomes and cost effectiveness. Treatment delivery variables are likely to have a significant impact on both behavioral changes and the underlying neural processes during the course of aphasia rehabilitation (Brady, Kelly, Goodwin, & Enderby, 2012).

One treatment delivery variable that has been neglected in the aphasia literature is treatment dosage. While the amassing evidence suggests that aphasia therapy should be intensive overall, the intensity of treatment delivery within each session itself has yet to be examined; that is, dosage parameters have yet to be systematically explored or established for aphasia therapy. This lack of attention to specific intensity parameters is not unusual for the behavioral sciences. Warren, Fey, and Yoder (2007) and Cherney (2012) argue that behavioral scientists must begin to systematically define and investigate precise components of treatment intensity. Specifically, Warren and colleagues suggest that behavioral scientists describe dosage parameters using the following terminology: dose form, dose, dose frequency, total intervention duration, and cumulative intervention intensity. Dose form is defined as the therapeutic task or activity that delivers the teaching episodes. Dose is defined as the number of times a teaching episode or active ingredient occurs per session. Dose frequency is defined as the number of intervention sessions per unit of time. Total intervention duration is defined as the total period of time in which a particular intervention is provided. Lastly, cumulative intervention intensity is defined as

the product of dose, multiplied by the dose frequency, multiplied by the total intervention duration.

Previous studies have shown that individuals who receive more intensive treatment improve to a greater degree than those who receive less intensive aphasia therapy (e.g., Brady et al., 2012). Such positive effects of intensive treatment have been demonstrated both behaviorally and at the neural level (Varley, 2011). Unfortunately, intensity has not been well defined thus far in the aphasia literature. Often, "intensive treatment" refers to treatment with high dose frequency (i.e., many sessions within a specified period of time), not treatment with high cumulative intervention intensity. Cumulative intervention intensity is rarely calculated because the dose or the session duration has not been controlled or reported upon (Cherney, 2012). Before researchers can define the optimal cumulative intervention intensity, dose must be examined and reported across a variety of dose forms, with well-specified active ingredients (Warren, Fey, & Yoder, 2007). The purpose of the current study was to explore dose during a repeated confrontation naming protocol for persons with chronic aphasia.

Anomia treatment intensity and dosage

As the most commonly observed symptom of aphasia, anomia continues to be one of the most frequently and extensively studied aspects of aphasia rehabilitation (Beeson, 2013; Benson, 1988; Maher & Raymer, 2004). Typically, anomia is assessed through confrontation picture naming of nouns or verbs. Anomia treatment aims to increase access to and retrieval of the underlying semantic or phonological representation of lexical items through a variety of techniques (Avila, Lambon-Ralph, Parcet, Geffner, & Gonzalez-Darder, 2001). Treatment techniques typically include stimulation of semantic and/or phonological networks and are often

delivered in the context of errorless learning models (Raymer et al., 2012) or constraint-induced aphasia therapy models (Kurland, Pulvermuller, Silva, Burke, & Andrianopoulos, 2012), among others. Clinical researchers have demonstrated efficacy across phonologically-based approaches (e.g., Kendall et al., 2008), semantically-based approaches (e.g., Boyle, 2004; Falconer & Antonucci, 2012; Kiran & Iakupova, 2011), gestural approaches (e.g., Ferguson, Evans, & Raymer, 2012; Raymer et al., 2012), and combinations of these various approaches (e.g., Boo & Rose, 2011). Despite this documented treatment efficacy, practicing clinicians often struggle to extract findings from the existing evidence base and apply them in a manner that provides optimal, time- and cost-effective treatment for their clients with anomia.

Optimal success of any anomia treatment protocol is likely to depend upon a number of treatment delivery variables and their relationship to individual characteristics of each patient. Converging evidence regarding the relationship between structural brain change and subsequent language gains (e.g., Meinzer, Harnish, Conway, & Crosson, 2011; Varley, 2011) has led clinical researchers to begin to actively manipulate treatment delivery variables that capitalize on principles of neuroplasticity to optimize treatment paradigms (e.g., Kurland et al., 2012). One treatment delivery variable that has gained a substantial amount of attention across aphasia protocols is treatment intensity, focusing on dose frequency; participants who engage in a greater number of hours in therapy improve to a greater degree than those who receive less (Brady et al., 2012; Meinzer et al., 2011; Pulvermuller et al., 2001); for an exception see (Sage, Snell, & Ralph, 2011). Although operational definitions of treatment intensity remain unclear for individuals with aphasia, therapy is generally considered to be intensive when participants receive at least nine hours of therapy per week (Cherney, Patterson, Raymer, Frymark, & Schooling, 2008). From a neurobiological perspective, intensive treatment is a preferred service

delivery model, as it best facilitates experience-dependent plasticity and neuronal reorganization (Cramer et al., 2011; Kurland et al., 2012). Researchers have begun to demonstrate the positive effects of intensive treatment through examination of structural brain changes, as observed via functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) imaging techniques (Kurland, Baldwin, & Tauer, 2010; Kurland et al., 2012; Marcotte et al., 2012). Kurland and colleagues (2010) used fMRI to provide evidence of significant and persistent structural changes of a left frontal network, along with improved naming performance following a short, intensive treatment protocol. Marcotte and colleagues (2012) demonstrated that structural changes include both functional reactivation (i.e., functional recovery of perilesional language areas in the left hemisphere), and functional reorganization (i.e., recruitment of perilesional non-classic language areas of left hemisphere or a homologous right hemisphere area). Optimal treatment gains are highly dependent upon the ability of a treatment protocols to harness and capitalize on these mechanisms of neurobiological recovery and neuroplasticity (Kleim & Jones, 2008).

