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NEUROPLASTICITY, DOSAGE, AND REPETITION PRIMING EFFECTS IN

INDIVIDUALS WITH STROKE-INDUCED APHASIA

By

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Neuroplasticity, Dosage, and Repetition Priming Effects in Individuals with Stroke-Induced Aphasia

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Intensity significantly impacts aphasia treatment efficacy, yet research protocols have not answered questions about optimal intensity and/or dosage. A single-subject ABA design investigated the influence of repetition priming on naming performance for four individuals with stroke-induced aphasia. The participants completed an intensive training protocol with repeated attempts to name pictures. Independent variables included training status and stimulus dosage. The dependent variable was response accuracy. Response accuracy increased for all participants during the training phase, and training effects persisted through the maintenance phase for all participants. Stimulus dosage did not consistently influence response accuracy for the participants.

Keywords: aphasia, anomia, repetition priming, neuroplasticity, stimulus dosage, intensity

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Chapter One: Introduction

Every 45 seconds, someone in the United States suffers a cerebral vascular accident (CVA), or stroke. Although CVA is the fourth-leading cause of death in the United States, over 795,000 individuals per year in this country survive strokes (Centers for Disease Control [CDC], 2012). These stroke survivors often experience a multitude of post-CVA impairments, which may include deficits to cognition, movement, eating/swallowing, emotional control, vision, perception/orientation, and communication. Many CVA survivors require rehabilitation to improve function of a number of these impairments, frequently in the area of communication. Communicative impairments in post-CVA individuals may include dysarthria, apraxia, or aphasia (National Institute of Neurological Disorders and Stroke [NINDS], 2001).

Stroke-induced impairments negatively affect an individual's ability to effectively communicative with others. In addition to overt communication abilities, any number of other stroke-induced impairments may negatively affect an individual's ability to communicate. For example, cognitive impairments following stroke may affect memory, analytic reasoning, judgment, and pragmatic skills (NINDS, 2001). In turn, said impairments may hinder a person's ability to maintain appointments, display appropriate pragmatics when interacting with others, or remember tasks. These effects of stroke often significantly impact an individual's communication abilities and reduce their overall quality of life. Following a stroke, stroke survivors often work with a team of therapists, including speech-language pathologists (SLPs) to rehabilitate impaired functions and minimize the impact that these impairments may have on the individual's participation in life. SLPs, specifically, work to rehabilitate the cognitive and communicative impairments resulting from a CVA.

One of the most common deficits that SLPs treat in post-stroke individuals is aphasia. The majority of individuals who experience aphasia are individuals who have experienced a CVA; approximately 38% of stroke survivors receive this diagnosis (Pedersen, Jorgensen, Nakayama, Raaschou, & Olsen, 1995). Aphasia has been formally described in a number of different ways, but is most often defined as an acquired multimodal deficit that may affect an individual's expressive and receptive language in the areas of writing, speaking, drawing, and gesturing (McNeil & Pratt, 2001). Aphasia often manifests very differently between individuals, and may affect any or all modalities of language in a unique manner. Language intervention for aphasia typically consists of restorative therapy techniques coupled with compensatory communication strategies to help a person with aphasia (PWA) achieve functional language gains and improve their quality of life. Table 1 provides a brief description of the classification of aphasic symptoms and related neural coordinates (adapted from Davis, 2007).

Table 1

Classification of Aphasic Symptoms

Non-Fluent Aphasias				Fluent Aphasias		
Subtype	**Behavioral Description**	**Anatomical Correlates**		**Subtype**	**Behavioral Description**	**Anatomical Correlates**
Global Aphasia	Global deficits; severely impaired expressive and receptive skills	Large lesion, left hemisphere		Wernicke's Aphasia	Poor auditory comprehension and repetition; speech is fluent, but full of jargon; poor awareness	Posterior portion of left hemisphere; usually within temporal lobe, near Wernicke's area
Transcortical Motor Aphasia	Poor spontaneous speech; intact auditory comprehension	Anterior portion of left hemisphere, superior to		Transcortical Sensory Aphasia	Similar to Wernicke's, but good repetition; may be echolalic	Posterior portion of temporal lobe, near parietal lobe; Wernicke's area is spared

	and repetition	Broca's area		Conduction Aphasia	Good auditory comprehension; very poor repetition	Area inferior to supramarginal gyrus
Broca's Aphasia	Telegraphic, effortful speech; agrammatism, with poor repetition; good auditory comprehension	Anterior portion of left hemisphere; near Broca's area; often frontal lobe		Anomic Aphasia	Anomia is most significant deficit; comprehension and repetition usually intact	Area near angular gyrus

Despite the long-accepted anecdotal agreement of clinicians and educators, sufficient evidence to support the efficacy and effectiveness of language rehabilitation following stroke has only been recently established (Kleim & Jones, 2008; Thompson, 2000). The past fifteen years have proven to be exceptionally progressive for brain and neuroscience researchers. Advances in technology have allowed clinicians and researchers to integrate classic cognitive-behavioral models of treatment (e.g., Holland, 1980; Davis & Wilcox, 1985) with biological perspectives (e.g., Coltheart, 1983; Ellis & Young, 1988), which has allowed for a better understanding of the damage, resulting deficits, and eventual language recovery associated with aphasia (Meinzer, Harnish, Conway, & Crosson, 2011; Varley, 2011). Current technology, including functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), helps medical professionals make connections between neural levels of damage, behavioral symptoms, and eventual recovery mechanisms (Baillieux et al., 2010; Peck et al., 2011). As a result of this modern technology, behavioral changes that follow training may be observed at the structural level.

Research advances have changed the landscape of aphasia treatment. To effectively treat all deficits that negatively affect communication, SLPs specializing in aphasia (i.e.,

aphasiologists) must understand the process of healing that occurs in the brain following a CVA. Neuroscience-inspired aphasiology clarifies the role of the brain to process information and to learn at a neural level. Furthermore, for individuals who experience aphasia resulting from stroke, significant recent evidence suggests that the brain can functionally reorganize damaged areas of neural pathways following the injury, and even regain lost function (Hillis & Heidler, 2002; Kleim & Jones, 2008; Raskin, 2011; Thompson, 2000; Vitali et al., 2007). This idea of cortical change is known as neuroplasticity. Neuroplasticity is a primary tenet of neuroscience-inspired treatment approaches used by a growing number of SLPs.

Neuroplasticity cannot be explained without first understanding the ways in which learning occurs through neural pathway activation in non-injured brains. As far back as 1949, neuroscientists claimed that if two cells are repeatedly concurrently active, they will become associated (Hebb, 1949). Thus, activity in one cell or system of cells will facilitate activity in its associated correlate. This is referred to as the "Hebbian Principle," and helps to explain the general basis of learning via synaptic connections (Hebb, 1949). A common adage to describe this phenomenon is "cells that fire together, wire together" (Varley, 2011). Early researchers discovered that, in healthy brains, connections will develop and form associative links if two initially unrelated inputs begin to co-occur and synaptic systems are repeatedly active at the same time (Hebb, 1949). These connections are not confined to just one modality; they may be linked across a number of different senses or actions. This linkage results from simultaneous activation of heteromodal neurons (i.e., neurons designated to different actions), even those that are of distinctly different processes (Thompson et al., 2000). For example, Schlolz, Klein, Behrens, and Johansen-Berg (2009) used fMRI and PET in healthy brains to demonstrate that six weeks of

training in the complex motor skill of juggling brought about structural changes in the white and grey matter of the occipital and parietal cortex.

Despite this awareness of the learning process in healthy brains, researchers have only recently begun to understand the ways in which synaptic connections change during rehabilitation from brain injury. Applying both imaging technologies such as fMRI and PET with human participants along with animal models, researchers can now investigate the different ways that the brain functionally reorganizes following injury (Murphy & Corbett, 2009; Nudo, Milliken, Jenkins, & Merzenich, 1996). According to Hillis and Heidler (2002), functional reorganization is the system-wide cortical plasticity that often occurs following a stroke. Functional reorganization results from repaired interaction between brain structures and cognitive functions. Repaired interaction between structures and function is purportedly linked to the following circumstances: regression of diaschisis following a stroke, restoration or restitution of partially damaged pathways, and the recruitment of undamaged pathways not formerly used for a function (Hillis & Heidler, 2002; Wambaugh, et al., 2012). Following relearning and rehabilitation, researchers have found that the brain can recreate entire neural pathways that have been destroyed, thereby regaining lost function in impaired areas, including speech and language (Hallett, 2001).

The brain's ability to regain lost function relies heavily on what point it is at in the course of recovery. During the acute (hours to days following CVA) and sub-acute (days to a few months following CVA) stages of stroke recovery, some spontaneous recovery of neural pathways occurs. This spontaneous recovery often occurs independent of rehabilitative treatment, and is characterized by reactive plasticity, which is the rapid neuronal growth and healing resulting in functional change (Marcotte et al., 2012). In the sub-acute and chronic

(months and years following a CVA) stages of recovery, functional brain recovery occurs.

Evidence in the aphasiology literature suggests that this functional stage of recovery is the ideal

point at which to begin intensive treatment to best facilitate experience-dependent plasticity and

neural reorganization (Kleim & Jones, 2008; Brady, Kelly, Godwin, & Enderby, 2012;

Cornelissen et al., 2003). Researchers have found evidence to indicate that the human brain is

capable of responding to behavioral therapeutic principles to partially or fully regain function

lost due to cortical damage associated with CVA.

Neuroplasticity, whether reactive (i.e., spontaneous recovery) or experience-dependent (i.e.,

treatment-induced) can manifest in one of two ways, functional reactivation or functional

reorganization. Functional reactivation consists of functional recovery of perilesional (i.e., areas

in close proximity to the affected region) classic language areas in the left hemisphere.

Functional reactivation generally results in better language outcomes for PWA. Functional

reorganization occurs when a perilesional non-classical language area of the left hemisphere, or a

homologous (i.e., similar location on opposite hemisphere) right hemisphere area is recruited for

language tasks (Marcotte et al., 2012). Researchers have found that rehabilitation for PWA

should maximize this experience-dependent plasticity. Kleim and Jones (2008) suggested ten

principles that may best assist with effective treatment to maximize functional outcomes for

PWA as demonstrated in Table 2.

Table 2

Ten Principles of Neuroplasticity

Principle	Description
1. Use it or lose it	Failure to use certain brain functions can lead to functional decline

2. Use it and improve it	Rehabilitation focused on a specific brain function can improve that function
3. Specificity	Plasticity is determined by the nature of the training
4. Repetition matters	In order for plasticity to be achieved, sufficient repetition must occur
5. Intensity matters	In order for plasticity to be achieved, sufficient training intensity must occur
6. Time matters	Plasticity may manifest in different ways throughout rehabilitation
7. Salience matters	Items targeted must be salient to the individual undergoing rehabilitation
8. Age matters	Treatment-induced change occurs more extensively in younger brains
9. Transference	Plasticity occurring in one aspect of language can enhance the acquisition of similar behaviors across different aspects of language
10. Interference	Plasticity occurring in one aspect of language may interfere with acquisition of similar behaviors.

When treating clients, SLPs must consider the effect that these ten principles have on language recovery and must do their best to implement treatment that maximizes functional outcomes. SLPs must also understand that aphasia is variable and manifests differently in each client, depending on the type and severity of symptoms and period of time in the recovery process. Thus, the manner in which these ten principles are targeted will vary across and within clients over the course of the rehabilitation process. Treatment should be uniquely designed according to the client's goals, as well as their subtype of aphasia. Effective treatment utilizes a client's strongest language modalities, while simultaneously targeting their weakest modalities.

While each subtype of aphasia varies across and within clients, the most ubiquitous symptom of aphasia is anomia. Anomia is a word retrieval deficit that affects an individual's ability to access, retrieve, and produce lexical items stored in memory (Nozari, Kittredge, Dell, & Schwartz, 2010). It is not, however, a loss of lexical representations. Anomia is often anecdotally referred to as the "tip of the tongue" phenomenon, during which the individual

experiences significant difficulty in producing words or names of objects (Brown & McNeill, 1966). Clinically, anomia results in communication breakdowns and frequently causes frustration for both the PWA and their conversation partners.

Two general classifications of anomia are often made in regards to spoken language production: (1) a semantic encoding deficit; and (2) a phonological encoding deficit (Maher & Raymer, 2004). An individual with anomia stemming from a semantic encoding deficit may produce lexical errors that are similar in meaning to the target word (e.g., "cat" for "dog", or "leash" for "dog"). An individual with anomia stemming from a phonological encoding deficit may produce an off-target form of the intended word (e.g., "dod" for dog). Despite these two general classifications, however, the types of errors made by persons with anomia do not directly correlate with the underlying linguistic impairment. More often, errors made by individuals with anomia depend on participant variables (i.e., size and location of lesion) and lexical variables (i.e., word frequency or word length).

Individuals experiencing anomia produce a variety of additional error types including omissions, perseverations (i.e., repetition of a particular response), mixed paraphasias (i.e., a combination of semantic and phonological errors), picture descriptions, and neologisms (i.e., meaningless non-word). Lexical retrieval by these individuals is behaviorally characterized by reduced accuracy and increased latency. Nevertheless, PWA who experience anomia make qualitatively similar errors in comparison to healthy participants (Silkes & Rogers, 2012).

Numerous approaches have been developed to treat anomia. Treatment approaches typically focus on semantic encoding or phonological encoding. Collectively across both semantic and phonological treatment paradigms, improved naming skills are typically elicited by a confrontational naming task, and facilitated by semantic or phonological cuing. A semantic cue

is a prompt that contains meaningful information about the target (i.e., "you sit on this" for chair). A phonological cue is a prompt that typically contains the first sound or syllable of the target word (i.e., "st.." for stair). Both semantic and phonologically based treatments elicit relatively equivalent positive changes (e.g., Edmonds, Nadeau, & Kiran, 2009). Consequently, many clinicians and clinical researchers employ a combined approach, including both semantic and phonological cuing in anomia treatment (e.g., Dell, Martin, & Schwartz, 2007). Regardless of treatment approach, SLPs must consider the significant effect that anomia has on the language capabilities of PWA.

In addition to anomia-related deficits, SLPs must also account for mechanisms of learning present in their clients with aphasia. Language rehabilitation is supported by both explicit learning processes, which require conscious attention, and implicit learning processes, which is an unconscious process that results in effortless access of learned items (Butler & Berry, 2004). Implicit learning tasks are unknowingly encoded into memory, and include recall, recognition, and priming. Research has consistently shown that although PWA demonstrate lower levels of response accuracy and slower reaction times than non-brain injured individuals, they still follow the same continuum of learning (e.g., Carson, Carson, & Tikofsky, 1968; Dede, 2012; Demeurisse & Capon, 1987). Throughout stages of rehabilitation, individuals with aphasia typically have more difficulty with explicit learning mechanisms. As a result, implicit learning mechanisms are the ideal method to use for PWA, as learning tasks are effortlessly encoded, limiting the frustration and overt errors often associated with explicit learning mechanisms.

One implicit learning mechanism is repetition priming. Repetition priming refers to the priming effect(s) observed as a result of more than one presentation of a given stimulus (Reber,

Gitelman, Parrish, & Mesulam, 2004). It has been proposed as a mechanism of learning that leads towards the development of automaticity that typically accompanies expertise (Poldrack et al., 1999; Reber et al., 2004). Repetition priming is most often presented as confrontational picture naming tasks of nouns and verbs in the treatment of anomia, where stimulus items are presented many times. Effective repetition priming is defined as increased naming accuracy and decreased reaction time (Butler & Berry, 2004; Kaschak, Kutta, & Jones, 2011).

Although repetition priming has been shown to be independent of skill learning (Schwartz & Hashtroudi, 1991; van Turennout, Bielamowicz, & Martin, 2003), it is likely to share the same underlying processes and neural substrates with skill learning (Dennis & Schmidt, 2003). Repetition priming is thought to reflect learning at the level of the stimulus item, is primarily implicit in nature, and requires no controlled attention processes (Brown, Jones, & Mitchell, 1996; Shiffrin & Schneider, 1977). In healthy non-brain-injured adults, repetition priming has been shown to be persistent up to 48 weeks and is sensitive to the number of repetitions (e.g., Cave, 1997; Brown, Jones, & Mitchell, 1988). In PWA, persistence of repetition priming effects have been documented both at short-lived and long-lasting intervals but has not been shown to be sensitive to the number of repetitions given (e.g., Rochon, Leonard, & Laird, 2006; Patterson, Purell, & Morton, 1983). As such, repetition priming is an ideal tool by which to incrementally investigate acquisition, generalization, and maintenance of trained items during spoken language production with PWA.

In addition to repetition priming, another learning factor regarding language rehabilitation for post-CVA clients is the importance of errorless learning. This mechanism of learning is applied by reducing or eliminating the possibility of the individual making an error, and relies heavily on principles of neuroplasticity (Frikriksson, Baker, & Moser, 2009). If a

PWA is allowed to make numerous errors without receiving correction, maladaptive neural pathways are likely to result. In contrast, errorless learning uses the Hebbian principle of using two initially distinct systems to create and strengthen previously non-existent synaptic connections, resulting in regained function. Furthermore, researchers suggest that this process facilitates implicit learning mechanisms, and is therefore particularly well suited to the procedural motor learning required for word production in individuals with anomia (Page, Wilson, Shiel, Carter, & Norris, 2006; Varley 2011).

