STAGES OF RECOVERY IN INDIVIDUALS WITH DEEP TO PHONOLOGICAL DYSPHASIA: INSIGHT INTO TREATMENT APPROACHES

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ABSTRACT

The presented dissertation grew out of the need to achieve a better understanding of the relationship between language processing and short-term memory (STM) in persons with aphasia (PWA). Deep dysphasia and phonological dysphasia form a classification of aphasia identified by a pattern of speech errors attributed to chronic verbal STM impairment. Exploring evidence demonstrating the pattern of speech errors mediated by STM impairment in PWA, research objectives were three-fold:

- To add to the knowledge base on deep dysphasia and phonological dysphasia and extend the characteristic presentation of this;
- To determine the characteristic profile of recovery in deep dysphasia, providing further evidence that deep dysphasia is an impairment that exists at the most severe point along a continuum of recovery which in milder form demonstrates phonological dysphasia.
- To evaluate the efficacy of treatment approaches developed on the basis of Dell and O'Seaghdha's (1992) two-step interactive activation model of word production and using repetition to improve verbal STM and word processing.

First, a comprehensive systematic review of the deep dysphasia and phonological dysphasia literature base was conducted. This review addressed the paucity of case studies reporting the diagnoses of dysphasia. Studies investigated individuals with chronic STM impairment in the auditory modality as well as other characteristic markers of deep and phonological dysphasia, such as an imageability effect. In repetition tasks, an imageability effect indicates that concrete (high-image) words are repeated with greater ease when compared to accuracy in the repetition of abstract (low-image). The review supported the

hypothesis that these profiles reflect a chronic impairment of auditory-verbal STM existing on a continuum of severity. Evidence from this review supports the hypothesis that deep dysphasia and phonological aphasia are two points on a continuum of an impairment mediated by verbal STM (Martin, Saffran & Dell, 2006, Willshire & Fisher, 2004).

Second, with the insights from this review, a single-subject multiple-baseline, multiple-probe treatment study was undertaken. The participant LT presented with a pattern of repetition consistent with the continuum of deep-phonological dysphasia, including an imageability effect in repetition (Martin et al., 1996, Wilshire & Fisher, 2004). This treatment approach sought to directly remediate language and short-term memory abilities using a repetition task targeting imageability effect. In order to improve access to and repetition of low-image (LI) words, this approach aimed to enhance semantic context. Results of this study indicate improving LT's access to abstract word pairs improved verbal STM as well as language processing.

Third, the single-case study led to the development of a four-condition, multi-participant facilitation study that aimed to improve access to and repetition of LI words by embedding them in a context that enhanced their imageability. The goal of this manipulation was to increase the probability of accessing lexical and semantic representations of abstract words in repetition by enriching their semantic-syntactic context. Ten participants with chronic impairment in verbal STM demonstrated that this approach participants' ability to repeat those words when presented in isolation.

Evidence from PWA has confirmed that a damaged language processing system includes disruption to STM (Martin & Saffran, 1992; Martin et al., 1996; Martin &

Saffran, 1997; Martin & Saffran, 1999; Martin & Ayala, 2004; Kalinyak-Fliszar, Kohen, & Martin, 2011; Allen et al., 2012). Recent investigations have provided evidence that STM tasks can be used as mechanisms to improve language processing (Kalinyak-Fliszar et al., 2011; Salis, 2012; Berthier et al., 2014). Despite the central role repetition plays in functional communication and the difficulties PWA encounter with repetition due to STM impairment, few treatment approaches have targeted STM and the language processes supporting repetition (Martin, Kohen, & Kalinyak-Fliszar, 2010; Kalinyak-Fliszar, 2011; Berthier et al., 2014). This dissertation research filled that void and demonstrated the promise of clinical approaches that directly target language processing and auditory verbal STM impairment in PWA.

DEDICATION

To my parents, who taught me that the greatest privilege is knowledge
and raised me with values that continue to define my purpose in life.

My mother has been my enigma, she moves with the grace
of a formally trained dancer, speaks with the intellect
of a college professor, and has maintained the
most unshakeable belief in my potential.

My father has been my tender pillar of guidance,
I remain in awe as he humbly solves intricate
state accounting matters with the same ease
he strums the chords of a blues guitar riff.

Your love is responsible for this and every accomplishment I have achieved.

ACKNOWLEDGMENTS

This dissertation has been a labor of love. It would have remained a distant dream if not for the support of the people dearest to me and the courage of the persons with aphasia who participated in this research. It is of utmost importance to express my sincere gratitude to the members of my doctoral committee. My advisor, Dr. Nadine Martin, has been an inspiration with her lifelong commitment to improving the field of Aphasiology research on a global scale. Dr. Jamie Reilly's insights made me dig deeper. Dr. Mary Purdy from Connecticut offered thoughtful comments. I would also like to thank Michalene Kalinyak-Fliszar and Francine Kohen, my colleagues within the Eleanor M. Saffran Center for Cognitive Neuroscience, and my many other mentors, within and outside Temple University, who encouraged me to pursue a career in scientific research.

While pursuing this doctorate, I have worked as a visiting home health-care speech and language pathologist. From my patients, I have received countless words of encouragement. I am grateful to all the persons with aphasia who have enhanced my understanding of this field of research. I extend my deepest gratitude to the individuals who enthusiastically volunteered their time and efforts to participate in my research study.