Specific treatment delivery variables, including dose, have yet to be extensively explored in the context of anomia rehabilitation. Anomia studies typically report the characteristics of their participants, details of the treatment approach, and the overall intensity of the protocol (i.e., total intervention duration). Less frequently do investigators provide the exact number of times the picture was presented to the participant or how many times the participant was asked to repeat the target picture (Cherney, 2012). For an exception, see Martin and colleagues (Martin, Fink, Laine, & Ayala, 2004).

Although no known anomia treatment studies to date have been designed to systematically manipulate dose conditions, Harnish and colleagues recently documented dose

response in the context of a picture naming treatment protocol (Harnish et al., 2014). In this intensive cued treatment protocol, eight participants were given eight opportunities in which to name each of 50 target words per 60 minute session. Dose frequency was four times per week, and the total intervention duration was two weeks. For each of the eight naming opportunities, participants were given a different cue: (1) no cue, (2) orthographic cue (i.e., the entire word printed below the picture), (3) repeating, (4) naming after a three second delay, (5) semantic cue (i.e., three semantic features provided by a therapist), (6) phonological cue (i.e., the therapist says the first letter and first phoneme of the picture name), (7) repeating, and (8) naming after a three second delay. Collectively, each participant attempted to name the 50 target pictures eight times during each session for a total of 400 attempts per session. The cumulative intervention intensity was 3200 teaching episodes. Six of the eight participants demonstrated significant improvement in naming performance after a single training session (i.e., 400 naming opportunities). All eight participants demonstrated significant improvement in naming ability after three treatment sessions (i.e., 1200 naming opportunities). These positive treatment effects persisted for six of the seven participants who completed the maintenance phase eight weeks following the treatment phase. Effect sizes ranged from small to large across the eight participants.

Although this protocol was carefully constructed to document dose and dose frequency across time during a picture naming task, some confusion arises about which "active ingredient" contributed most to the observed naming improvements: the cued training approach or the dose. Despite the potential confound, this initial first step to understanding the influence of the dose response curve for anomia treatment protocols is encouraging. The findings of Harnish and colleagues (2014) provide a foundation for continued deliberate within- and across-session dose

investigations. Further studies are needed to manipulate dose and dose frequency conditions across various dose forms (i.e., therapeutic tasks) to better inform cumulative intervention intensity and optimal treatment delivery.

Repetition as a learning mechanism and fundamental principle of neuroplasticity

Learning can be broadly categorized as either implicit or explicit in nature. Explicit learning requires conscious or controlled attention to the learning process and conscious recollection of prior learning experiences (Tulving & Schacter, 1990). Implicit learning, on the other hand, does not require intentional or conscious awareness of the learning process (i.e., recall and recognition). While anomia treatment protocols most often rely on explicit learning mechanisms, benefits have been shown with implicit learning as well (Silkes et al., 2013). As such, treatment approaches should be developed to target these implicit processes.

The act of repetitive exposure and/or practice (i.e., repetition priming) is an implicit learning mechanism that leads to behavioral changes as a result of more than one presentation of a given stimulus (Brown, Jones, & Mitchell, 1996; Cave & Squire, 1992; W. S. Francis & Saenz, 2007; Reber, Gitelman, Parrish, & Mesulam, 2005). Repetition priming (i.e., repeated exposure to practice of a stimulus) has been proposed as a mechanism of learning that can foster the development of the automaticity that typically accompanies expertise (Poldrack et al., 1999; Reber et al., 2005). Behaviorally, repetition priming is observed as increased response accuracy or decreased reaction time. At a neural level, repetition priming typically results in a reduced level of cortical activity, often referred to as repetition suppression or neural priming (Wiggs & Martin, 1998). Repetition suppression is hypothesized to reflect a sharpening of the population of neurons recruited (Wiggs & Martin, 1998) or a reduced “prediction error” that can occur when a

stimulus conforms to a more probable (i.e., previously seen) stimulus compared to a less probable (i.e., novel) stimulus (Friston, 2005). Repetition is thought to be required to induce lasting neural changes for newly learned or relearned behaviors (Kleim & Jones, 2008). That is, repetition facilitates neural plasticity by strengthening the learned behavior and ensuring that the behavior persists in the absence of training.