Coupled with understanding principles of neuroplasticity and paradigms of learning, an SLP must also consider how frequently treatment must occur to see effective changes in clients with aphasia. Robey (1998) conducted a meta-analysis exploring treatment frequency and concluded that the more intense the aphasia treatment, the greater improvement the PWA will make. A recent Cochrane evidence-based systematic review concluded that there is strong evidence to support intensive therapy over the use of less intense, conventional treatment (Brady et al., 2012). Brady et al. (2012) also concluded that intensive treatment provides faster and more significant benefits than conventional therapy. Additionally, one of the primary principles of neuroplasticity presented by Kleim and Jones (2008) is *intensity matters*. That is, rehabilitative treatment will be most effective when it is intense, in regard to both the overall time spent per week in treatment, and the number of presentations of stimuli. From a neuroscience perspective, intensive treatment is a preferred service delivery model, because it best facilitates experience-dependent plasticity and neuronal reorganization. Optimal treatment gains are highly dependent upon a treatment protocol's ability to harness and capitalize on mechanisms of neurobiological recovery and neuroplasticity (Kleim & Jones, 2008). Researchers have begun to use fMRI and PET imaging techniques to examine structural and behavioral treatment effects relative to

principles of neuroplasticity, including intensity (e.g., Marcotte et al., 2012; Peck et al., 2011; Baillieux et al., 2010).

Clinical definitions of what constitutes intensive therapy vary; however, participants who receive a greater number of treatment sessions improve to a larger degree than those who receive fewer treatment sessions (Bhogal, Teasell, & Speechley, 2003). Therapy is generally considered intensive when participants receive at least five hours of therapy per week (Cherney et al., 2008). For example, Kurland, Baldwin, and Tauer (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 (i.e., 12 hours per week for 5 weeks) treatment protocol. Kurland et al. (2012) compared behavioral naming outcomes and structural changes seen via fMRI following two treatment protocols: first with Promoting Aphasics' Communicative Effectiveness (PACE; Davis & Wilcox, 1985), which was completed for three hours per week for 12 weeks, and then with the higher-intensity Constraint-Induced Aphasia Therapy (CIAT-Pulvermuller, et al., 2001), completed nine hours per week for five weeks. CIAT yielded more significant effects than PACE, both behaviorally and structurally. Thus, the positive effects of intensive treatment are evident through behavioral modalities, including increased naming accuracy, and through neuroplastic structural changes, as observed via fMRI. Despite substantial support to indicate that intensive treatment is effective and efficacious, few studies have begun to directly manipulate treatment delivery variables alone, while keeping all other variables constant.

While treatment intensity as a delivery variable has received considerable attention in the aphasia literature, other treatment delivery variables including dosage, have yet to be systematically explored. Specifically, little is known about within- and/or across-session dosage.

Despite the fact that repeated verbal practice of picture-naming is inherent to nearly all anomia treatment protocols, no studies have directly manipulated stimulus dosage to determine a dose-response curve in PWA. In particular, the number of repetitions of a given stimulus required to yield consistent improvement of naming accuracy has not been investigated. Lexical retrieval studies typically report the characteristics of their participants, details of the treatment approach, and the overall intensity of the protocol. 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 (for an exception please see Martin, Fink, Laine, & Ayala, 2004).

Although much research has been conducted exploring principles of neuroplasticity, and significant work has been completed reviewing mechanisms of learning in brain-injured individuals, few studies have been conducted to explore the effects of neuroplasticity in conjunction with learning principles for brain injured individuals especially in relation to stroke-induced aphasia. More research must be conducted to explore how neuroplasticity and implicit learning modalities may positively interact to improve the language rehabilitation and restoration in PWA. Additionally, more research must examine questions of dosage and repetition priming effects in regard to principles of neuroplasticity and implicit learning.

Repetition priming is a learning paradigm that may be used to investigate behavioral changes associated with manipulations of stimulus dosage during confrontational naming tasks for individuals with anomia. Dosage and intensity manipulations may be made based on stimulus set size, number of presentations, and through varying the frequency of repetitions. As previously mentioned, repetition priming is implicit, and occurs with little conscious effort. It is

therefore an ideal process by which to investigate acquisition, generalization, and maintenance of trained items during confrontational naming tasks.

To remove the influence of anomia treatment approach (e.g., semantic, phonological, gestural), a high-intensity repetition priming paradigm was designed to assess stimulus dosage on the acquisition and maintenance of picture naming accuracy for PWA. The purpose of the current study was to document the behavioral effects of solely repetition on naming accuracy among PWA. It also aimed to directly and systematically investigate the influence of dosage on naming performance. The following research questions were addressed during the study:

1. Can a highly intensive protocol using mere repetition significantly influence response accuracy for a picture naming protocol for PWA?
   - o H0: Repetition priming does not occur in PWA. That is, continual exposure to stimuli will not result in improved naming accuracy.
   - o H1: Repetition priming occurs in PWA, and repeated exposure to confrontational naming stimuli with mere repetition will increase response accuracy in a statistically significant manner.

2. Is repetition priming persistent across time for PWA?
   - o H0: Repetition priming is not persistent across time for PWA. Increased accuracy will not be maintained after training sessions are discontinued.
   - o H1: Repetition priming is persistent across time for PWA. Increased response accuracy will be observed across immediate and delayed probes, and after withdrawal of the training protocol, as measured by maintenance probes.
   - o Independent variables manipulated: Immediate vs. delayed training probes; maintenance sessions at least six weeks following the last training session.

3. Are repetition-priming effects sensitive to in-session dosage manipulations?

   o H0: Stimulus dosage will not influence response accuracy. No difference in response accuracy for 1 vs. 4 trials per session will be observed during acquisition or maintenance phases.

   o H1: Larger number of trials per session (e.g., 4 trials per session vs. 1 trial per session) will result in larger increases in response accuracy.

   o Independent variable manipulated: Number of presentations (1-trial vs. 4-trials) per training session.

Chapter Two: Methods

Experimental Design

A single-subject ABA design was used with replication across four participants with chronic aphasia to document the acquisition and maintenance of naming for trained pictures and generalization to naming for untrained pictures using a repetition priming paradigm. Participants were enrolled in a training protocol that involved repeated exposure to pictures, along with repeated attempts to name those pictures, to determine the effect of repetition and dosage on confrontational naming performance. Primary independent variables included stimulus dosage (1 vs. 4 picture-naming trials per session) and generalization variables (trained vs. untrained pictures). Word frequency (high vs. low word frequency) and word length (1 vs. 2 syllables) were controlled. The dependent variable was response accuracy.

The single-subject ABA design allowed for examination of the acquisition and maintenance of picture naming using a repetition priming paradigm. The A phase of the design was the baseline period, during which the dependent variable of response accuracy was measured for trained and untrained pictures across four probe sessions. During the B phase, training consisted of up to 15 treatment sessions containing trained targets with varying dosage (i.e., 1 vs. 4 picture-naming trials per session). During training sessions, target stimuli were accompanied by the spoken and written name of the depicted item. Training probes were also systematically conducted during the B phase. These training probes assessed naming accuracy of trained and untrained pictures independent of accompanying written or auditory cues. In the remaining A phase, treatment was withdrawn. Probes were completed at least six weeks following completion of the B phase to assess maintenance of trained stimuli and generalization to untrained stimuli.

Research Setting

Ethics approval was obtained from the Institutional Review Board for the Protection of Human Subjects in Research at The University of Montana (IRB #151-12). Informed consent, cognitive-linguistic evaluation, and administration of all phases of the research protocol took place in Missoula, Montana at the University of Montana in the UM RiteCare Speech, Language, and Hearing Clinic, which is housed in the lower level of the Curry Health Center.

Consent Procedures

Prior to the initial cognitive-linguistic assessment session, consent documents (see Appendix A) were provided to the potential participant so they could have sufficient time to review the documents and to allow for assistance with reading documents from a caregiver or spouse, if necessary. On the first day of cognitive linguistic evaluation, the experimenter presented the consent forms to be reviewed and signed. Informed consent procedures were followed in accordance with the approved guidelines of the Institutional Review Board at the University of Montana (45 CFR 46.117). The University of Montana Institutional Review Board (IRB) approved consent forms under protocol number 151-12 (see Appendix B). The experimenter explained the purpose and procedures of the study to each participant, with an emphasis that participation in the study was completely voluntary. Due to presence of expressive and receptive language deficits inherent in each participant, extra effort was taken to ensure that participants completely understood all components of the study's purpose and procedures. A consent form containing simplified language, as well as multimodality support was used to ensure complete understanding (see Appendix C) In addition to consent documents, participants reviewed and signed a recording release for audio and video, medical release of information, and Health Insurance Portability Accountability Act of 1996 (HIPAA) information documents.

Following completion of consent procedures, information related to stroke history, time post-onset, age, and native language was obtained from the participant or their caregiver. Subsequent to obtaining consent, personal, medical, and social histories were collected from the participant or their caregiver. Medical records were obtained as available to confirm medical history pertaining to the individual's CVA(s), including neurology exam reports, CT and/or MRI reports/scans, and speech and language diagnostic reports. Medical information pertinent to the study was recorded on a data entry sheet. When all inclusionary criteria were met, the participants were scheduled to undergo a comprehensive cognitive-linguistic evaluation.

Study Inclusion Requirements

Cognitive-linguistic evaluations took place at The University of Montana RiteCare Speech, Language, and Hearing Clinic (UM RiteCare SLHC), under the direct supervision of an ASHA-certified and Montana-licensed speech-language pathologist. If the participant had been administered any of the required assessments within six months of the evaluation, those scores were used in lieu of re-administering the particular test. Refer to Table 3 for a summary of tests that were administered. Following completion of the protocol, portions of the cognitive-linguistic battery were re-administered to assess linguistic changes (see Appendix D).

Table 3

Study Inclusion Test Battery

Test	Description/Purpose	Inclusionary/Exclusionary Criteria
Vision Screening	Snellen chart	Pass= 20/30 at 2.3 feet with or without glasses/contacts Fail= referral to optometrist prior to enrollment
Hearing Screening	Portable audiometer;	Pass= 35 dB

	Tested bilaterally at 500, 1000, 2000, and 4000 Hz	Fail= referral to audiologist prior to enrollment
Oral-Mechanism Evaluation	To examine the structure and function of oral mechanism	Descriptive information obtained
Informal Assessment of Visual Neglect	Participant asked to perform cancellation task to rule out visual field deficits	Descriptive information obtained
Western Aphasia Battery-Revised (WAB-R) *Kertesz (2006)*	To assess language across modalities	Aphasia Quotient (AQ) = __/100 Pass = AQ >25/100 Fail = Excluded from study
Boston Naming Test (BNT) *Goodglass & Kaplan (1983)*	To assess lexical retrieval	Raw Score= __/60 Descriptive only
Raven's Coloured Progressive Matrices *Raven (1976)*	To assess non-linguistic cognitive skills	Raw Score = __/36 Pass = >12/36 Fail = excluded from study
Apraxia Battery for Adults-Second Edition (ABA-2) *Dabul (2000)*	To assess motor planning and programming	Pass= no scores in the "severe" to "profound" range Fail = exclude from study
Beck Depression Inventory-II (BDI-II) *Beck, 1996*	To assess presence and severity of depression	Raw score = __/63 Pass = 0-19 Exclude from study = 20-63
Subtest 54 of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) *Kay, Lesser, & Coltheart (1992)*	To assess confrontational naming with high and low frequency stimuli	Raw Score = __ /60 Descriptive information obtained

Participants

Four individuals with chronic aphasia participated in this investigation.

Recruitment. The researcher recruited PWA from the University of Montana Acquired Neurogenic Communication Disorders Registry and Repository (IRB#183-11), the University of Montana RiteCare Speech, Language, and Hearing Clinic, and the surrounding communities. Recruitment was accomplished through word of mouth through local medical facilities, flyers (see Appendix E), the University of Montana Big Sky Aphasia Program website, mass and individual emails, and social media.

Participant selection. Eligible participants included individuals who were 18-90 years old; participants under the age of 18 were excluded, as the experiment was designed to investigate spoken language of adults with aphasia resulting from CVA. Eligible participants included right-handed individuals who had suffered a left hemisphere stroke three months or more prior to enrollment in the study, had a clinical diagnosis of aphasia, were medically stable, had adequate or corrected vision and hearing, and were native speakers of English. Participants who reported a history of psychiatric conditions, demonstrated cognitive changes due to stroke, or who experienced degenerative conditions such as dementia were not included in this study. No exclusions were made according to gender or ethnicity.

Participant profiles. This study included four right-handed adults with chronic aphasia as participants. According to existing medical records, each participant's aphasia resulted from a stroke. Three of the four participants had experienced a single left hemisphere stroke, while one of the participants (A001) had experienced multiple infarcts in subcortical areas. Each participant presented with medically documented chronic aphasia and anomia that ranged in severity from mild to severe. At the time of the investigation, persons with aphasia (PWA) were between nine

months and 21 years post stroke, with no subsequent language or cognitive decline. Participants were native speakers of American English between the ages of 55-70 who lived at home. 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. PWA were permitted to enroll in this study regardless of ongoing enrollment in speech/language therapy. Participant characteristics and pre-treatment assessment results are shown in Table 4.

Case #1: UM A001 RP. Participant A001 was a 55-year-old male who presented with an ischemic CVA to the right thalamus and basal ganglia that had occurred approximately 48 months prior to study enrollment. The Western Aphasia Battery-Revised (WAB-R) was administered during initial cognitive-linguistic testing, and he obtained an Aphasia Quotient (AQ) of 99.6, indicative of minimal anomic aphasia. A001 achieved a score of 59/60 on the Boston Naming Test (BNT), indicating picture naming skills of black and white illustrations of concrete nouns to be within normal limits.

A001 did not meet pre-treatment performance deficits, nor had he experienced a CVA to the left hemisphere; however, the primary complaint of this participant was difficulty with high-level confrontational naming, in absence of most other aphasic deficits. The participant was included in the current study because of his strong desire to participate in the study and his motivation to decrease response time and increase response accuracy. As A001 did not meet all inclusionary criteria, his data should not be directly compared to the performance of the three other participants; instead, A001 served as a control-like participant for this study.

Case #2: UM A002 RP. Participant A002 was a 62-year-old female who presented with a left middle cerebral artery (MCA) ischemic CVA that had occurred 22 months prior to the initial cognitive-linguistic testing session. According to speech-language pathology assessment

completed six months post-CVA, A001 demonstrated moderate-severe non-fluent aphasia, impacting expressive modalities (i.e., writing and verbal expression). At the time of enrollment in the study, A002 presented with moderate expressive aphasia and mild apraxia. The WAB-R was administered prior to enrollment, and the participant obtained an AQ of 76.2, indicative of anomic aphasia. Confrontational picture naming was moderately impaired, characterized primarily by phonemic paraphasias. A002 achieved a score of 28/60 on the BNT, indicative of moderately impaired confrontational picture naming. Picture naming was characterized primarily by phonemic paraphasias resulting in non-words (e.g., /sImp/ for "shrimp"), and occasional semantic paraphasias (e.g., "couch" for "bed").

   Case #3: UM A003 RP. Participant A003 was a 70-year-old male who presented with an ischemic left MCA stroke that occurred 10 months prior to the initial cognitive-linguistic testing session. He presented with severe expressive and receptive aphasia, moderate apraxia of speech, and moderate-severely impaired attention and memory. As a result of severe receptive aphasia, the participant's repetition skills were significantly impacted. He obtained a WAB-R AQ score of 37.1, indicative of global aphasia. A003's confrontational picture naming was severely impaired, and he scored 0/60 on the BNT. His naming was frequently characterized by neologisms (e.g., "shumpterbrissel" for "rose") and non-responses (e.g., "I don't know"). A003 did exhibit some intact responsive speech, including greetings.

   Because of A003's severity across modalities, he was not an ideal participant. Investigators were concerned about his exceptionally poor performance on standardized assessments including the BNT. After a trial period (i.e., baseline probes), however, it was clear that he could fully participate in the protocol, despite significant memory and attention deficits. Following commencement of the training phase, A003 displayed stimulability for correct

productions following audio and orthographic cues, further justifying his inclusion in the protocol.

   Case #4: UM A004 RP. Participant A004 was a 67-year-old male who presented with a left hemisphere hemorrhagic CVA that had occurred approximately 20 years prior to the initial cognitive-linguistic testing session. He presented with moderate expressive aphasia, moderate apraxia, and moderate dysarthria. A004 obtained a WAB-R AQ score of 59.0, consistent with conduction aphasia. His spontaneous expressive language was moderately affected, and characterized by short phrases containing phonemic paraphasias resulting in non-words (e.g., /pʌnzɚ/ for "plunger"). A004 obtained a score of 27/60 on the BNT, indicative of moderately impaired confrontational picture naming skills, and characterized by numerous phonemic paraphasias. Refer to Table 4 for a summary of the participants' profiles and scores on the pre-treatment cognitive-linguistic batteries.