Behaviorally, repetition priming reflects learning at the level of the stimulus item (Brown et al., 1996), and is proposed to require no controlled attentional processes (Rochon et al., 2006; Shiffrin & Schneider, 1977). In healthy adults, repetition priming has been shown to be persistent up to 48 weeks (Cave, 1997; Mitchell & Brown, 1988), and to be sensitive to the number of repetitions presented (Mitchell & Brown, 1988). In persons with aphasia, persistence of repetition priming effects has been documented both at short-lived (Howard, Pattersone, Franklin, Orchard-Lisle, & Morton, 1985) and long-lasting (Rochon et al., 2006) intervals. Repetition priming provides an optimal foundation upon which to develop a theory of learning for individuals with aphasia; importantly, this paradigm does not require conscious, explicit cognitive processes during learning, thus minimizing the influence of cognitive factors that are likely to vary across individuals with aphasia. Repetition, as a fundamental mechanism of learning and neuroplasticity, is important to theories of rehabilitation that are considering treatment intensity and dosage. As such, repetitive practice is an ideal tool by which to incrementally investigate the acquisition and maintenance of trained items during spoken language production with individuals with anomia (Kalinayk-Fliszar, Kohen, & Martin, 2011).

The primary purpose of the current pilot study was to investigate the influence of two conditions of dose on confrontation naming performance during a repeated practice protocol. The behavioral effects of repeated practice on naming performance were examined among

persons with aphasia as measured by confrontation naming accuracy. Specifically, this study was designed to answer three primary questions: (1) does repeated practice significantly improve naming accuracy for persons with chronic aphasia in the context of a naming protocol?; (2) does a within-session dose manipulation significantly influence naming accuracy?; and (3) does repeated practice during this naming protocol influence other aphasia outcome measures (e.g., comprehensive language batteries)? We hypothesized that repeated practice would positively improve naming accuracy to a small degree relative to lexical retrieval benchmark effect sizes, with the high-dose condition eliciting larger improvements than the low-dose condition. Naming improvements were anticipated to persist following termination of the training protocol. Lastly, because repetition priming has been demonstrated to be stimulus specific, we hypothesized that naming improvements would not generalize to other outcome measures of confrontation naming or to comprehensive language batteries.

Methods

Experimental design

A single-subject ABA design with replication across seven participants with chronic aphasia was used to investigate the acquisition and maintenance of confrontation naming for trained pictures and generalization to untrained pictures using a repeated practice protocol in the absence of feedback. Participants were enrolled in a training protocol that involved two naming opportunities per trial: (1) naming pictures independently, and (2) repeating the name of the pictures after the target was presented with both an orthographic cue (i.e., the whole written word) and a whole word auditory cue. Primary independent variables included within-session dose (i.e., low-dose vs. high-dose) and training condition (i.e., trained vs. untrained pictures).

Lexical variables including word frequency (i.e., high vs. low word frequency) and word length (i.e., 1 vs. 2 syllables) were controlled for trained and untrained stimuli. The dependent variable was naming accuracy.

The single-subject ABA design allowed for examination of the acquisition and maintenance of picture naming during a repeated practice protocol. The A phase of the design was the baseline period, during which naming accuracy was measured for trained and untrained pictures across four probe sessions. The B phase consisted of a maximum of 15 sessions and included the training of targets with a low-dose within-session condition (i.e., 1 picture-naming trial per session) and a high-dose within-session condition (i.e., 4 picture-naming trials per session). During these training sessions, participants attempted to name target stimuli independently, and were then given the opportunity to name the target stimuli following the spoken and written name of the depicted item. Training probes were also systematically conducted during the B phase. Training probes assessed naming accuracy of trained and untrained pictures independent of accompanying written or auditory cues. Training probes were collected immediately following every third training session and immediately before every fourth training session. In the subsequent A phase, training was withdrawn. Three maintenance probes were completed between six and 19 weeks following completion of the B phase to assess maintenance of trained stimuli and generalization to untrained stimuli. All participants completed all phases of the protocol; each participant's delivery schedule was unique, however, resulting in variable overall dose frequencies, total intervention durations, and cumulative intervention intensities (see Table 1).

[Table 1 near here]

Participants

Seven adults with chronic aphasia served as study participants. All participants were right-handed, native speakers of American English, and were between the ages of 41-90 years of age. Each participant's aphasia resulted from a single left hemisphere stroke. At the time of the investigation, participants were between six months and 21 years post stroke. Participants presented with mild to severe symptoms of expressive language impairment with no evidence of visual agnosia, a concomitant severe to profound apraxia of speech (AOS), or severe to profound dysarthria. All participants were able to repeat the names of nouns to some degree. Participants were not excluded based upon receptive language deficits. All participants had negative histories for additional neurological, psychiatric, or substance abuse disorders, per self-report and medical records, and had corrected to normal hearing and vision. Participants were permitted to maintain their ongoing speech-language therapy as long as it did not target word retrieval through naming tasks. Two of seven participants received ongoing therapy during this experimental protocol. Refer to Table 2 for a summary of the participants' profiles.

[Table 2 near here]

Participants were administered a comprehensive cognitive-linguistic evaluation before being enrolled in the study. The evaluation included the following: (1) hearing and vision screening; (2) visual neglect screening; (3) visual agnosia screening; (4) motor speech examination (Duffy, 1995); (5) *Western Aphasia Battery-Revised* (WAB-R; Kertesz, 2006), part 1 to document aphasia type and severity; (6) *Boston Naming Test, 2nd edition* (BNT-2; Kaplan, Goodglass, & Weintraub, 2001) to document confrontation naming abilities of nouns; (7) subtest

54, "Picture Naming by Frequency," of the *Psycholinguistic Assessments of Language Processing in Aphasia* (PALPA; Kay, Lesser, & Coltheart, 1992) to document confrontation naming abilities of nouns relative to their frequency; (8) *Raven's Coloured Progressive Matrices* (RCPM; Raven, 1998) to assess nonverbal reasoning; (9) *Apraxia Battery for Adults, Second Edition* (ABA-2; Dabul, 2000) to document impairments of motor planning and programming of speech; and (10) *Beck Depression Inventory-II* (BDI-II; Beck, Steer, & Brown, 1996) to document the presence or absence of depression. The following subset of the cognitive-linguistic battery was re-administered to participants following completion of the training phase to assess generalization of language change and confrontation naming abilities: (1) *WAB-R*, part 1; (2) *BNT-2*; and (3) subtest 54 of the *PALPA*. See Table 3 for a summary of the participant's pre- and post-training performance on these standardized measures.

[Table 3 near here]

Informed consent procedures were followed in accordance with the approved guidelines of the Human Subjects Division of the University of Washington and the Institutional Review Board for the Protection of Human Subjects in Research at the University of Montana. Participants were recruited from medical facilities in the Seattle-Tacoma Metropolitan area, from the University of Montana DeWit RiteCare Speech, Language, and Hearing Clinic in Missoula, Montana, and from word of mouth. Four participants completed the protocol at the University of Washington and three participants completed the protocol at the University of Montana. Participants were not compensated for their participation in this study other than reimbursement for travel and/or parking.

Procedures

Stimuli

One hundred and forty target pictures were randomly selected from a previously developed corpus of 240 digitized color photographs depicting 1- and 2-syllable concrete nouns (Kenny, 2006; Krohn, 2005; Potts, 2006). Forty pictures were selected as trained stimuli and 100 pictures were selected as untrained stimuli (see appendix A). All stimuli were balanced for word frequency and syllable length. High-frequency words were defined as greater than or equal to 150 instances per million words; low-frequency words were defined as less than or equal to 20 instances per million words (W. N. Francis & Kucera, 1982).

Trained stimuli. The 40 trained pictures were randomly assigned to one of two dose conditions, resulting in 20 low-dose stimuli and 20 high-dose stimuli. Low-dose and high-dose stimuli were balanced for word frequency and syllable length. Low-dose stimuli were presented once during each training sessions; high-dose stimuli were presented four times per training session. At the time that this protocol was designed, little evidence was available in the literature about within session dose. Most anomia studies reported set size (i.e., the number of stimuli presented), but did not report within session dose. Clinicians often present a stimulus 1-2 times during a session for anomia treatment protocols. Without existing evidence in the literature about dose, we estimated that four trials would be sufficient to qualify as a high-dose condition. During training sessions, a second presentation of each stimulus was accompanied by the spoken and written name of the picture to ensure that each participant had at least one opportunity to accurately produce the name of the target picture during the training sessions. The names of the trained pictures were audio-recorded with a female voice and edited for duration using Computerized Speech Lab (CSL) 4150 (Kay PENTAX, Lincoln Park, NJ).

Untrained stimuli. The 100 untrained stimuli were presented during probe sessions and were balanced for word frequency and syllable length. Each untrained stimulus item was only presented once during the entire protocol. That is, during each probe session, participants attempted to name completely novel, untrained stimuli. The rationale behind this methodological approach was to remove the influence of multiple exposures to a stimulus. Evidence from repetition priming studies demonstrates, in healthy individuals, that a single repeated exposure to a stimulus can increase response accuracy on subsequent trials (Wiggs & Martin, 1998).

Instrumentation

Pre- and post-training cognitive-linguistic evaluations were video-recorded. Experimental sessions were carried out using E-Prime (E-Prime 2.0, Psychology Software Tools, Pittsburgh, PA, 2010) on a desk-top computer. An Olympus Digital Voice Recorder (VN-24-PC) was used to record participants' responses to evaluate reliability for naming accuracy at the University of Washington. A Logitech C615 HD Webcam was used to record participants' responses to evaluate reliability for naming accuracy at the University of Montana. Audio files for the trained stimuli were imported into E-Prime and presented through Bose QuietComfort 2 Acoustic Noise-Canceling Headphones or Sennheiser Professional HD 25-1 II Noise-Cancelling Headphones at a level audible to each participant.

Delivery schedule

Baseline probe sessions. Four baseline probes assessed pre-training picture-naming performance of the 40 trained and 100 untrained stimuli. The four baseline probe sessions took place on separate days, all within a two-week period. Each baseline probe lasted approximately

30 minutes, and participants were instructed to name aloud trained and untrained pictures, once, as quickly as possible while maintaining accuracy. Pictures were presented in randomized order. No feedback or cuing was given during probe sessions. An extended baseline approach would have been ideal to establish a stable baseline prior to beginning the training phase.

Each trial proceeded as follows during the baseline probe sessions: (1) a fixation mark (*) appeared on the computer screen to prepare the participant; (2) the target picture was presented on the computer screen and the participant attempted to name the picture; (3) the target picture was withdrawn and a screen with a red "X" appeared to encourage the participant to stop naming attempts; and (4) the next trial was initiated. Refer to Figure 1 for a depiction of the trial sequence for all probe sessions.