Table 4

Participant Profiles

	UM A001	UM A002	UM A003	UM A004
Age	55	61	70	67
Gender	Male	Female	Male	Male
Months Post-Onset CVA	48	22	10	240
CVA Type	Ischemic	Ischemic	Ischemic	Hemorrhagic
CVA Location	Right thalamus and basal ganglia	Left MCA	Left MCA	Left Hemisphere, unspecified
Premorbid Handedness	Right	Right	Right	Right
Western Aphasia Battery-Revised (WAB-R) Aphasia Quotient	99.6/100	76.2/100	37.1/100	59.0/100
WAB-R Aphasia Classification	Anomic	Anomic	Global	Conduction

Boston Naming Test	59/60	28/60	0/60	27/60
Raven's Progressive Matrices	36/36	34/36	14/36	26/36
Apraxia Battery for Adults	No apraxia	Mild Apraxia	Moderate Apraxia	Moderate Apraxia
Beck Depression Inventory-II	13/63	25/63	8/63	2/63
Visual Neglect (Cancellation task)	No Evidence	No Evidence	No Evidence	No Evidence
Subtest 54 of Psycholinguistic Assessment of Language Processing in Aphasia (PALPA)	59/60	44/60	0/60	21/60

Procedures

Stimuli. One hundred and forty target pictures were randomly selected from a previously developed corpus of 240 digitized color photographs, assessed for easy recognition, and depicting 1- and 2-syllable concrete nouns (Kenny, 2006; Krohn, 2005; Potts, 2006). From this corpus of 140, forty pictures were selected as trained stimuli and 100 pictures were selected as untrained stimuli; trained and untrained stimuli were balanced across 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 (Francis & Kucera, 1982). During training sessions, pictures were accompanied by the spoken (auditory) and written (orthographic) name of the picture. Names of the trained pictures were previously audio-recorded with a female voice and edited for word duration using Computerized Speech Lab (CSL) 4150 (KayPENTAX, Lincoln Park, NJ). The 40 trained pictures were randomly assigned to one of two groups (1 trial per session or 4 trials per session) to assess differential effects of stimulus dosage.

Instrumentation. Pre- and post-training evaluations were video-recorded. Experimental

sessions were carried out using E-Prime (EPrime, Psychology Software Tools, Pittsburgh, PA)

on a Lenovo ThinkCentre desk-top computer. A head-mounted microphone (AKG MicroMic

C520 vocal microphone) interfaced with a voice key through the E-Prime serial response box

served as a timing mechanism to record participant response. The microphone was routed

through a Tube MP Project Series Professional Microphone and Instrument Tube Preamplifier to

allow for individually-based calibration of voice onset detection. The pre-amplifier was

connected to a serial response box (Psychology Software Tools, Pittsburgh, PA), then interfaced

with the computer. Response time, in milliseconds, was collected by E-Prime based on the time

between the onset of the visual stimulus and the initiation of speech. Microphone calibration

took place immediately prior to every probe and training session. A Logitech C615 HD Webcam

was used to video-record participants' responses to evaluate reliability for response accuracy.

Audio files were imported into E-Prime and presented through Sennheiser Professional HD 25-1

II Noise-Cancelling Headphones at a level audible to each participant.

Delivery schedule

Baseline Probe Sessions. Following completion of cognitive-linguistic testing and

subsequent enrollment, participants were administered four baseline probes to assess pre-training

confrontational naming performance. Each of the four baseline probes took place on separate

days within a two-week time period. During each baseline probe session, participants were

instructed to name 32 target pictures (consisting of ten to-be trained items and 22 randomly

selected to-be untrained items) as quickly as possible while maintaining accuracy. Participants

were discouraged from self-correcting errors, coughing, or clearing their throats during the

sessions, so as not to erroneously record response times within E-Prime. Target pictures were delivered randomly via the software program E-Prime. Each trial proceeded as follows:

(1) a black fixation mark (*) appeared at the center of a white computer screen for 2000 milliseconds (ms);

(2) the target picture appeared at the center of the computer screen for 17000 ms at which time the participant attempted to name the picture;

(3) a red "X" appeared in the middle of a white screen for 4000 ms to encourage the participant to stop verbal production;

(4) the black fixation point reappeared to prepare the participant for the next trial.

Figure 1. Example of one picture-naming presentation during baseline probe.

Training Sessions. Training sessions were initiated no more than two weeks following completion of baseline probes. Participants attended training sessions 2-3 times per week for a maximum of 15 training sessions. The training delivery schedule varied across participants. Each training session lasted approximately one hour, during which participants attempted to name the 40 trained targets. Twenty trained items were presented once per session, and 20 items were presented four times per session, for a total of 100 naming attempts per training session. Trained stimuli were randomly presented; the number of trials that intervened between repetitions was not controlled and order of the targets was not controlled. The 100 target trials were divided equally into five runs, with breaks provided between runs, as needed.

Following the initial naming attempt, the picture was presented again, this time with an audio cue and an orthographic cue; this second attempt was designed to allow for a correct production of the target (i.e., errorless learning). Participants were instructed to name pictures aloud as quickly as possible while maintaining accuracy; they were discouraged from self-correcting errors, coughing, and/or clearing their throat. Trials proceeded as follows:

(1) a black fixation mark (*) appeared at the center of a white computer screen for 2000 ms;

(2) the target picture appeared at the center of the computer screen for 10000 ms at which time the participant attempted to name the picture;

(3) a red "X" appeared in the middle of a white screen for 2000 ms to encourage the participant to stop verbal production;

(4) the target picture reappeared for 12000 ms; the target was accompanied by both the auditory presentation of the name of the target and the orthographic form; the participant then attempted to repeat the name of the picture;

(5) a red "X" appeared in the middle of the white screen for 4000 ms to encourage the participant to stop verbal production;

(6) the black fixation mark reappeared to prepare the participant for the next target.
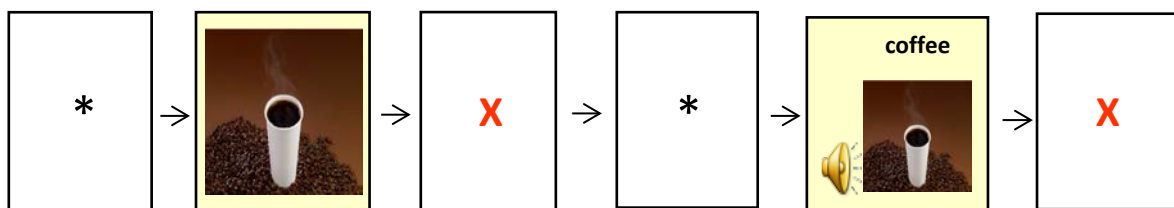

Figure 2. Example of one picture-naming presentation during training session.

Training Probe Sessions. Training probes were administered immediately following every third training session and immediately prior to every fourth training session to assess both

immediate and delayed effects of training on response accuracy. Final training probes were administered immediately following the last training session. Each training probe contained the 40 trained items, in addition to 20 randomly selected untrained targets to assess differences between trained and untrained stimuli. During each training probe, participants were asked to name pictures as quickly as possible while maintaining accuracy. Participants were discouraged from self-correcting errors, coughing, or clearing their throats during the sessions. Target pictures were presented randomly according to the software program E-Prime. Each trial proceeded as follows:

(1) a black fixation mark (*) appeared at the center of a white computer screen for 2000 milliseconds (ms);

(2) the target picture appeared at the center of the computer screen for 17000 ms at which time the participant attempted to name the picture;

(3) a red "X" appeared in the middle of a white screen for 4000 ms to encourage the participant to stop verbal production;

(4) the black fixation point reappeared to prepare the participant for the next trial.

Figure 3. Example of one picture-naming presentation during training probe.

Maintenance Probe Sessions. At least six weeks following the last training session, participants returned for three sessions to assess behavioral performance after training withdrawal. Each maintenance probe assessed response accuracy of the 40 trained items, along

with 20 randomly selected untrained pictures to assess generalization to untrained stimuli.

During each maintenance probe, participants were asked to name pictures as quickly as possible while maintaining accuracy. Participants were discouraged from self-correcting errors, coughing, or clearing their throats during the sessions. Target pictures were presented randomly according to the software program E-Prime. Each trial preceded as follows:

(1) a black fixation mark (*) appeared at the center of a white computer screen for 2000 milliseconds (ms);

(2) the target picture appeared at the center of the computer screen for 17000 ms at which time the participant attempted to name the picture;

(3) a red "X" appeared in the middle of a white screen for 4000 ms to encourage the participant to stop verbal production;

(4) the black fixation point reappeared to prepare the participant for the next trial.

Figure 4. Example of one picture-naming presentation during maintenance probe.

Data Collection and Analysis

Response Accuracy Data. The experimenter recorded responses verbatim during all training and probe sessions. The experimenter then reviewed 100% of the recorded probe sessions to ensure accurate transcription of participants' responses. During each session, responses were transcribed and judged for accuracy using a binary +/- system. Upon review at a later time, the experimenter coded the transcribed responses. Accurate (+) response codes 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(s) attempts with the first attempt being correct (e.g., "coffee…croffee"). Errored (-) responses were assigned an error code according to a modified taxonomy adapted from the Philadelphia Naming Test (Roach, Schwartz, Linebarger, Martin, & Bochetto, 1988). See Appendix F for an example of the coding taxonomy used in this study.

For each phase of the protocol (i.e., baseline probes, training probes, and maintenance probes), descriptive statistics including means and ranges for response accuracy were calculated. Line graphs for response accuracy were produced for each participant, depicting performance across phases of the experimental protocol for trained vs. untrained items and 1-trial/session vs. 4 trials/session items. Visual analysis of line graphs was used to interpret level, trend, variability, onset of training effects, and the magnitude of change relative to baseline performance.

Reliability Procedures. Two undergraduate students in the Communicative Sciences and Disorders department at the University of Montana, uninvolved with data collection, served as judges for this study. Prior to study involvement, judges completed all necessary HIPAA and human subject's training. Collectively, the reliability judges reviewed 100% of the audio/video-recorded probe data for all participants. The judges, while blind to the original experimenter's judgments, transcribed participant responses, using the International Phonetic Alphabet (IPA) when participants produced phonemic errors that resulted in nonwords. Judges then made a binary +/- accuracy judgment for each trial, following the accuracy rules described above. The reliability judge then assigned error codes according to the error coding taxonomy previously mentioned. All 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 for each participant. Cohen's Kappa is

used to calculate an inter-rater agreement statistic to evaluate the agreement between two

classifications on nominal or ordinal scales, while accounting for standard error.

$$Cohen's Kappa = \frac{total\ agreement - chance}{total\ responses - chance}$$

Figure 5. Cohen's Kappa equation.

Effect Sizes for Response Accuracy. To determine the amount of change in response

accuracy as a result of the research protocol, effect sizes were calculated for trained and

untrained items, as well as 1-trial per session and 4-trials per session presentation of targets.

Busk and Serlin's d^{45} compared mean performance during the maintenance phase (B) to the

mean performance during the baseline phase (A), relative to the variance (SD) observed during

the baseline phase ($d = M_B-M_A/SD_A$). This effect size calculation assumes that the variance

observed during baseline is the variance inherent to each participant before beginning treatment

(Beeson & Robey, 2005). Busk and Serlin's d^{45} does not consider performance during the

training phase. Beeson and Robey (2005) synthesized data from SLP-directed treatment studies

involving PWA to provide benchmarks for effect sizes relative to single subject design studies

investigating lexical retrieval, as displayed in Table 5.

Table 5

Lexical Retrieval Effect Sizes

Lexical Retrieval Relative to Aphasia Treatment Research	Spontaneous Recovery Effect Size	Small Effect Size	Medium Effect Size	Large Effect Size
Effect Size	0.6	4.0	7.0	9.5

These benchmarks will serve as a reference point for a discussion about effect sizes

calculated for the current study. However, repetition priming is not expected to produce effect

sizes close to those produced by the impairment-based, linguistically motivated treatments

designed to improve spoken language production for PWA, as considered by Beeson and Robey (2005). That is, the current repetition priming protocol was not designed to be a treatment study and was instead designed to investigate the learning behavior in PWA in the context of repetition priming, and to determine how stimulus dosage and intensity variables influence such priming in individuals with anomia. As the current investigation was not designed to be an overt treatment protocol, it was not expected to yield large effect sizes. Instead, effect sizes were expected to fall between the spontaneous recovery (i.e., in absence of all treatment) effect size to a small effect size.

Chapter Three: Results

Participant delivery schedule and stimulus dosage

All participants completed all phases of the protocol; however, each participant's delivery schedule was unique, resulting in variable overall dosage (see Table 6). A001 participated in three training sessions per week, for a total of nine training sessions. Over the course of the training protocol, A001 was exposed to the trained items a total of 360 times; he attempted to name the trained 1-trial/session pictures 360 times, and the 4-trials/session pictures 1440 times across the training protocol. Training probes were attempted immediately following every third training session, and immediately before every fourth training session. Two training probes were terminated due to technical difficulties and the participant completed a total of three training probes. He returned for three maintenance probes and post-treatment cognitive linguistic testing at seven weeks and eight weeks following his last training session.

A002 participated in 2-3 training sessions per week, for a total of 13 training sessions. Over the course of the training protocol, she was exposed to the trained items a total of 520 times; she attempted to name the trained 1-trial/session pictures 520 times and the 4-trials/session pictures 2080 times. Training probes were completed immediately following every third training session and immediately prior to every fourth training session, for a total of seven training probes. A002 returned for the first two maintenance probes nine weeks following completion of the training phase. Due to scheduling and travel difficulties stemming from inclement weather, the final maintenance probe was completed 19 weeks following the previous two maintenance probes.

A003 participated in three training sessions per week for a total of 15 training sessions. Over the course of the training protocol, A003 was exposed to the trained items a total of 600

times; he attempted to name the trained 1-trial/session pictures 600 times and the 4-trials/session

pictures 2400 times across the training protocol. He completed a total of nine training probes,

which occurred immediately following every third training session and prior to every fourth

training session. A003 returned for three maintenance probes and post-treatment cognitive-

linguistic testing at nine and ten weeks following completion of the training phase.

A004 participated in three training sessions per week for a total of nine training sessions.

Due to technical difficulties, he was administered five baseline probes prior to beginning the

training phase. During the training phase, he was exposed to trained items a total of 360 times;

he attempted to name the trained 1-trial/session pictures 360 times and the 4-trials/session

pictures 1440 times. A004 completed seven training probes throughout the training phase of the

protocol. A004 returned for three maintenance probes six weeks following the final training

session. Post-treatment cognitive-linguistic testing was completed 11 weeks following

completion of the training phase of the protocol. Refer to Table 6 for a summary of the

participants' stimulus dosage during the training phase of the protocol.

Table 6

Stimulus dosage by participant

	UM A001	UM A002	UM A003	UM A004
Total Training Sessions	9	13	15	9
Total Naming Attempts Trained Items (1 trial/session)	360	520	600	360
Total Naming Attempts Trained Items (4 trials/session)	1440	2080	2400	1440

Accuracy Data: Training variables

      Descriptive Statistics. Means were calculated for each participant across each phase of the protocol for trained vs. untrained items, and stimulus dosage (1 trial/session vs. 4 trials/session) relative to response accuracy. Refer to Table 7 for a summary of means.

Table 7

Means for response accuracy of trained and untrained items and stimulus dosage

		UM A001	UM A002	UM A003	UM A004
Baseline Phase	**Untrained**	89%	72%	0%	36%
	Trained	97%	62%	0%	41%
	1 trial/session	97%	48%	0%	36%
	4 trials/session	89%	77%	0%	44%
Training Phase	**Untrained**	91%	72%	3%	55%
	Trained	99%	94%	5%	80%
	1 trial/session	99%	93%	4%	80%
	4 trials/session	91%	93%	4%	80%
Maintenance Phase	**Untrained**	89%	72%	7%	59%
	Trained	100%	94%	13%	86%
	1 trial/session	100%	93%	13%	85%
	4 trials/session	89%	95%	13%	87%

      Visual analysis. Line graphs were produced for each participant to depict response accuracy across phases of the protocol (i.e., baseline, training, and maintenance probes) for trained and untrained items (see figures 6-9).

      A001. Across the four baseline probes, A001 averaged 92.1% overall response accuracy; minimal visual differences between trained (mean= 97.5%; range= 90-100%) and untrained (mean= 89.2%; range= 86-95%) items were observed during the baseline phase. During the training phase, some difference was observed between trained (mean= 99%; range= 97-100%) and untrained (mean= 91.6%; range= 86-95%) items; however, as A001's response accuracy was high for all items, significant differences were not observed. Response accuracy persisted into the maintenance phase for all items; A001 averaged 94.9% overall response accuracy, with a

larger difference in accuracy of trained items (mean= 100%) as compared to untrained items (mean= 89.3%; range= 88-91%) relative to the baseline phase (see figure 6).
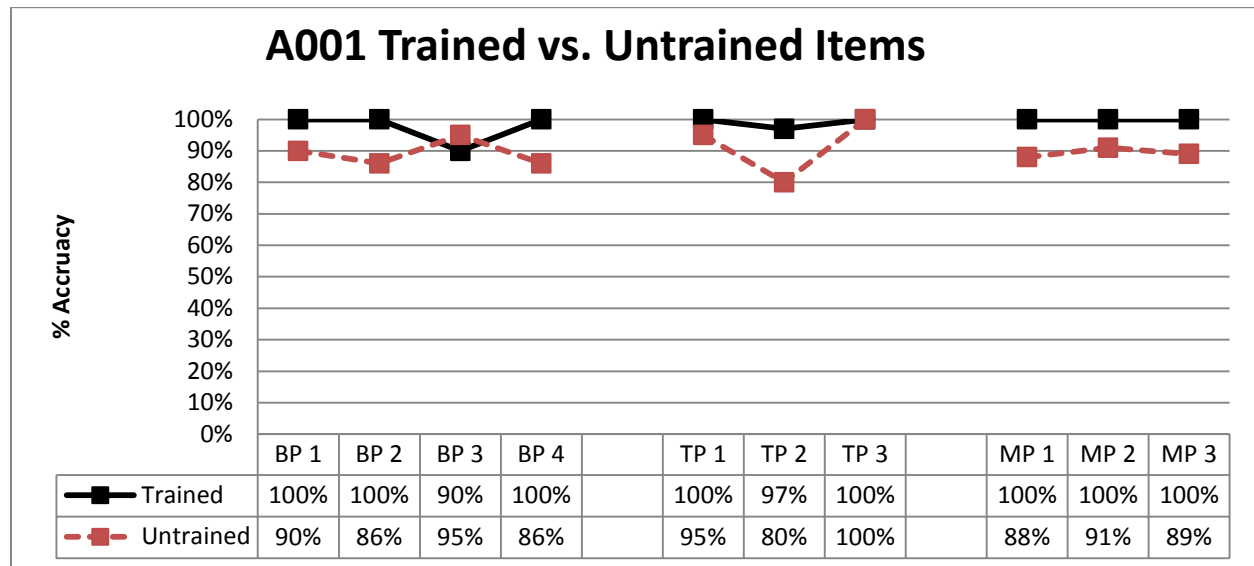

A001 Trained vs. Untrained Items

	BP 1	BP 2	BP 3	BP 4		TP 1	TP 2	TP 3		MP 1	MP 2	MP 3
Trained	100%	100%	90%	100%		100%	97%	100%		100%	100%	100%
Untrained	90%	86%	95%	86%		95%	80%	100%		88%	91%	89%

Figure 6. A001 naming accuracy for trained and untrained items across experimental phases.

A002. Across the four baseline probes, A002 averaged 67.5% overall accuracy. Trained items (mean= 62.5%; range= 42-83%) were responded to slightly less accurately than untrained items (mean= 72.5%; range= 65-75%) during the baseline phase. Upon initiation of the training phase, a large disparity between trained items and untrained items was observed via visual inspection, with trained items (mean= 93.8%; range= 90-98%) being responded to more accurately than untrained items (mean= 72.1%; range= 60-80%). A002 demonstrated a 25.5% increase, relative to baseline, for response accuracy of trained items at the time of the first training probe. After the first training probe, performance remained relatively consistent for both trained and untrained items for the remainder of the training phase. The split between trained and untrained items persisted through the maintenance phase; A002 averaged 94.3% (range= 90-98%) for trained items and 72.3% (range= 60-83%) for untrained items during the maintenance phase (see figure 7).
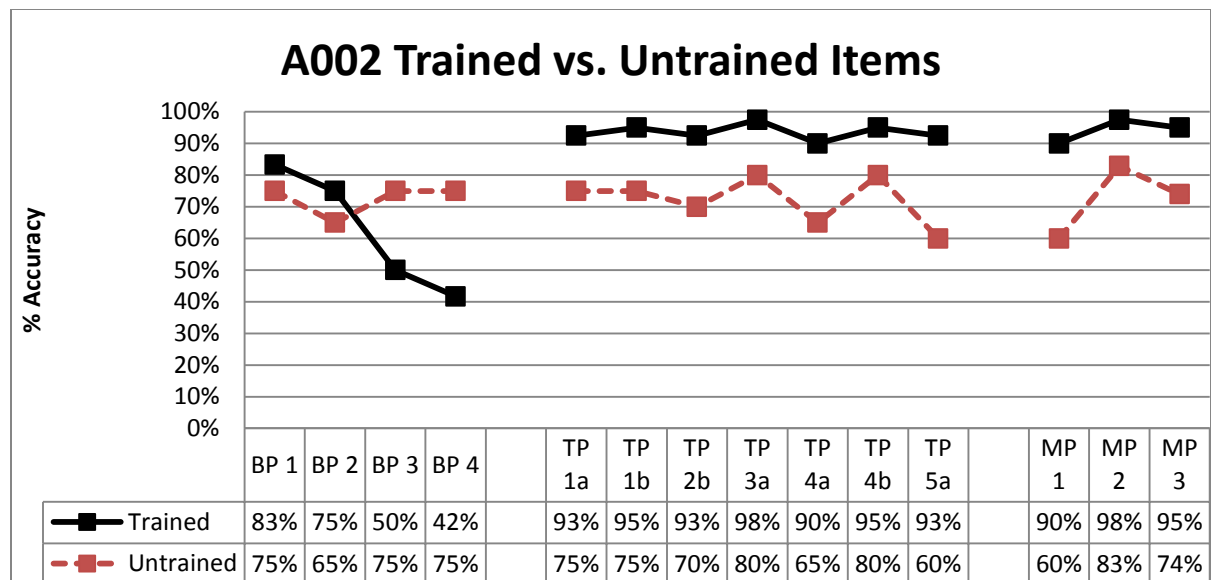
Figure 7. A002 naming accuracy for trained and untrained items across experimental phases.

A003. Across the four baseline probes, A003 averaged 0% accuracy for both trained and untrained items. With the onset of the training phase however, overall performance improved, and an immediate split occurred between trained and untrained items. During the training phase, A003 averaged 7.1% (range= 0-10%) for trained items, as compared to 2.1% (range= 0-15%) for untrained pictures. Response accuracy increases persisted into the maintenance phase for both trained (mean= 13.3%; range= 5-20%) and untrained (mean=6.6%; range= 3-11%) items, with slightly better performance visually observed for trained items during the maintenance phase (see figure 8).
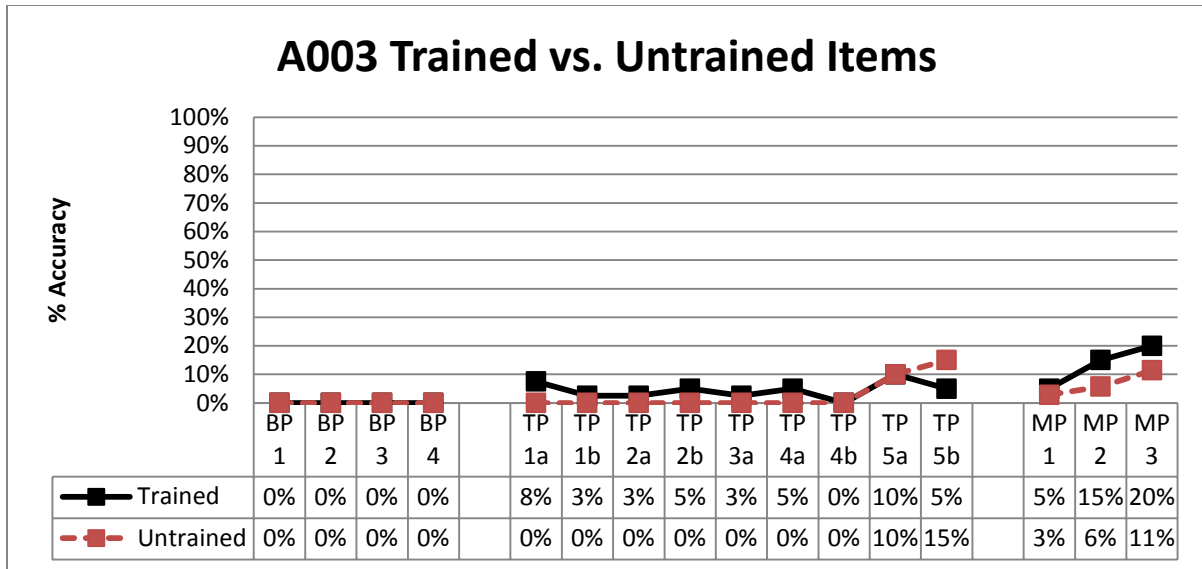
A003 Trained vs. Untrained Items

	BP 1	BP 2	BP 3	BP 4		TP 1a	TP 1b	TP 2a	TP 2b	TP 3a	TP 4a	TP 4b	TP 5a	TP 5b		MP 1	MP 2	MP 3
■ Trained	0%	0%	0%	0%		8%	3%	3%	5%	3%	5%	0%	10%	5%		5%	15%	20%
■ Untrained	0%	0%	0%	0%		0%	0%	0%	0%	0%	0%	0%	10%	15%		3%	6%	11%

Figure 8. A003 naming accuracy for trained and untrained items across experimental phases.

A004. Across the five baseline probes administered to A004, he averaged 36.7% accuracy. No consistent visual differences were observed between trained (mean= 41.2%; range= 38-42%) and untrained (mean= 36%; range= 30-45%) items during the baseline phase. Following initiation of the training phase, a substantial split between trained and untrained items immediately occurred, with trained items being responded to more accurately than untrained items. A004 demonstrated a 34% increase, relative to baseline, for response accuracy of trained items at the time of the first training probe. By the end of the training phase (i.e., the last two training probes), A004 averaged 80.5% accuracy on trained items, reflecting a 39.5% increase in response accuracy relative to baseline performance. This increase in response accuracy persisted throughout the maintenance phase; he averaged 86% (range= 80-90%) for trained items and 59% (range= 57-63%) for untrained items across three maintenance probes. Response accuracy for untrained items increased slightly and gradually during the training and maintenance phases, relative to baseline performance (see figure 9).
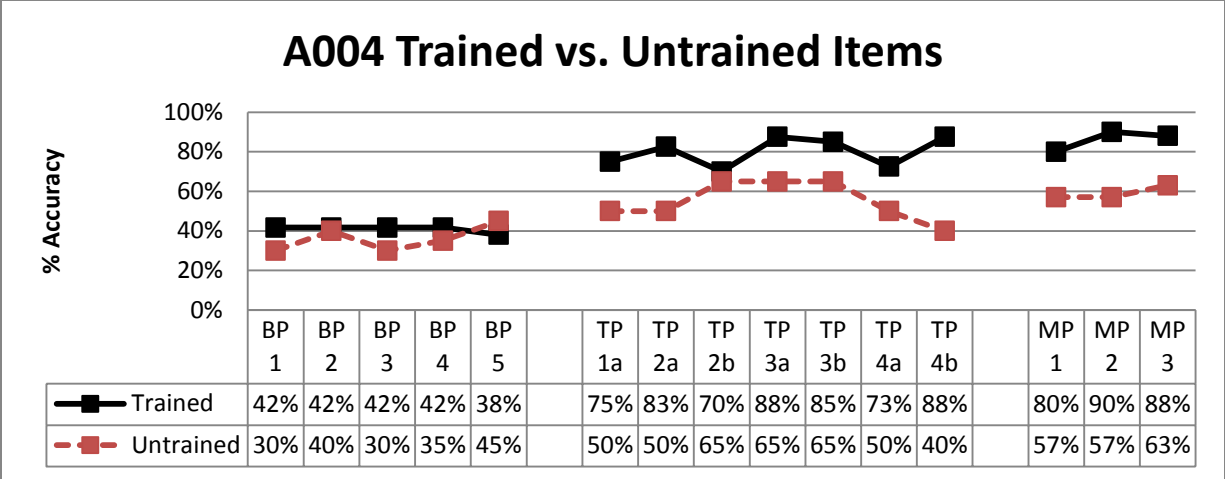
A004 Trained vs. Untrained Items

	BP 1	BP 2	BP 3	BP 4	BP 5		TP 1a	TP 2a	TP 2b	TP 3a	TP 3b	TP 4a	TP 4b		MP 1	MP 2	MP 3
Trained	42%	42%	42%	42%	38%		75%	83%	70%	88%	85%	73%	88%		80%	90%	88%
Untrained	30%	40%	30%	35%	45%		50%	50%	65%	65%	65%	50%	40%		57%	57%	63%

Figure 9. A004 naming accuracy for trained and untrained items across experimental phases.

Accuracy Data: Dosage Variables

Line graphs were produced for each participant to depict response accuracy across phases of the experimental protocol for 1-trial and 4-trials/session items (see figures 10-13).

A001. Across the four baseline probes, A001 averaged 97.5% response accuracy for trained items (range=90-100%). Trained items selected to be 1-trial/session (mean=97.5%; range= 90-100%) appeared more stable than items selected to be 4-trials/session (mean= 89.2%; range= 86-95%) during the baseline phase. During the training phase, this pattern continued; 1-trial/session targets were responded to more accurately overall (mean= 99%; range= 97-100%) than 4-trials/session targets (mean= 91.6%; range= 80-100%). 1-trial/session items were also more consistently accurate during the maintenance phase; A001 achieved 100% accuracy for 1-trial/session targets, as compared to an average response accuracy of 89.3% (range= 88-91%) for 4-trials/session items (see figure 10).
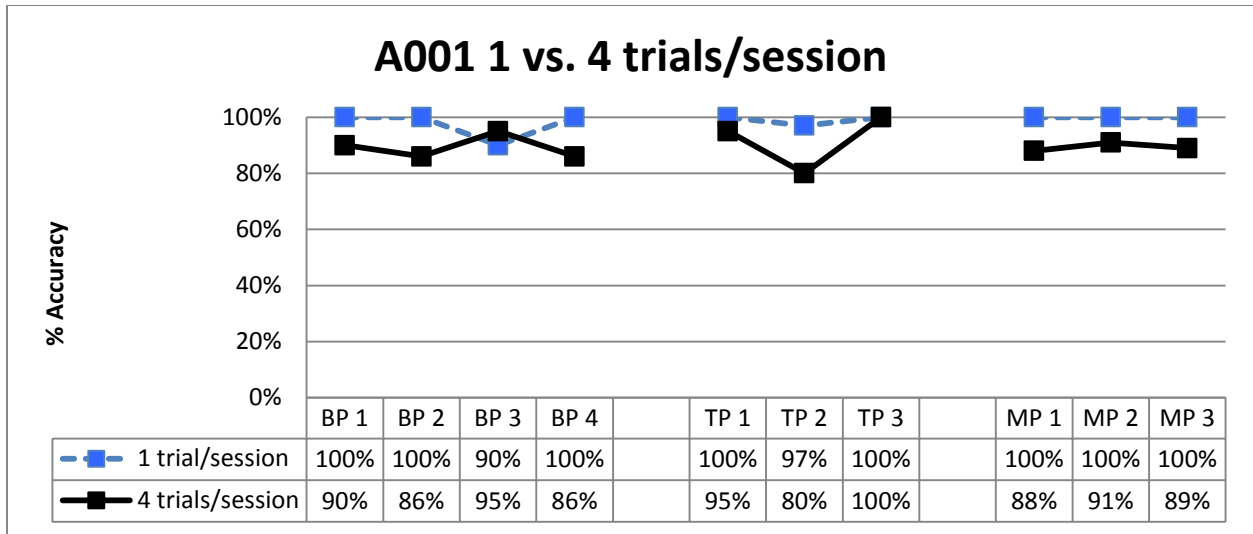
	BP 1	BP 2	BP 3	BP 4		TP 1	TP 2	TP 3		MP 1	MP 2	MP 3
1 trial/session	100%	100%	90%	100%		100%	97%	100%		100%	100%	100%
4 trials/session	90%	86%	95%	86%		95%	80%	100%		88%	91%	89%

Figure 10. A001's response accuracy for 1 vs. 4 trials per session items across experimental phases.

A002. Across the four baseline probes, A002 averaged 62.5% accuracy for trained items (range= 42-83%). During the baseline phase, trained items selected to be 1-trial/session (mean= 48%; range= 0-75%) were responded to less accurately and less consistently than those selected to be 4-trials/session (mean= 77%; range= 50-100%). Although response accuracy improved overall during the training phase, no observable differences were present during the course of the training phase for 1-trial/session (mean= 93.5%; range= 85-100) vs. 4-trials/session (mean= 93.5%; range= 85-100%) items. Her performance during the maintenance phase remained consistent; 1-trial/session items were responded to with an average of 93.3% accuracy (range= 90-100), while 4-trials/session items, on average, were 95% accurate (range= 90-100%; see figure 11).
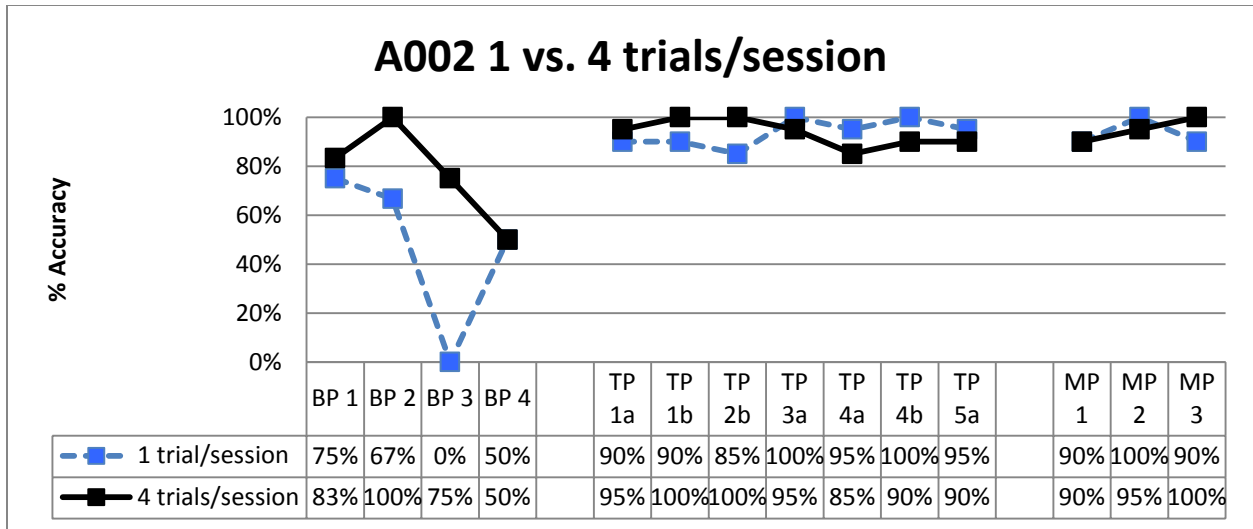
A002 1 vs. 4 trials/session

	BP 1	BP 2	BP 3	BP 4		TP 1a	TP 1b	TP 2b	TP 3a	TP 4a	TP 4b	TP 5a		MP 1	MP 2	MP 3
1 trial/session	75%	67%	0%	50%		90%	90%	85%	100%	95%	100%	95%		90%	100%	90%
4 trials/session	83%	100%	75%	50%		95%	100%	100%	95%	85%	90%	90%		90%	95%	100%

Figure 11. A002's response accuracy for 1 vs. 4 trials per session items across experimental phases.