[Figure 1 near here]

Training sessions. Training sessions were initiated no more than two weeks following baseline testing. Participants attended training sessions 2-3 times per week for a maximum of 15 training sessions during a five-week period. The training delivery schedule varied across participants as a result of their availability (see Table 1). Training duration varied across participants based upon their level of fatigue, stamina, and skill mastery. Each training session lasted approximately one hour, during which time participants attempted to name the 40 trained targets while seated at desktop computer. Twenty of these target pictures appeared once per training session (i.e., low-dose); 20 targets appeared four times per training session (i.e., high-dose). Target stimuli were randomly presented; the number of trials that intervened between repeated target words was not controlled. These 100 target trials were divided equally into five

runs, with breaks provided between runs, as needed. The number of times that a target could appear in each run was not controlled. Participants were instructed to name the pictures aloud as quickly as possible while maintaining accuracy. Participants did not receive feedback at any time during training. That is, participants did not have information about whether they accurately produced the correct name for the target. We hoped to isolate the independent variable of dose as much as possible, as feedback has been hypothesized to be one treatment variable thought to influence behavioral performance (e.g., Austermann Hula, Robin, Maas, Ballard, & Schmidt, 2008).

Each trial proceeded as follows during the training sessions: (1) a fixation mark (*) appeared on the computer screen to prepare the participant; (2) the target picture was presented on the computer screen and the participant attempted to name the picture; (3) the target picture was withdrawn; (4) the target picture plus the orthographic cue and the auditory cue was presented and the participant attempted to repeat the name of the picture; (4) the target picture was withdrawn; (5) the next trial was initiated automatically. See Figure 2 for a depiction of a trial sequence during training sessions.

[Figure 2 near here]

Training probe sessions. Evidence from repetition priming studies is inconclusive about whether higher response accuracy is consistently observed immediately following training, as compared to delayed intervals. Reduced response accuracy at delayed intervals is hypothesized to result from a decay of priming (Burton, Bruce, & Johnston, 1990), but Mitchell and Brown (1988) found no evidence of decay as the intervals between training sessions increased from one

week to six weeks. As a mechanism of control for the current study, training probes were administered immediately after every third training session (i.e., immediate probes) and immediately prior to every fourth training session (i.e., delayed probes) to document immediate and delayed effects of training. A final training probe was administered immediately after the last training session. Training probes assessed the 40 trained items and 20 randomly selected novel, untrained items. Training probes were delivered and recorded in the same manner as baseline probes. No feedback was given during probe sessions.

Maintenance probe sessions. At least six weeks after completing the training portion of the study, participants returned for three sessions to assess maintenance of naming performance improvements (range: 6 weeks to 19 weeks). Maintenance probes assessed naming accuracy of the 40 trained items and 20 randomly selected novel, untrained pictures. Maintenance probes were delivered and recorded in the same manner as baseline and training probes. Feedback was not given during probe sessions.

Data collection and analysis

The experimenter transcribed each response verbatim and judged for accuracy using a binary +/- coding system during all training and probe sessions. One hundred percent of the recordings of the probe sessions were reviewed by the experimenter to ensure accurate transcription of participants' responses. The experimenter then coded the transcribed responses for accuracy. Accurate (+) responses included: (1) the exact production of the target; (2) the target plus a filler (e.g., "um/the/a coffee"); (3) multiple correct productions of the target; or (4)

multiple production attempts with the first attempt being correct (e.g., "coffee…croffee"). For the purposes of this study only first/initial attempts were included in the data analysis.

Descriptive statistics including means, ranges, and standard deviations for naming accuracy were calculated for each participant, across each phase of the experimental protocol relative to the independent variables (i.e., trained vs. untrained; low-dose vs. high-dose conditions) for both probe sessions and training sessions (see Table 4). Visual analysis of line graphs was used to depict level, trend, variability, and onset of training effects.

[Table 4 near here]

Effect sizes were calculated to assess the magnitude of change relative to baseline performance for trained and untrained items. Effect sizes were also calculated to examine the impact of dosage (i.e., low-dose vs. high-dose) on naming accuracy. Busk and Serlin's *d* was used to compare mean performance during the maintenance phase (A2) to the mean performance during the baseline phase (A1), relative to the variance (SD) observed during the baseline phase ($d = M_{A2}\text{-}M_{A1}/SD_{A1}$). Benchmarks for lexical retrieval treatment studies indicate that treatment brings about improvements with the following observed effect sizes: 0.6 (spontaneous recovery), 4.0 (small), 7.0 (medium), 10.1 (large) (Beeson & Robey, 2006).

Reliability procedures

Trained research assistants, uninvolved in data collection, served as reliability judges. Judges listened to 100% of the audio/video-recorded probe data for all participants. The International Phonetic Alphabet (IPA) was used only when participants produced phonemic

errors that resulted in non-words. Judges then made a binary +/- accuracy judgment for each trial, following the accuracy rules described above. Judges were blind to the original transcriber's transcriptions and accuracy judgments. Cohen's Kappa was used to calculate inter-judge reliability for the binary accuracy judgment between the experimenter and reliability judge.