A003. Across the four baseline probes, A003 responded to trained items with 0% accuracy. Throughout the training phase, A003 averaged identical response accuracy (mean= 4.4%; range= 0-10%) for both 1-trial/session and 4-trials/session items, with slightly more variability observed for 4-trials/session items. Similarly, response accuracy during the maintenance phase was improved from the training phase, but resulted in an identical overall average (mean= 13.3%) for 1 trial/session (range= 5-20%) and 4 trials/session (range= 5-25%) targets (see figure 12).
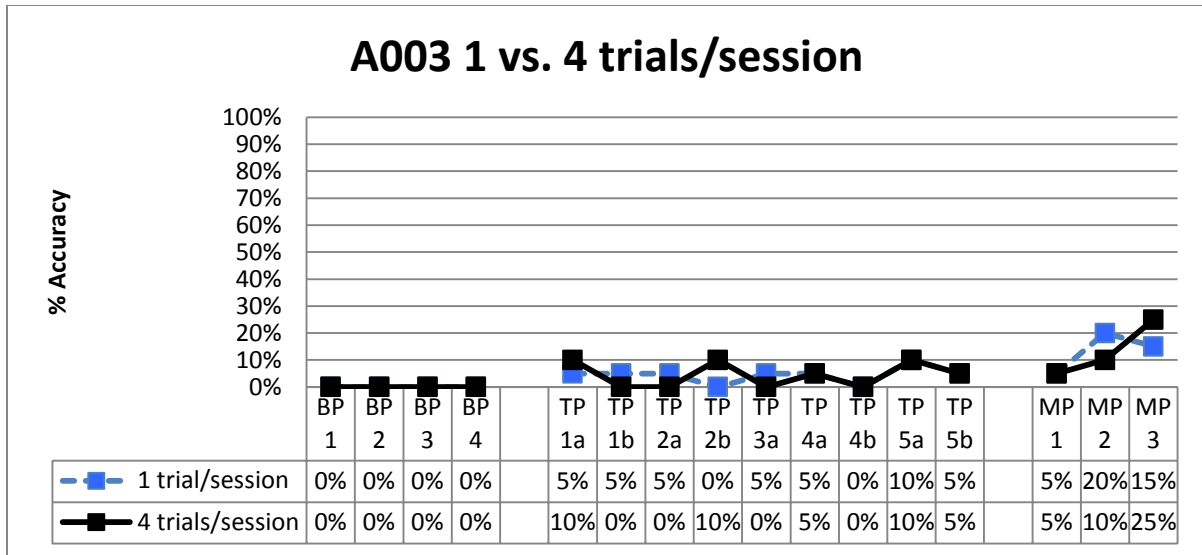
Figure 12. A003's response accuracy for 1 vs. 4 trials per session items across experimental phases.

A004. Across the five baseline probes that were administered to A004, he averaged 41.2% accuracy for trained items (range= 38-42%). During the baseline phase, an 8% difference in mean performance was observed between trained items selected to be 1-trial/session (mean= 35.6%; range= 0-50%) and items selected to be 4-trials/session (mean= 43.6%; range= 33-50%). This difference, however, appears to stem from a single 50% difference between 1-trial and 4-trials/session items at the third baseline probe. During the training phase, both 1-trial/session (mean= 80%; range= 75-90%) and 4-trials/session (mean= 80%; range= 65-90%) demonstrated a significant increase in response accuracy. During the maintenance phase, A004 achieved slightly higher response accuracy for 4-trials/session targets (mean=86.6%; range= 70-95%) than 1-trial/session targets (mean= 85%; range= 80-90%), but with significantly more variability observed for 4-trials/session items (see figure 13).
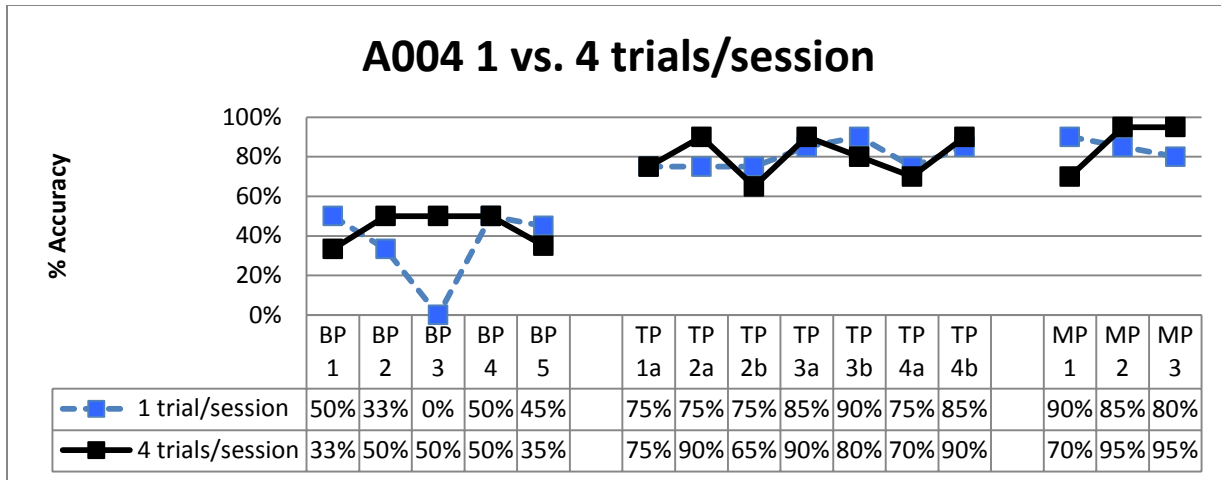
Figure 13. A004's response accuracy for 1 vs. 4 trials per session items across experimental phases.

Effect Sizes for Response Accuracy

To determine the amount of change in response accuracy as a result of the research protocol, effect sizes were calculated for trained and untrained items, as well as 1-trial per session and 4-trials per session presentation of targets. Effect sizes were calculated according to treatment benchmarks established by Beeson and Robey (2005). Refer to Table 8 for a summary of the effect sizes calculated for each participant in regard to response accuracy as influence by training status (e.g., trained vs. untrained) and stimulus dosage (e.g., 1 trial/session vs. 4 trials/session).

Table 8

Effect Sizes for response accuracy of trained and untrained items and stimulus dosage

		UM A001	UM A002	UM A003	UM A004
Effect Size: Trained Items	**Effect Size**	0.5	1.62	5.33	29.33
	Direction of Effect Size	Positive	Positive	Positive	Positive
	Size Relative to Benchmark	No change	Small	Small	Large
Effect Size:	**Effect Size**	0.012	-0.04	2.33	14.53

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Untrained Items	Direction of Effect Size	Positive	Negative	Positive	Positive
	Size Relative to Benchmark	No change	No change	Small	Large
Effect Size: 1 trial/session	Effect Size	0.5	1.63	2.66	8.79
	Direction of Effect Size	Positive	Positive	Positive	Positive
	Size Relative to Benchmark	No change	Small	Small	Medium-Large
Effect Size: 4 trials/session	Effect Size	0.012	0.86	2.66	18.78
	Direction of Effect Size	Positive	Positive	Positive	Positive
	Size Relative to Benchmark	No change	No change	Small	Large

Error Types

To examine the change in types of errors made by each of the participants across the training protocol, a visual analysis was conducted to compare maintenance probes to baseline probes. See Appendix F for the error coding judgment sheet.

A001 During the baseline phase, A001's average response accuracy was 92.1%. Of his 7.9% errors, 80% were judged to be semantic paraphasias, 10% were mixed paraphasias, and 10% were phonological paraphasias resulting in non-words. During the maintenance phase, A001 made fewer errors (mean= 5.1%) relative to baseline, and all errors were considered semantic paraphasias (see figures 14 & 15).
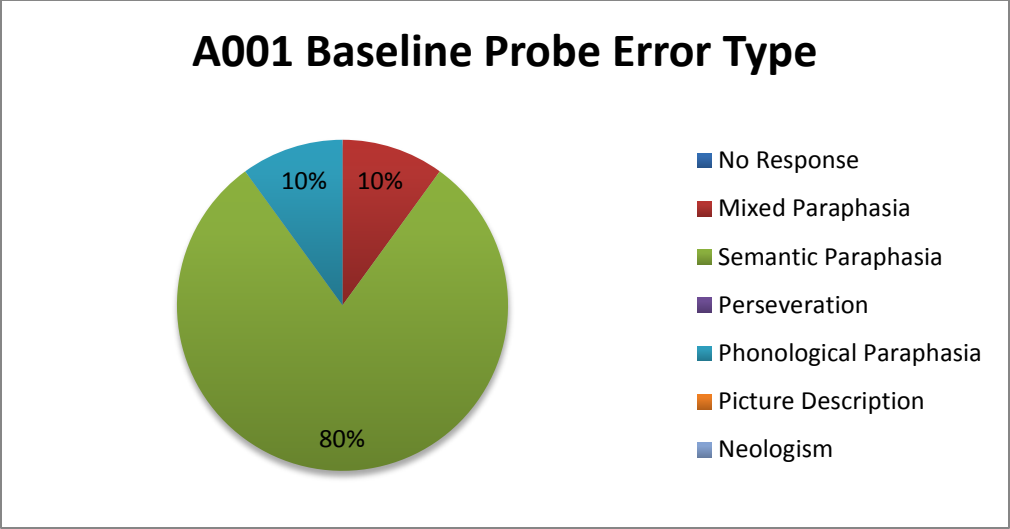
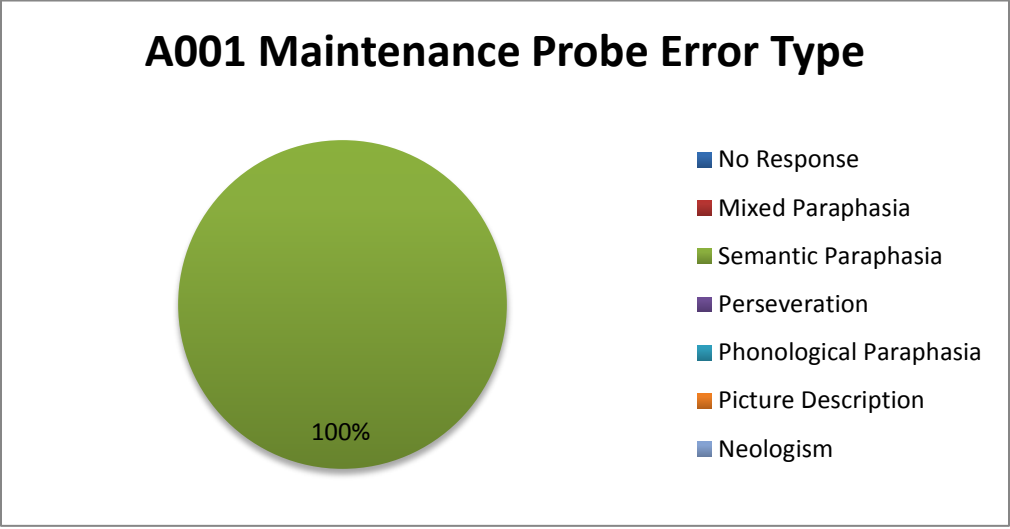Figure 14. Proportion of errors made by A001 during the baseline phase.

Figure 15. Proportion of errors made by A001 during the maintenance phase.

A002. Although A002 made a similar proportion of error types in the baseline and maintenance phases, she made fewer errors overall in the maintenance phase (mean= 16.7%) as compared to the baseline phase (mean= 32.5%). During the maintenance phase, A002 produced a lower proportion of neologisms (1%) and mixed paraphasias (6%), with a higher proportion of

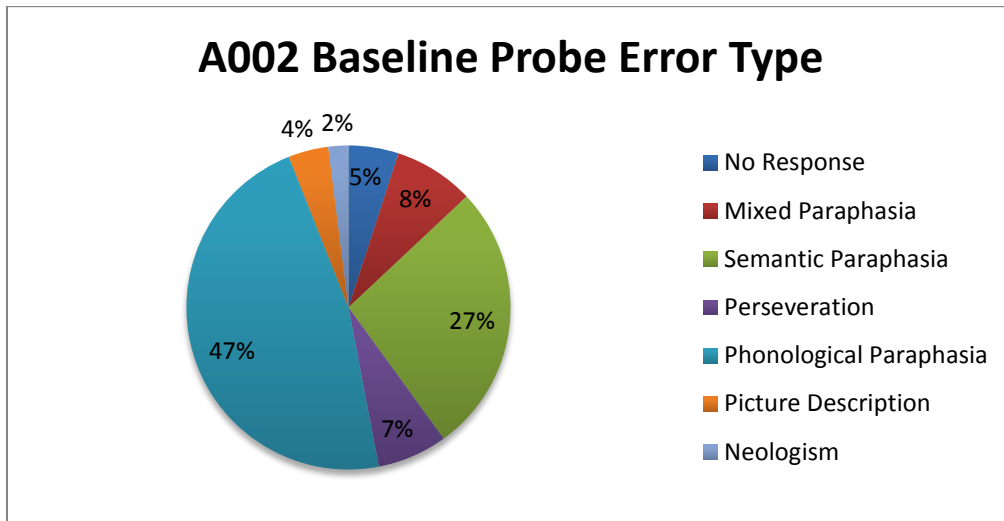phonological (57%) and semantic (29%) paraphasias as compared to baseline (see figures 16 & 17).

A002 Baseline Probe Error Type

- No Response
- Mixed Paraphasia
- Semantic Paraphasia
- Perseveration
- Phonological Paraphasia
- Picture Description
- Neologism

4% 2% 5% 8% 27% 7% 47%

Figure 16. Proportion of errors made by A002 during the baseline phase.

A002 Maintenance Probe Error Type

- No Response
- Mixed Paraphasia
- Semantic Paraphasia
- Perseveration
- Phonological Paraphasia
- Picture Description
- Neologism

1% 6% 6% 29% 57% 1%
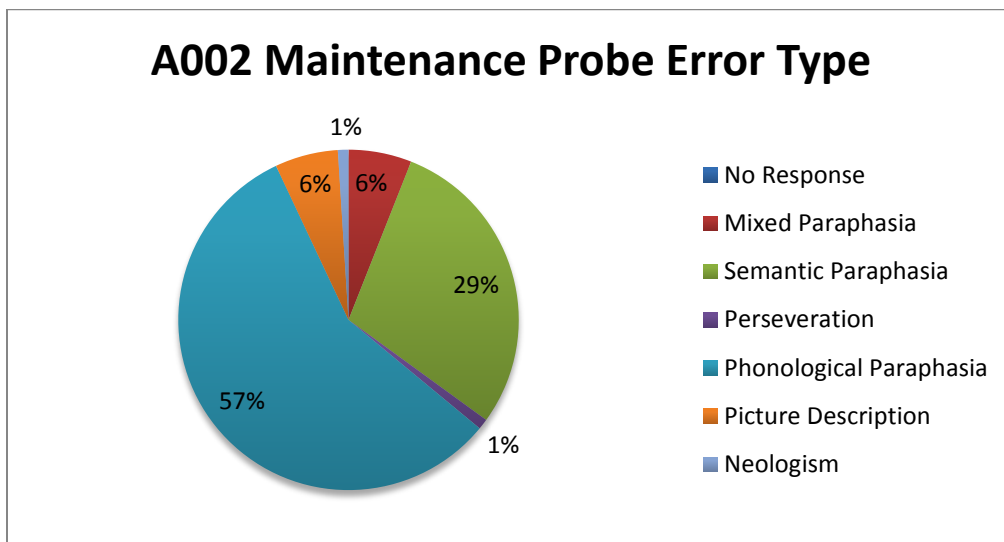
Figure 17. Proportion of errors made by A002 during the maintenance phase.

A003. A003 also made a fewer proportion of errors during maintenance probes (89.8%) compared to baseline probes (100%). A003 produced a smaller proportion of semantic paraphasias, mixed paraphasias, and a slightly smaller proportion of perseverations during the

maintenance phase. However, he produced a larger proportion of neologisms, phonological paraphasias, and non-responses during the maintenance phase relative to the baseline phase (see figures 18 & 19).
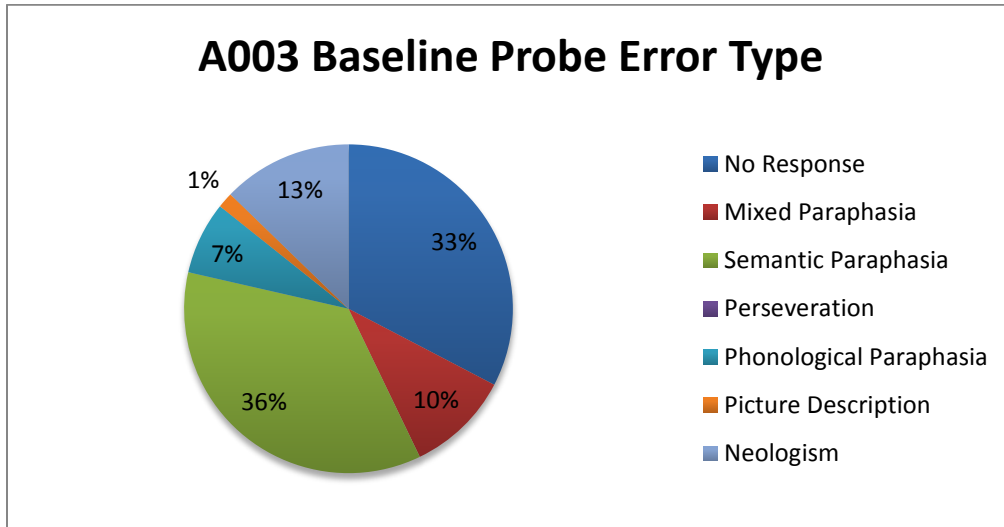

A003 Baseline Probe Error Type

- No Response — 33%
- Mixed Paraphasia — 10%
- Semantic Paraphasia — 36%
- Perseveration
- Phonological Paraphasia — 7%
- Picture Description — 1%
- Neologism — 13%

Figure 18. Proportion of errors made by A003 during the baseline phase.

A003 Maintenance Probe Error Type

- No response — 34%
- Mixed Paraphasia — 6%
- Semantic Paraphasia — 26%
- Perseveration — 6%
- Phonological Paraphasia — 6%
- Picture Description
- Neologism — 22%
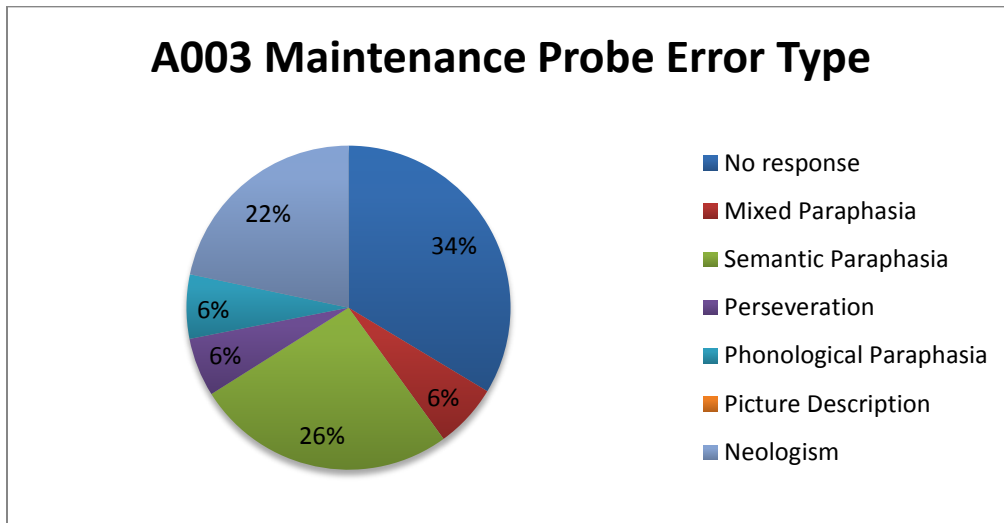
Figure 19. Proportion of errors made by A003 during the maintenance phase.

A004. A004 made significantly fewer errors during the maintenance phase (26.7%) as compared to the baseline phase (63.3%). The proportion of errors made by A004 during both

maintenance and baseline phases remained relatively consistent, with the exception of a larger

proportion of non-responses during the maintenance phase. All other error types were made at a

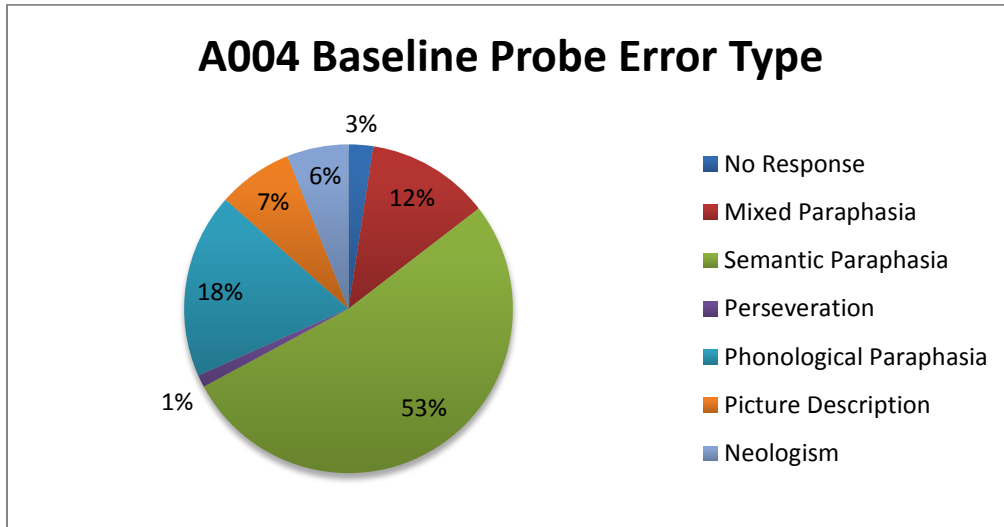lower rate during maintenance phase, relative to baseline (see figures 20 & 21).

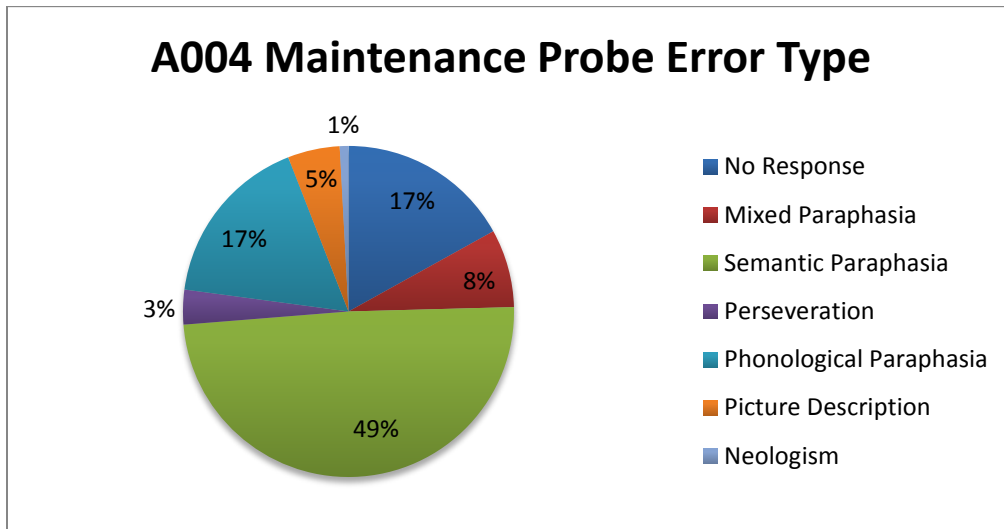Figure 20. Proportion of errors made by A004 during the baseline phase.

Figure 21. Proportion of errors made by A004 during the maintenance phase.

Training Sessions

Data for participants A002, A003, and A004 were considered for an analysis of the results of training sessions. Participant A001 was not included in this analysis as he demonstrated near-ceiling performance across training sessions.

Visual analysis: accuracy across training sessions. To examine the variability of response accuracy for trained items that occurred across training sessions, a visual analysis was completed. This analysis considered the first attempt at naming for all trained items, compared with the effect of a direct model on performance accuracy across training sessions (see figures 22-24).

Participant A002 averaged 92% (range= 81-98%) accuracy across training sessions upon initial picture presentation, which increased to 96.7% (range= 85-100%) following audio and orthographic cues (see figure 22).
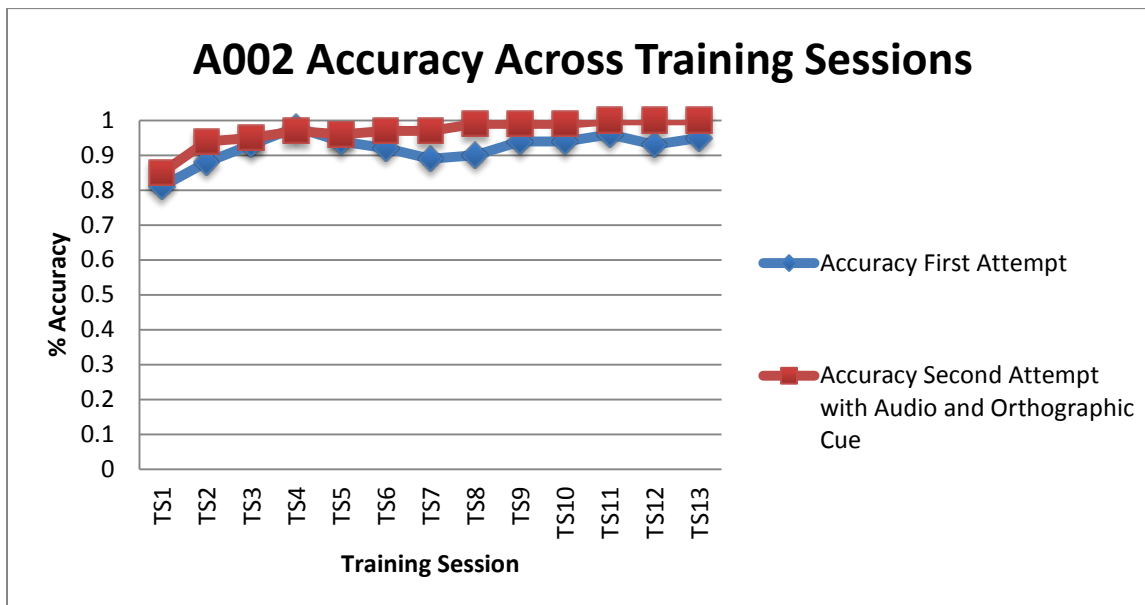

Figure 22. A002's response accuracy across training sessions with and without supports.

Participant A003 averaged 2.6% (range= 0-7%) accuracy across training sessions upon first naming attempt, which increased to an average of 48.8% (range=31-69%) following audio and orthographic cues. His increase was significant, relative to his average performance upon first naming attempt. Although he displayed difficulty without support throughout the protocol, his picture naming accuracy increased dramatically upon orthographic and audio supports; furthermore, his accuracy upon second attempt continued to increase steadily over the course of training sessions (see figure 23).
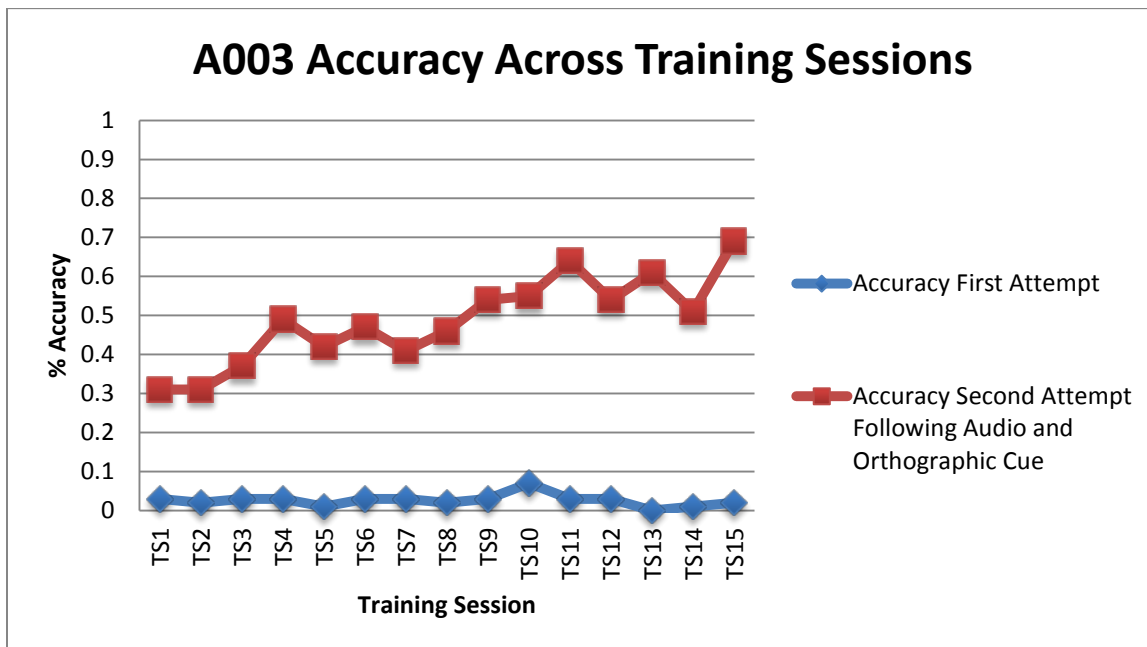

Figure 23. A003's response accuracy across training sessions with and without supports.

Participant A004 averaged 77.3% (range= 58-88%) accuracy across training sessions upon first naming attempt, which increased to an average of 92.4% (range= 82-99%) accurate following audio and orthographic cues. A004's diagnosis of conduction aphasia, and his co-morbid apraxia and dysarthria should have negatively impacted his direct model repetition skills;

however, like the other participants, his accuracy increased markedly following additional supports (see figure 24).
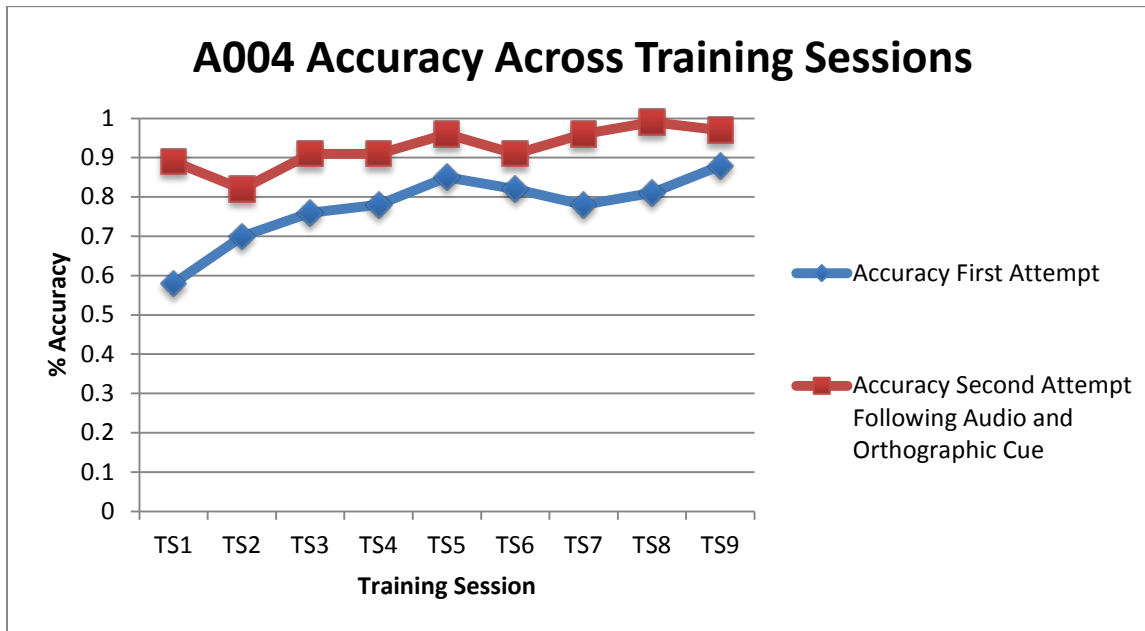

Figure 24. A004's response accuracy across training sessions with and without supports.

Stimulus dosage across training sessions. To compare the impact of within-session dosage manipulation of trained items on response accuracy, visual analysis of performance across training sessions was completed for participants A002, A003, and A004 (see figure 25). Two of the participants exhibited increased response accuracy across training sessions for 4-trials/session items as compared to 1-trial/session items. A002 demonstrated slightly higher accuracy across training sessions for 4-trials/session items (average= 93.1% accurate) as compared to 1-trial/session items (average= 87.6% accurate). Similarly, A004 demonstrated a slightly higher response accuracy average for 4-trials/session pictures (average= 79.1%) in comparison to 1-trial/session pictures (average= 70.1%). A003 exhibited no difference across training sessions between 1-trial/session items compared to 4-trials/session items (average= 2.6%).
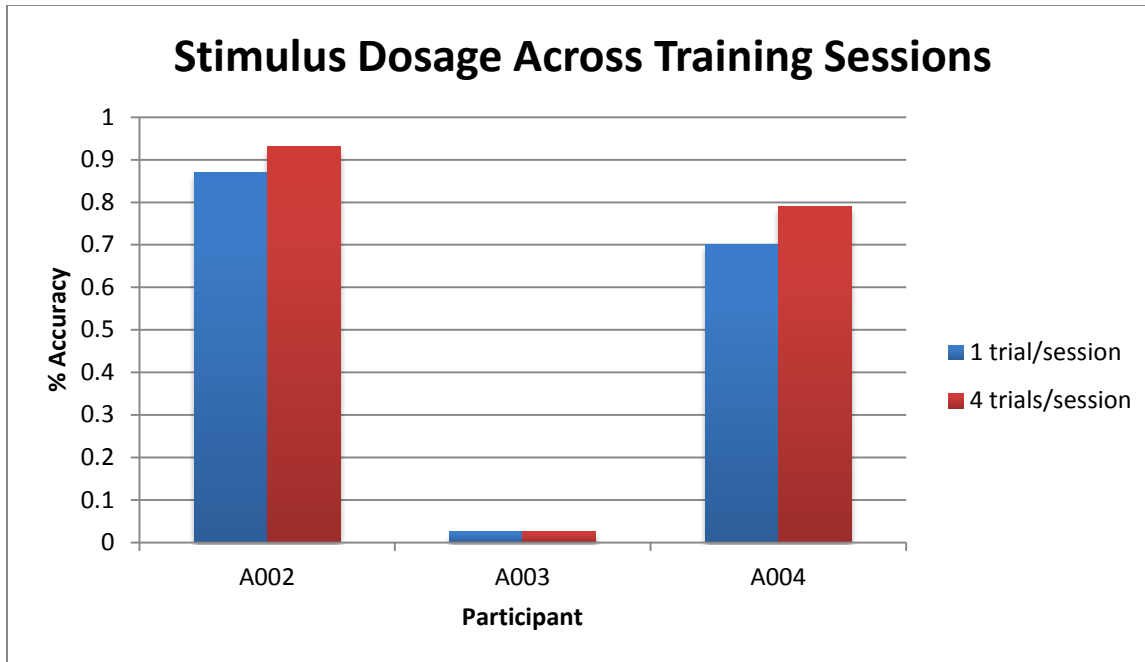
Figure 25. Participant accuracy for dosage manipulation (i.e., 1 trial/session vs. 4 trials/session) across training sessions.