After accounting for standard error, inter-rater reliability between the original experimenters and the reliability judges was calculated for each participant using Cohen's Kappa (Fleis, Levin, & Paik, 2003). Inter-rater reliability ranged from 0.67 - 0.99, indicating good to very good strength of agreement across participants. The average inter-rater reliability across participants was 0.89. See Table 5 for a summary of reliability judgments for each participant.

[Table 5 near here]

Results

Effect of dose condition on picture naming accuracy

Naming accuracy for trained items was plotted across all phases of the protocol relative to the two dose conditions (i.e., high-dose and low-dose). Naming accuracy for untrained items was also plotted across all phases of the protocol. See Figures 3-9.

[Figures 3-9 near here].

The magnitude of change (i.e., effect size) from the baseline phase to the maintenance phase ranged from 0.12 to 29.33 for the trained items and -0.92 to 14.53 for the untrained items (see Table 6). Three of the seven participants demonstrated notable effect sizes (one small (P2), one medium (P1), and one large (P7)) for the trained items according to the lexical retrieval effect size benchmarks (Beeson & Robey, 2006). One of these seven participants (P3) was at near ceiling levels for naming accuracy during the baseline phase; as such, a meaningful effect size was not observed for this participant. Another participant (P6) was at 0% accuracy during baseline testing; as such, effect size could not be calculated for this participant. Untrained item effect sizes were reflective of the spontaneous recovery benchmark for six of the seven participants. One participant (P7) demonstrated a large effect size for both trained and untrained items.

Effect sizes from the baseline phase to the maintenance phase ranged from 0.56 to 19.1 for the high-dose condition and from -1.5 to 8.79 for the low-dose condition (see Table 6). Three of the seven participants demonstrated positive effect sizes (two large and one small) for the high-dose condition according to Beeson and Robey's (2006) benchmarks. Two of the seven participants demonstrated positive effect sizes (one medium and one small) for the low-dose condition.

[Table 6 near here]

Effect of repeated practice on generalization measures

Participants were re-administered a sub-set of the cognitive-linguistic battery at the completion of the study to assess general language change and generalization of confrontation

naming. These measures included the *WAB-R*, part 1; the standard form of the *BNT-2*; and subtest 54 of the *PALPA*. Consistent improvements across language modalities as measured by the *WAB-R* AQ scores were not observed; three of the six participants who completed a second administration of the *WAB-R* demonstrated improvements (P2, P5, P7). One of these three participants demonstrated clinically significant change (i.e., a greater than 5 point improvement) on the *WAB-R* (Persad, Wozniak, & Kostopoulos, 2013). Standard error of measurement (SEM) was calculated for each aphasia type using test-retest reliability information available in the *WAB-R* administration manual (Kertesz, 2006). Three participants (P2, P5, P7) demonstrated marked improvement (i.e., greater or equal to 2 SEM units) on the *WAB-R* AQ (Milman, Vega-Mendoza, & Clendenen, 2014; Nitko, 1996). Two participants (P1, P3) scored lower on the *WAB-R* post-training; P1's decrease was clinically significant. Refer to Table 3 for pre- and post-training outcome measure scores.

Six of the seven participants significantly improved on the *BNT-2* (P1, P2, P4, P5, P6, P7) per SEM. SEM was calculated using test-retest reliability information as reported by Flanagan and Jackson (1997). All seven participants improved on subtest 54 of the *PALPA*. Subtest 54 of the *PALPA* does not have available normative data to calculate SEM. Collectively, these two measures suggest that overall naming improved. See Table 3 for a summary of scores.

Discussion

Intensive aphasia rehabilitation protocols and intensive comprehensive aphasia programs (ICAPs) are emerging as the preferred model of delivery for optimal stroke rehabilitation. While some intensive programs adhere to operational definitions brought forth in the ICAP literature regarding the minimum number of hours of treatment (Rose, Cherney, & Worrall, 2013), no

known anomia studies to date have manipulated dose as an independent variable. The primary goal of this study was to pilot an anomia training protocol to assess the influence of dose on naming accuracy using repeated practice as the training platform. This initial protocol was designed to be exploratory in nature and to determine feasibility. From a feasibility perspective, we were interested in whether individuals with a range of aphasia types and severities could tolerate such a repetitive and demanding protocol in the absence of feedback. For example, P6 was not an ideal candidate for the protocol as his naming performance was profoundly impaired (i.e., he achieved a baseline of 0 for naming). However, we were interested in the feasibility of working with a client with such profoundly impaired naming abilities in an intensive naming protocol. After a trial period, it was clear that P6 could fully participate in the protocol and ultimately increased his naming ability to a small degree. We also enrolled one participant (P3) who was minimally impaired relative to naming performance (i.e., 83.8% overall naming accuracy during baseline). While P3's performance during baseline was near ceiling, we were interested in understanding how repeated practice would impact variability and ultimate naming performance. Mildly impaired participants are rarely documented in treatment protocols, yet remain clinically impaired and report continued difficulties with word retrieval during conversational discourse. Ultimately, we hope this line of research will help clinicians develop intensive aphasia rehabilitation protocols with clear intensity and dose parameters that are efficacious, effective, and both time- and cost-effective.