Lexical variables across training sessions: word frequency. To consider lexical variables including word frequency, visual analysis was conducted to examine participant performance on words that occur frequently in the English language, compared to words that occur less frequently (see figure 26). Participants A002, A003, and A004 all performed better on high frequency words as compared to lower frequency words. A002 averaged 97.2% accuracy on high frequency words, and 86.6% on low frequency words across training sessions. A003, on average, responded to 4.5% of high frequency words accurately over training sessions, while he averaged only .6% accurate for low frequency words. A004 followed this trend as well, averaging 87.7% accurate for high frequency words, as compared to 66.8% accurate for low frequency words.
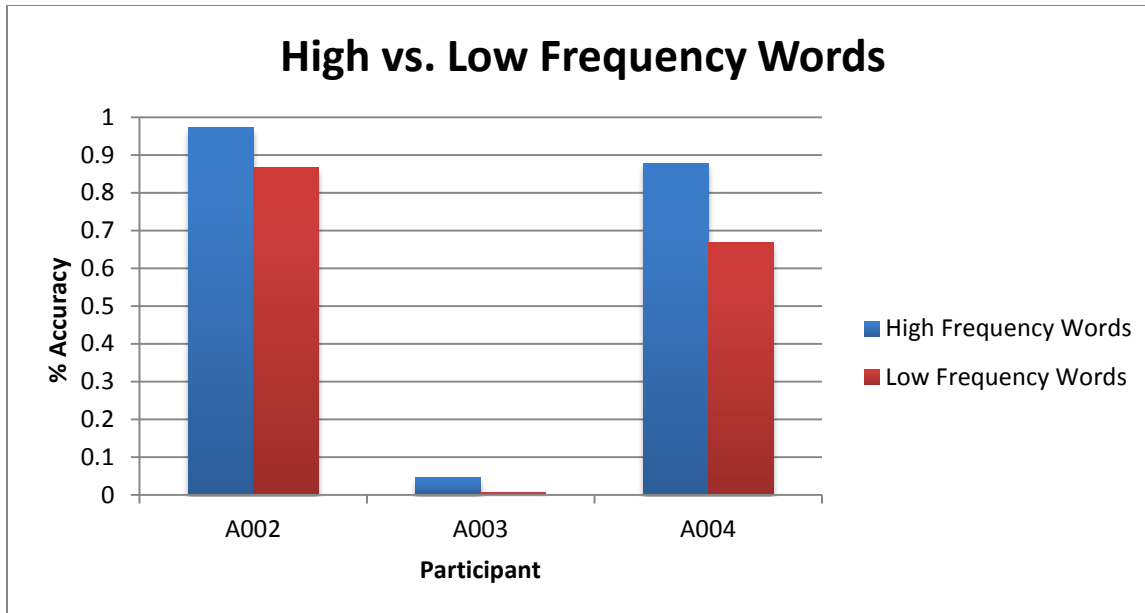
High vs. Low Frequency Words

Figure 26. Response accuracy for high vs. low-frequency words across training sessions.

Lexical variables across training sessions: word length. To examine the effect of word length (i.e., 1 vs. 2 syllables) on participant performance, visual analysis was conducted for A002, A003, and A004 (see figure 27). Participant A002 performed slightly better across training sessions for one-syllable words (average= 94.3%) than she did for two-syllable words (average= 89.8%). A004 also demonstrated higher response accuracy on shorter words over training sessions; averaging 84% accurate for one-syllable words, and 70.6% accurate for two-syllable words. In contrast, A003 averaged slightly lower picture naming accuracy for one-syllable words (average= 1.5%) versus two-syllable words (average= 3.7%).
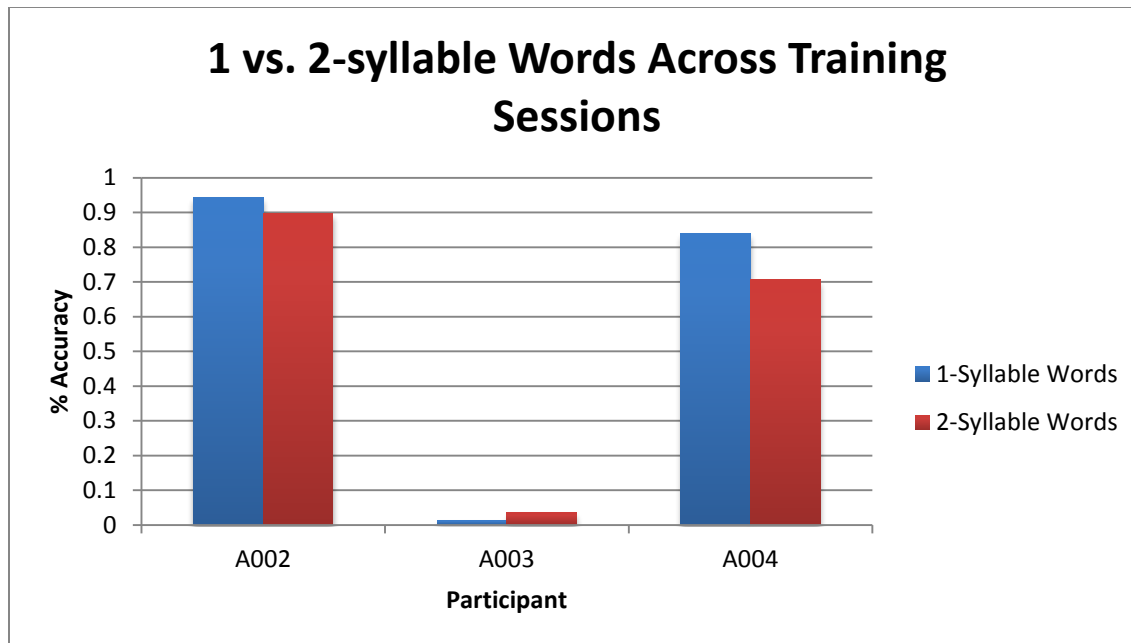
Figure 27. Response accuracy for word length variables (i.e., 1 syllable vs. 2 syllable words) across training sessions.

Reliability

The undergraduate judge responsible for reliability reviewed all probe data, transcribed participant responses, and made binary accuracy judgments of participant responses, while blind to the original experimenter's accuracy judgment. Cohen's Kappa was used to calculate inter-judge reliability for the binary accuracy judgment between the original experimenter and reliability judge for each participant.

Reliability results have been calculated for one participant thus far, A002. After accounting for standard error, inter-rater reliability between the original experimenter and the reliability judge was calculated to be 0.92. This reliability rating is denoted as *very good*, the strongest possible rating of agreement (see Appendix G; Fleiss, Levin, & Paik, 2003). Reliability ratings for the remaining participants have not yet been calculated.

Post-study cognitive-linguistic testing

A sub-set of the cognitive-linguistic battery was re-administered to participants at the completion of the study to assess general language change across modalities (see Appendix D). This subset included portions of the Western Aphasia Battery-Revised (WAB-R) necessary to calculate the Aphasia Quotient (AQ), the Boston Naming Test (BNT), and subtest 54 of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA). See Table 9 for post-protocol assessment results.

Participant A001 was not re-administered the WAB-R, as he achieved a nearly perfect score upon initial administration. His scores on the BNT and the PALPA improved slightly to perfect scores, indicative of no confrontational naming impairment. Participant A002 improved her WAB-R AQ score by three points, and markedly increased her scores on the BNT and the PALPA. Improvements seen on these assessments, particularly the BNT and the PALPA, indicate that A002 experienced generalization of picture naming skills to new, untrained targets. The researcher opted not to re-administer the WAB-R to participant A003 following protocol completion, as he exhibited significant difficulty with evaluation upon the first WAB-R administration. A003's scores on both the BNT and the PALPA increased from 0% accuracy on both assessments to 5% and 10%, respectively. Participant A004 demonstrated markedly improved scores across all three assessments, adding 7.5 points to his WAB-AQ score, and doubling his scores on both the BNT and the PALPA. Scores on A003's BNT and PALPA changed from moderate level of severity to mild level of severity.

Table 9

Results of post-treatment testing at least 6 weeks following completion of protocol

	UM A001		UM A002		UM A003		UM A004	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
WAB-R AQ	99.6	*DNT	76.2	79.2	37.1	*DNT	59.0	66.5
BNT	59/60	60/60	28/60	45/60	0/60	3/60	27/60	52/60
PALPA	59/60	60/60	44/60	52/60	0/60	6/60	21/60	58/60

*DNT= Did not test

Chapter Four: Discussion

The purpose of the current study was to document the behavioral effects of mere repetition on naming accuracy among individuals with anomia. It also aimed to directly and systematically investigate the influence of dosage on naming performance. Results of this single-subject ABA design with replication across participants indicate that repetition priming positively influences response accuracy for PWA.

Summary of Results

Training phase relative to baseline phase. Based upon results reported in the previous section, all four participants demonstrated an increased ability to accurately name pictured during the training phase relative to baseline naming performance. The participants did not share underlying linguistic impairments, and their severity level varied from minimal to severe speech and language deficits. Participant A001's anomia was minimally present; A002's anomia was characterized by phonemic and occasional semantic paraphasias; A003's anomia was characterized by frequent neologisms and non-responses; and A004's anomia was characterized primarily by a phonological encoding impairment likely to stem from conduction aphasia and co-morbid apraxia and dysarthria.

Training phase: acquisition. Although all four participants demonstrated improved response accuracy during the training phase relative to the baseline phase, the onset and rate of improved response accuracy varied from participant to participant. A001 performed at near-ceiling levels for trained items throughout the baseline and training phases; thus, will not be included in this portion of discussion. A002, A003, and A004 all demonstrated significantly increased response accuracy for trained items after the first set of three training sessions; that is,

the onset of increased response accuracy was observed at the first training probe, demonstrating immediate acquisition.

The magnitude of change observed following immediate acquisition varied across participants. A002 improved from 42 to 93% accurate for trained items from the fourth baseline probe to the first training probe; A003 improved from 0 to 8% accurate for trained items during this time span; and A004 improved from 38 to 75% accurate for trained items upon administration of the first training probe.

The consistency of improved response accuracy also varied across participants. Participant A002 demonstrated rapid improvement for trained items following induction of the training phase; followed by relatively steady performance across training probes, ranging from 90-98% accuracy, and the same response accuracy for trained items (93%) on the first and last training probe. A003 demonstrated improved but inconsistent response accuracy throughout the training phase. He demonstrated the largest number of errors during training sessions; yet despite his significant difficulty with the protocol, the repetition priming protocol eventually led A003 to an increased ability to name trained items, suggesting that thresholds for the onset of repetition priming may differ as a result of the underlying impairment. Participant A004 demonstrated a somewhat variable but relatively steady increase in response accuracy across the entire training phase.

Persistence of repetition priming. All individuals with aphasia demonstrated persistence of repetition priming for response accuracy of trained items after training had been withdrawn for at least six weeks. Although this persistence is observable by visual inspection for each participant, the most compelling data are the effect sizes that directly compare maintenance probe performance to baseline probe performance while adjusting for the variance inherent to

each participant. Effect sizes for response accuracy of trained items ranged from 0.5 (no change) to 29.33 (large change). Participant A004 exhibited the largest effect size for trained items (d=29.33), which, according to Beeson and Robey's (2005) benchmarks reflect a large change in response accuracy. Participant A001, who was at near ceiling levels during baseline, did not demonstrate a significant effect size (d=0.5) for trained items.

Untrained items followed this pattern as well. All four PWA demonstrated positive effect sizes associated with untrained items during the maintenance phase relative to the baseline phase. A001 again demonstrated the smallest increase in response accuracy for untrained items, with an effect size of 0.012 (no change), while A004 demonstrated the largest change for untrained items, with an effect size of 14.53 (large change). As previously discussed, the substantial change for both trained and untrained effect sizes is relatively surprising, given that the benchmark for effect sizes is based upon direct treatment studies addressing lexical retrieval in PWA (Beeson & Robey, 2005). Mere repetition priming, in the absence of a treatment protocol designed to target the underlying linguistic impairment, was not expected to lead to effect sizes comparable to those obtained in direct treatment studies.

Within-session dosage sensitivity. Upon visual inspection, the stimulus dosage variable (i.e., 1 trial/session vs. 4 trials/session) did not consistently influence naming performance during the protocol. All participants demonstrated improved performance across phases for both 1 trial/session and 4 trials/session trained items. Effect size calculation revealed that A001 demonstrated a smaller effect size for 4 trials/session items (d=0.012; no change) vs. 1 trial/session items (d=0.5; no change). A002 demonstrated slightly higher effect size for 1-trial/session items (d= 1.63; small change) as compared to 4-trials/session items (d= 0.86; no change). In fact, the effect size calculated for 1-trial/session targets would have likely even more

disparate were it not for response accuracy of 0% for 1-trial/session items on the third baseline probe. A003 demonstrated identical effect size calculations for both dosage variables (d=2.66; small change), while A004's naming accuracy did appear to be influenced by stimulus dosage, as he demonstrated a larger effect size for 4 trials/session (d=18.78; large), as compared to 1trial/session targets (*d*=8.79; medium).

Overall, within-session dosage manipulation appears to elicit inconsistent results for PWA in regard to response accuracy. One possible explanation for the lack of observable difference between 1 trial/session vs. 4 trials/session items may be the large number of repetitions attempted by each participant by the time the first probe session occurred. Three training sessions occurred prior to the first probe session, in addition to the four baseline probes during which trained items were probed. Collectively, the participants had already attempted to name each of the 1-trial/session items 10 times, and each of the 4-trials/session items a total of 28 times at the time of the first training probe. Results suggest that the additional attempts may be unnecessary to elicit additional change in naming accuracy. That is, the intensive nature of the protocol may be sufficient in producing effective repetition priming. Four repetitions within a session may even contribute to fatigue, particularly in individuals with concurrent apraxia or dysarthria. Frustration and/or fatigue may contribute to a decrease in response accuracy for the 4-trials/session items within a session. Future investigations should examine the within-session variability in response accuracy for the 4-trials/session items. That is, future investigations should examine the first naming attempt each training session in contrast to second, third, and fourth attempt to better understand the influence of the stimulus dosage variable on repetition priming for PWA.

Lexical variables. To consider lexical variables including word frequency and word length, an analysis across training sessions was conducted for participants A002, A003, and A004. As expected, all three participants performed better on high frequency words as compared to low frequency words. Improved performance on high frequency words relative to low frequency words may be due in part to the underlying semantic representations of objects, and a stronger association to words that occur more frequently in the English language. An examination of word length revealed that A002 and A004 demonstrated higher response accuracy on one-syllable words, relative to two-syllable words. A003, however, demonstrated slightly higher response accuracy for two-syllable words as compared to one-syllable words. This result was unexpected; A003 was expected to have a lower response accuracy average for two-syllable words because of co-morbid moderate apraxia. However, A004 also experienced moderate apraxia, yet still did slightly better on two-syllable words as compared to one-syllable words. These differences are likely attributable to individual participant variables.

Post-protocol cognitive-linguistic testing. Results achieved by participants on post-treatment cognitive-linguistic evaluation indicate that additional skill learning did occur, and improvements manifested in other confrontational naming tasks (as evidenced by score increases on the BNT and the PALPA), and for the two participants who were assessed, appeared to elicit some transference across language modalities, as observed by increases on the WAB-R.

Post-protocol changes cannot be exclusively attributed to this experimental protocol, as participants continued to receive speech and language services throughout the protocol, provided treatment not be focused on naming. A substantial amount of time passed between initial and final assessment phases, which may have also contributed to score changes. However, results for

all participants improved markedly, providing behavioral evidence that neuroplastic changes occurred, resulting in improvements across language modalities.

Conclusions

The purpose of this investigation was to document the behavioral effects of mere repetition on naming accuracy, and to systematically investigate the influence of dosage on response accuracy among individuals with aphasia. The results of this study indicate that individuals with aphasia respond positively to repetition priming for response accuracy. Results of this investigation support many of the principles of neuroplasticity as described by Kleim and Jones (2008):

1. Use it or lose it: this protocol did not utilize a control group; no functional decline in absence of training was able to be systematically observed. However, this protocol did require intensive activation of neuronal pathways for confrontational naming tasks, which provides possible implications for this principle.