Results from this preliminary study suggest that repeated practice of nouns, with the absence of feedback, has the potential to improve and maintain naming accuracy to varying degrees for persons with aphasia. These findings complement those by Breitenstein and colleagues who also found improved word learning in individuals with aphasia without feedback

(Breitenstein, Kamping, Jansen, Schomacher, & Knecht, 2004). These results are in line with studies of naming in aphasia (e.g., Harnish et al., 2014) and are consistent with mechanisms of learning (e.g., Dennis & Schmidt, 2003), principles of neuroplasticity (e.g., Kleim & Jones, 2008), the motor rehabilitation literature (e.g., Murphy & Corbett, 2009; Nudo, Milliken, Jenkings, & Merzenich, 1996), and animal models of neuroplasticity (e.g., Greenough, 2005). Collectively, this body of research aligns with the broader notion that meaningful improvement is possible for people with chronic aphasia.

Influence of repeated practice on naming accuracy

Naming performance of the seven participants with aphasia enrolled in this protocol suggests that repeated practice can facilitate persistent improvements of naming accuracy of trained items relative to untrained items, with the magnitude of change varying across participants. Naming accuracy improvements were meaningful for three of the seven participants (P1, P2, P7) as reported by effect sizes. Interestingly, these three participants varied across both individual characteristics and training delivery domains. For example, they varied across time post onset (6, 42, 240 months, respectively); aphasia type (anomic, Wernicke's, Broca's, respectively); and presence of co-occurring apraxia of speech (no apraxia, no apraxia, moderate apraxia, respectively). These participants also differed across a number of training delivery domains including the number of training sessions per week (2-3, 2, 3 respectively) and the total number of training sessions (15, 6, 9, respectively). Given the absence of a specific anomia treatment approach (e.g., phonological or semantic), explicit cuing techniques (e.g., phonemic or semantic cues), or systematic feedback used in this repeated practice protocol, these improvements are noteworthy and in line with evidence from studies that examine implicit

learning (i.e., repetition priming) in persons with aphasia (e.g., Silkes et al., 2013). Further investigation of a larger cohort of individuals with aphasia is warranted to assess the influence of aphasia type and severity (among other individual characteristics) on the strength of the effect.

Consistent with previous repetition priming studies (e.g., Reber et al., 2005) and anomia treatment studies (e.g., Kurland et al., 2012) training the 40 target stimuli during this repetition protocol did not lead to improvements of untrained stimuli. This finding was expected given that repetition is, by definition, item specific and is not theorized to elicit skill learning.

Influence of dose on naming accuracy

The number of trials within a session appeared to elicit inconsistent responses in individuals with aphasia relative to naming accuracy during training. Effect size calculations indicated significant changes for three of the seven participants for the high-dose condition and for two of the seven participants for the low-dose condition.

One possible explanation for the lack of meaningful difference between low dose and high dose conditions during training may be the large number of trials attempted by the participants by the time the first training probe was conducted. Three training sessions occurred prior to the first training probe. By the time the first training probe was administered, participants had attempted to name each of the 20 low-dose stimuli a total of 60 times and each of the 20 high-dose stimuli a total of 240 times. Including the auditory and orthographic cue opportunity, participants had attempted to name each of the 20 low-dose stimuli a total of 120 times and each of the high-dose stimuli a total of 480 times. Collectively, each participant had 600 naming opportunities by the time the first training probe was administered. Harnish and colleagues

(2014) reported significant naming improvements after 400 naming opportunities over the course of three treatment sessions for six of their eight participants.

Another possible explanation for this inconsistent response to the two dose conditions could be related to participant variables, including the variable treatment schedule across participants. The cumulative intervention intensity varied across participants; however, no relationship was observed between cumulative intervention intensity and the magnitude of effect sizes for the two dose conditions. The three participants (P1, P4, and P6) who all had the same cumulative intervention intensity (i.e., 600 naming opportunities for the low-dose condition and 2400 naming opportunities for the high-dose condition), produced a wide range of effect sizes (see Table 6). No relationships were observed between the other participants' cumulative intervention intensities and their effect sizes for the dose conditions.

Our initial findings suggest that naming improvements can be observed with only a few sessions of training as long as sufficient opportunities for practice are provided (i.e., somewhere between 480 and 1200 naming opportunities). With this relatively small corpus of 40 trained words, one presentation per session may have been sufficient to boost naming performance. Alternatively, four trials per session may not have been sufficient to be considered a "high-dose" condition. Harnish and colleagues found eight naming opportunities per session to significantly improve naming performance for their participants. It should be noted, however, that each of these eight naming opportunities offered a different cuing strategy which likely contributed to naming performance in a fundamentally different manner than simple, repeated practice. Further investigation across a larger group of participants is warranted to fine tune this dose parameter in isolation. Specifically, future investigations should examine the initial naming attempt in each

training session relative to the subsequent attempts to better understand the influence of dose for naming protocols.

Additionally, individual characteristics of persons with aphasia must be systematically investigated. For some participants, the high-dose condition may, in fact, contribute to fatigue and frustration, particularly for individuals with concomitant moderate to severe apraxia of speech or dysarthria. Interference from the multiple attempts may negatively impact some participants' performance on the high-dose condition (Martin et al., 2004). Further investigation is warranted to tease these factors apart.