2. Use it and improve it: results obtained from this protocol indicate that all participants experienced marked improvements in response accuracy for naming tasks, directly correlated to repetition and use.

3. Specificity: repetition priming, by definition, reflects item-specific learning. Trained items were item-specific, and were responded to at a greater proportion of accuracy than untrained items.

4. Repetition matters: as the primary component of this study, repetition provided a means to produce improvements in response accuracy across participants with a variety of underlying linguistic impairments.

5. Intensity matters: by nature, this protocol was intense. Participants spent an average of four hours per week completing this protocol, and were required to attend to stimuli for at least one hour each session.

6. Time matters: this protocol was designed to address individuals in the chronic stage of recovery (months to years following CVA), and was not designed to examine time post onset relative to performance. In fact, the participant who demonstrated the largest gains was the furthest post onset (240 months post-CVA). Individual variables likely had more to do with effects observed than time post onset. Based on this limited sample of individuals, repetition priming does not appear to be particularly sensitive to the time of delivery relative to time post onset of aphasia.

7. Salience matters: All individuals enrolled in this study considered anomia to be of significant negative impact on their language. Picture stimuli contained a previously developed corpus of common concrete nouns. Thus, a protocol specifically designed to address picture naming, especially with frequently encountered concrete nouns, was particularly salient to all study participants.

8. Age matters: This protocol was not designed to examine participant age variables relative to repetition priming outcomes. Participants' ages ranged from 55-70, and underlying cognitive-linguistic impairments appeared to have a greater effect on performance than did participant ages.

9. Transference: Throughout acquisition and maintenance phases, participants demonstrated larger effect sizes associated with trained items compared to untrained items. This finding was consistent with previous findings documented in the literature; repetition priming is, by definition, item specific and is not expect to elicit skill learning. Positive effect sizes

for untrained items were nevertheless observed in all four participants. Although effect sizes were not equivalent to those observed for trained items, effect sizes for untrained items were still present, which suggests some level of transference did occur during the protocol. In addition, all participants anecdotally reported positive changes that expanded beyond the naming protocol and into spontaneous verbal speech. Post-protocol cognitive-linguistic testing showed language improvements, not exclusive to picture naming, for all four participants as measured by a small battery of standardized assessments.

10. Interference: Participants were not encouraged to discontinue traditional speech and language services. The experimenter did not consult with the participants' primary speech and language clinicians; thus, it is not known what level of interference into other areas of language may have occurred while participants completed the experimental protocol.

The current investigation has demonstrated that these principles of neuroplasticity are essential in designing future anomia treatment protocols. Individual participant variables (i.e., age, site and severity of lesion, type of aphasia, etc.) contribute to participant progress; however, it is likely that if a number of these principles of neuroplasticity are systematically implemented, SLPs treating anomia may observe significant changes in a relatively short amount of time. Changes demonstrated by participants during this experimental protocol were substantial, and persisted following removal of practice.

Future Directions

This investigation, by nature of design, contained a remarkable amount of data. There are many future analyses that should be conducted to further investigate the preliminary information gained from the protocol. Future analyses may include:

1. Analyze training data in greater detail to look at the pattern of errors within and across training sessions.

2. Assess the within-training session variability in response accuracy for the 4-trials/session items.

3. Assess lexical variables (i.e., word frequency, word length, etc.) over probe sessions.

4. Examine error types across training sessions.

5. Analyze error types across baseline and maintenance phases in greater detail.

6. Complete similar protocol using imaging technology to correlate observed behavioral changes with structural changes.

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The University of Montana Subject Information and Informed Consent

Title: Investigation of Repetition Priming and Individuals with Anomia

Project Director(s):

<u>**Principle Investigator**</u>
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Jenna Griffin – Graduate Student Researcher
Melanie Rosenthal – Undergraduate Student Researcher
Molly Jones – Undergraduate Student Researcher
Jesse Engen – Undergraduate Student Researcher

<u>**Special instructions**</u>
We want you to be in a research study.
This form will help you decide if you want to do this.
Please read this form carefully.
We can read and/or summarize this form for you if your reading is impaired.
You may ask questions.
You can decide **yes** or **no** to be in the study.
We will give you a copy of this form to take home.

<u>**PURPOSE OF STUDY**</u>
We want to learn about people who have speech, language, and/or cognitive-communication problems because of having a stroke or traumatic brain injury. Many stroke or traumatic brain injury survivors have speech and/or language difficulties that reduce their ability to communicate

during their daily activities. Speech-language pathologists work with people with aphasia to help them with their communication.

The purpose of this study is to learn more about the processes that occur in our brains during intensive and repetitive speech and language rehabilitation. We are hopeful that this knowledge will help speech-language pathologists provide the optimal amount of practice for people with speech and language impairments following a brain injury.

PROCEDURES

We would like to ask your permission to use information about your speech and language that was already collected by The University of Montana Neurogenic Communication Disorders Registry and Repository. This data will help us to understand what types of speech and/or language difficulties you have. We will also use information about yourself that you provide. If you agree to participate in this study, you will:

   (1) Fill out a questionnaire about personal and medical history;
   (2) Have your hearing and vision checked;
   (3) Have your speech, language, and thinking skills tested (if you have not already done so);
   (4) Complete pre-experimental baseline probes: 4-5 sessions on separate days; each session will last 1-2 hours;
   (5) Participate in experimental sessions: Name many pictures from a computer screen with a lot of repetition during each session 2-4 times per week for up to 5 weeks;
   (6) Return for follow-up testing 3 times approximately 3 weeks after the last day of the experiment and then another 3 times approximately 6 weeks following the last day of the experiment;
   (7) *No* payment will be offered, but we can give you your test results.
   (8) You will be video- and audio-taped during the testing sessions so that we have an accurate record of your responses.

The questionnaire and screening will take about 10-20 minutes to fill out. The speech, language, and cognitive testing will take 1-2 sessions; each session will last approximately 2-4 hours. The study will take place in Missoula, MT at The University of Montana RiteCare Speech, Language, and Hearing Clinic, located in Curry Health Center on the Lower Level. If you are unable to come to The University of Montana we can do the hearing/vision screening, and speech, language and thinking testing at your home. Each experimental session will last between 1 and 2 hours. You will be able to take breaks during each session. We would like you to name pictures from a computer screen as quickly as possible. We would like to measure how long it takes you to respond. We will have you wear a microphone placed comfortably on your head so we can take measurements. You will wear headphones during the experimental sessions to reduce background noise and, in some instances, to allow you to hear the names of the pictures. Following the completion of the experiment, we ask that you come back so we can assess how well you have maintained your ability to name pictures. We would like you to come in 3 times approximately 3 weeks after the last experimental session and then another 3 times approximately 6 weeks after the last experimental session. We will also do some more speech and language testing on two separate occasions during these follow-up visits. Some of these exercises will be the same as the exercises done in the first two pre-experimental testing sessions. Each of these post-experimental sessions will last between 1 and 2 hours.

RISKS/DISCOMFORT

Some people do not like to be audio- or video-taped.

Some people feel uncomfortable when they are tested.

Some people get tired when they are tested or during intensive and repetitive practice. You may take as many breaks as you need during the testing.

If you tell us about plans to hurt yourself, we will notify the appropriate people (like your doctor or family). If so, you will not be able to be in the study.

BENEFITS

We hope the results of this study will lead to important changes in how we provide treatment for persons with communication disorders stemming from stroke and traumatic brain injury.

Although we hope the findings from this study will benefit society, you may not directly benefit from taking part in the study.

CONFIDENTIALITY

Your records will be kept private and will not be released without your consent except as required by law.

Only the researchers and authorized authorities will have access to the files.

Your identity will be kept confidential.

If the data from this study are written in a scientific journal or scientific meeting, your name will not be used.

The data will be stored in a locked file cabinet; digital data will be password-protected and stored in the researcher's office/lab on a computer work-station.

Your signed consent form will be stored in a locked cabinet separate from the data.

We want to audiotape and videotape your speech, language, and thinking during testing. This will give us a record of what happens, so we can go back to it later and transcribe what happened. The audiotapes and videotapes will be transcribed without any information that could identify you. The tape(s) will be kept forever with your ID code as the only identifier.

COMPENSATION FOR INJURY

Although we do not foresee any risk in taking part in this study, the following liability statement is required in all University of Montana consent forms.

In the event that you are injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of The University of Montana or any of its employees, you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title 2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the University's Risk Manager or Office of Legal Counsel. (Reviewed by University Legal Counsel, March 23, 2012).

VOLUNTARY PARTICIPATION/WITHDRAWL

Your decision to take part in this research study is entirely voluntary.

You may refuse to take part in or you may withdraw from the study at any time without penalty or loss of benefits to which you are normally entitled.

You may leave the study for any reason.
You will be asked to leave the study for the following reasons:

- If you tell us about plans to hurt yourself;
- The Principle Investigator thinks that it is in the best interest of your health and welfare; or
- The study is terminated.

QUESTIONS

You may wish to discuss this with others before you agree to participate in the study.
If you have questions about the research now or during the study, contact: Catherine Off, (406) 243-2104.
If you have any questions regarding your rights as a research subject, you may contact the Chair of the IRB through The University of Montana Research Office at 243-6670.

STATEMENT OF CONSENT

I have read the above description of this research study, and this study has been explained to me.
I have been informed of the risks and benefits involved.
I have had a chance to ask questions; all my questions have been answered to my satisfaction.
I have been assured that any future questions I may have will also be answered by a member of the research team.
I volunteer to take part in this research.
I understand I will receive a copy of this consent form.

_____   _____

Printed Name of Participant/Participant's Representative   Signature of Participant/Participant's Representative

_____   _____

Date   Relationship of Representative

STATEMENT OF CONSENT TO BE AUDIOTAPED/VIDEOTAPED

I understand that audio- and video-recordings may be taken during the study.

I consent to being audio- and/or video-recorded.

I consent to use of my audio- and/or video-recordings in presentations related to this study.

I understand that if audio-/video-recordings are used for presentations of any kind, names will not be associated with them.

I understand that audio-/video-recordings will be transcribed, and that no identifying information will be included in the transcription.

I understand that audio-/video-recordings will be physically or digitally stored in a locked or password-protected manner with no names associated with them information. These recordings will be kept forever.

_____   _____

Participant's Signature/   Date
Signature of Participant's Representative

_____   _____

Participant's Printed Name/Participant's Representative   Relationship of Representative

University of Montana Approval IRB #151-12

The University of
Montana

INSTITUTIONAL REVIEW BOARD
for the Protection of Human Subjects in Research
FWA 00000078

Research & Creative Scholarship
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Date: October 1, 2012

To: Catherine Off, CSD
             Annie Kennedy, CSD

From: Dan Corti, IRB Chair

RE: IRB 151-12: "Investigation of Repetition Priming and Individuals with Anomia"

Your IRB proposal cited above has been **APPROVED** under **expedited review** by the Institutional Review Board in accordance with the Code of Federal Regulations, Part 46, section 110. Expedited approval refers to research activities that (1) present no more than minimal risk to human subjects, and (2) fit within the following category for expedited review as authorized by 45 CFR 46.110 and 21 CFR 56.110:

4.   Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)
Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject=s privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

All consent forms used for this project must be date-stamped and signed by the IRB. Use the PDF sent with your approval notice as a "master" from which to make copies.

Amendments: Any changes to the originally-approved protocol must be reviewed and approved by the IRB *before* being made (unless extremely minor). Requests must be submitted using Form RA-110.

Unanticipated or Adverse Events: You are required to timely notify the IRB if any unanticipated or adverse events occur during the study, if you experience an increased risk to the participants, or if you have participants withdraw from the study or register complaints about the study. Use Form RA-111.

Continuation: Federal and University of Montana IRB policy requires you to file an annual Continuation Report (Form RA-109) for expedited studies. You must file the report within 30 days prior to the expiration date, which is September 30, 2013. *Tip: Put a reminder on your calendar now.* A study that has expired is no longer in compliance with federal or University IRB policy, and all project work must cease immediately.

Study Completion or Closure: Finally, you are also required to file a Closure Report (Form RA-109) when the study is completed or if the study is abandoned. See the directions on the form.

Please contact the IRB office with any questions at (406) 243-6672 or email irb@umontana.edu.

Appendix C

Aphasia Study Information Form for Individuals with Aphasia

Purpose of research: The researchers want to learn about how intensive, repetitive practice impacts your ability to communicate.

What you would do:
- Come to The University of Montana RiteCare Speech, Language, and Hearing Clinic
- Complete speech, language, and cognitive testing – this may take place across two sessions; speech therapists will help you with the tests; each session will last between 2 and 4 hours; you may take as many breaks as you need.
- Experiment: name pictures on a computer screen with a lot of repetition for approximately 1-2 hours per day, 2-4 times per week for up to 5 weeks or when you stop making progress.
- Return for follow up practice of picture naming several times 2-6 weeks after the end of the experimental protocol.
- Re-take some speech, language and cognitive tests at the end of the protocol.

Risks to you:
- Getting tired. We can take breaks.
- Feeling upset because questions ask about problems with aphasia. You do NOT have to answer any question you do not want to answer.
- Confidentiality. We use a secret code to identify your data. We will not use your name.

How this relates to UM Big Sky Aphasia Lab:
- We would use data from your aphasia assessment with Dr. Off
- Otherwise, this study is not related to other research with Dr. Off

Other information:
- Participation is voluntary. You do not have to participate if you do not want to
- You can stop at any time if you want to

Contact Person:
Catherine A. Off, PhD (Speech therapist and researcher)
Phone: 406-243-2104
Email: Catherine.off@umontana.edu (we cannot guarantee confidentiality of email)

Post-treatment Assessment Sheet

POST-TREATMENT ASSESSMENT SUMMARY SHEET

	Test	Score (Pass)	Pass/Fail
1	Western Aphasia Battery (WAB)	Aphasia Quotient =	
2	The Boston Naming Test (BNT)	Raw Score = __/60	
3	Subtests of the Psycholinguistic Assessment of Language Processes in Aphasia (PALPA)	Picture Naming by Frequency (Subtest 54): Raw Score = __/60	

Recruitment Flyer

STROKE AND BRAIN INJURY RESEARCH
We need YOUR Help!

Who is doing the research?
The Department of Communicative Sciences and Disorders at The University of Montana.

What is the research about?
How repetitive, frequent practice improves speech and language impairments stemming from stroke or brain injury.

What is involved?
- Participants will be asked to participate in a preliminary screening (including a brief biographical & medical questionnaire, and hearing and vision screening); testing of speech, language, and cognition; and multiple experimental sessions across several weeks.
- The preliminary screening should last approximately 1 hour and will take place separately from testing and the experimental sessions.
- Testing of speech, language, and cognition should last approximately 2-8 hours, which may be split across 2 sessions (within one day or across two separate days).
- During experimental sessions, participants will be asked to quickly name pictures as they appear on a computer screen.
- Participants will be asked to complete 4-5 pre-experimental baseline probes, each on separate days. Each probe session will last 1-2 hours.
- Participants will be asked to attend 2-4 training sessions per week for a maximum of 5 consecutive weeks or until they no longer show improvement (which may be less than 5 weeks). Each session will last between 1 and 2 hours. Participants will be asked to return 3 times approximately 6 weeks after the experimental protocol ends.
- Participants will be asked to complete speech and language tests 3 weeks and 6 weeks following the last training session to assess overall speech and language changes.
- Participation is completely voluntary and can be stopped at any time.

Who can participate?
- Adults between the ages of 18-90 years old who had an onset of aphasia with the presence of anomia at least 3 months ago with no subsequent decline.
- No known history of psychiatric conditions, substance abuse, or cognitive changes due to degenerative conditions.
- Corrected (e.g., glasses, contacts, hearing aids) to normal hearing and vision.
- Native speakers of American English

How can I learn more?
- Contact Catherine Off, Assistant Professor, at The University of Montana, (406)243-2104 or catherine.off@umontana.edu. We cannot guarantee the confidentiality of information sent by email.

Appendix F

Error Coding Taxonomy

Error Description	Error Code	Example
I. Accurate		
	A. Target only	
	B. Filler + target	um, uh, a, the
	C. Multiple correct productions	"mattress mattresses"
	D. Multiple productions the first	"bra bravere"
II. Errored		
	A. No response or "I don't	
	B. Mixed	
	i. Phonological + semantic	/dan/ for /kæt/
	ii. Phonological + unrelated	/flon/ for /kæt/
	C. Semantic	
	i. Unrelated word	"shoe" for "cat"
	ii. Supraordinate word	"mammal" for "cat"
	iii. Coordinate word	"dog" for "cat"
	iv. Subordinate word	"siamese" for "cat"
	v. Related adjective	"white" for "milk"
	vi. Related verb	"drink" for "milk"
	vii. Unrelated phrase	"See the boy" for "cat"
	D. Perseveration	Produces any previously
	E. Phonological	
	i. Omission	/æt/ for /kæt/
	ii. Substitution	/kɪt/ for /kæt/
	iii. Addition	/kræt/ for /kæt/
	iv. Nonword	
	F. Picture description	"a woman washing dishes"
	G. Neologism	
	i. Neologistic word	"shumpter"
	ii. Neologistic phrase	"pigmo brasel"

Appendix G

Strength of Inter-rater agreement using Cohen's Kappa*

Value of k	Strength of Agreement
< 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very Good

* = Adapted from Fleiss, Levin, and Paik (2003).