Influence of repeated naming practice on generalization measures

Three post-training assessments served as generalization measures for this study: the *WAB-R,* AQ; the *BNT-2,* and subtest 54 of the *PALPA.* Improvements on the measures that directly assessed confrontation naming skills (i.e., *BNT-2* and subtest 54 of the *PALPA*) suggest that naming abilities increased as a result of this protocol. Six out of seven participants significantly improved on the *BNT-2* and all seven participants improved on the *PALPA.* Therefore, the process of naming appears to have improved to a small degree for each participant, as reflected on these measures of confrontation naming. One explanation for this overall improvement of naming abilities could be consolidation (Shadmehr & Holcomb, 1997), suggesting that both the dose and the overall duration of the protocol may have ultimately led to improved naming abilities. Anecdotal reports from participants and their family members indicated that they perceived their naming abilities to have improved outside of the clinical setting.

Improvements on the *WAB-R* AQ scores were not observed consistently; two of the six participants (P2, P7) who completed a second administration of the *WAB-R* demonstrated clinically significant improvements (i.e., greater or equal to 5 points) and three of the six participants demonstrated significant improvements per SEM. These two participants also demonstrated significant effect sizes for naming. Given the focused and specific nature of this training protocol, significant changes relative to general language outcome measures were not predicted. Future studies should include controlled language sampling, including picture/scenario description tasks that include the trained stimuli, to provide additional evidence of contextual generalization.

Clinical implications

The primary goal of this study was to document the influence of repeated practice on confrontation naming accuracy for persons with aphasia to better understand how to optimize dose for anomia treatment. Results of this investigation suggest that repeated practice positively influences naming accuracy for some persons with aphasia. Our findings also suggest that a higher dose of training may lead to more persistent treatment effects for some persons with aphasia. From a clinical perspective, this finding suggests that clinicians who wish to use repeated practice as a mechanism for improved naming performance may need to adhere to a high-dose protocol over the course of several days without becoming discouraged. For more impaired individuals, clinicians will need to be adept at motivating the client to work through frustration and increased effort within each session and across multiple sessions. As feedback was not required to elicit improved naming performance, clinicians may consider implementing

home-based high-dosage naming practice using technology-based applications. This approach would serve as an efficient, cost-effective mechanism to supplement face-to-face therapy.

Numerous participant characteristics likely influenced the ultimate success of this naming protocol. Participants in this study demonstrated high motivation, determination, and intentional and focused attention. All individuals also had consistent transportation and reliable psychosocial support. During training sessions, participants named pictures for up to an hour and a half without other interfering tasks. The training sessions were intense, and clients never received feedback. All seven participants, regardless of baseline cognitive-linguistic impairments, aphasia severity, and/or aphasia classification completed this high-intensity protocol without significant fatigue or lapse in attentional processes.

Limitations and future directions

The current study was intended to provide initial feasibility information relative to manipulating dose during a confrontation naming protocol for individuals with aphasia. As a result of the pilot nature of the study, several issues complicate the interpretation of the results.

The most significant flaw to this study was the lack of an extended baseline. We recognize this flaw as one that has impaired our ability to accurately determine the influence of repeated practice of trained items across sessions. Fortunately, untrained stimuli were never repeated across sessions during the baseline period. Upon visual inspection of trained versus untrained items, little difference is observed, suggesting that the repeated opportunity to name the trained stimuli during the baseline period did not greatly influence naming performance. Future studies will involve the use of an extended baseline design to address this issue.

An additional limitation of this study was the lack of training probes after each training session as well as the lack of multiple training probes immediately following the completion of training. Subsequent studies will include multiple training probes immediately following the end of training and then collected at scheduled increments through six weeks post-training. This probe schedule will allow researchers to strategically observe the presence of the effect of withdrawal/decay that may occur following repeated practice.

Future studies will also need to better isolate the dose variable. While we were able to manipulate within-session dose for each participant, we were not able to control the dose frequency or total intervention duration, thus leading to variable cumulative intervention intensities across participants. Future studies will need to control all dose parameters.

This investigation, by nature of its design, contained a remarkable amount of data. While this primary analysis provides insight into the influence of repeated practice and dose on picture naming performance, a number of additional analyses will be conducted including: (1) analysis of within-training session variability for the high-dose and low-dose stimuli; (2) analysis of training session data to document the pattern of errors within and across training sessions; and (3) error analysis across phases of the experimental protocol. A single subject, multiple baseline study is currently under development to compare low-dose to high-dose picture-naming in an intensive protocol that takes place in a clinical setting.

Ultimately, anomia researchers should pursue the lines of research started here and by Harnish and colleagues (2014) to systematically investigate manipulations of dose, dose frequency, total intervention duration, and cumulative intervention intensity to optimize treatment delivery for persons with aphasia. Similar dose and intensity investigations should also

incorporate various anomia treatment approaches (e.g., semantic, phonological, gestural, etc.) to provide clear operational parameters for optimal outcomes.

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List of Figure Captions

9. Figure 9. Participant 7: Naming accuracy of trained low-dose, trained high-dose, and untrained items. Note: immediate training probes are indicated by “a” and delayed training probes are indicated by “b”.