My little brother Michael became my rock during the course of this program. Thank you for always picking up the phone, always telling me to stop what I am doing, put on my sneakers, and go for a run, "like an adult." Five marathons and over twenty half-marathons later, my favorite races will always be the ones we run together. I will always be grateful to my mother and father, who together embody all that I wish to become. The day my parents and brother helped me

move here, we made one stop. For the remainder of the drive, a seven-week-old puppy slept in the palm of my hand. In the seven years that have followed I have never been far

rom the pure, unconditional love of a special dog named Walter. Under the Philadelphia skyline, I found the love of my life. Brad, you have opened my heart wider than I thought possible. You selflessly have carried me through illness and have had more faith in me than I have had in myself. I can’t wait to marry you.

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CHAPTER 1
INTRODUCTION

The Role of Repetition in Communication and Language Processing

This dissertation research focused on repetition as a means of remediation of language processing and verbal short-term memory (STM) in persons with aphasia (PWA). Repetition is a fundamental building block of everyday communication (Tannen, 1989). Within conversation, repetition has many functions. It has been characterized as a basic support process in conversation (Wallace, Dietz, Hux & Weissling, 2012). A qualitative study by Hengst, Duff, and Dettmer (2010), viewing the role of repetition through a sociocultural lens, found that participants meaningfully reinforced one another's conversational contributions. Other studies have concluded that repeated engagement promoted both learning and memory as well as deeper communicative meaning (Francis, Clark, & Humphreys, 2003; Hengst et al., 2010; Berthier et al., 2014). The integrity of any conversational exchange can be compromised by impaired repetition. Insights drawn from communication disorders caused by repetition impairment have led to increased interest in the relationship between language processing and verbal STM in PWA (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Dell, Martin, & Schwartz, 2007; Martin & Saffran, 1997).

Aphasia is an acquired neurogenic communicative disorder characterized by impairment in language processing (McNeil & Pratt, 2001). Cerebrovascular accident (CVA) has been established to be the most common cause of aphasia (Lutz & Camicia, 2016), as well as the leading cause of long-term disability globally (Lundström, Smits, Borg, & Terént, 2014). Døli, Helland, and Andersen Helland (2016) reported that following CVA roughly fifty percent of individuals presented with emotional disorders such as depression or anxiety. The damage that impaired communication causes is exceptionally devastating. Aristotle famously opined that "man is by nature a social creature" (as cited in Lewis, 2004). A sudden disruption in one's social capabilities has a profoundly negative impact on quality of life, and in an investigation of sixty diseases aphasia outranked dementia, quadriplegia, HIV, and cancer in its negative effects (Lam & Wodchis, 2010).

Much of this impact is due to the communication impairment characteristic of aphasia: impaired expression, comprehension, reading and writing will limit social interactions (McNeil & Pratt, 2001). In PWA with verbal STM impairment the consequent inability to repeat words or phrases makes participating in conversational interactions difficult (Baldo, Katseff, & Dronkers, 2012). Indeed, in one of the earliest theoretical models of aphasia, Lichtheim (1885) proposed the use of repetition as one of many diagnostic tools in aphasia . Since then, repetition impairment has been well documented in case studies of aphasia (Geschwind, 1965; Warington & Shallice, 1969; Kertz & Benson, 1970; Shallice, & Warrington, 1975; Saffran & Martin, 1990; Martin & Saffran, 1990; Berndt & Mitchum, 1990; Martin & Saffran, 1997).

Historical Frameworks

Past investigators once recognized STM as a capacity that could be isolated from language processing (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Baddeley, 1986a, 1986b). Span tasks requiring the repetition of several words were conducted as studies of STM rather than language processing (Dell et al., 2007). Repetition is defined by the authors as an immediate and effortless task for normal speakers. Dell and colleagues (2007) reasoned that this automaticity may explain why early models of language processing and STM were developed and investigated separately.

In the early 1990's, error patterns in the repetition of PWA were first investigated as an impairment in the processes that mediate language processing and maintenance of information in STM. A deficit in repetition was characterized as being influenced by the ability to maintain access across levels of language representation (Saffran, 1990; Martin & Saffran, 1990; Berndt & Mitchum, 1990). These initial studies became the frame of an influential theoretical model that greatly improved the understanding of language processing in aphasia. This model, known as the activation-maintenance hypothesis (Martin & Saffran, 1997), was an extension of the interactive activation (IA) model of language processing (Dell, 1986; Dell & O'Seaghdha, 1992). Consistent with the assumptions of the original IA model, Martin and Saffran (1997) concurred that language took place across a time-course, but for the first time also addressed STM processing as part of the underlying impairment in PWA. Their activation maintenance hypothesis of language processing assumed that the processes that mediated language function, activation spread and activation decay, also made possible the maintenance of information in verbal STM (Martin & Saffran, 1997).

It is now widely accepted that damaged language processing systems invariably include disruption to verbal STM in PWA (Martin et al., 1996; Martin & Saffran, 1997; Martin & Saffran, 1999; Martin & Ayala, 2004; Kalinyak-Fliszar, Kohen, & Martin, 2011; Allen et al., 2012). Verbal STM can be due to an underlying impairment in phonological or semantic processing. The deep dysphasia and phonological dysphasia population presents with pervasive impairment of auditory-verbal STM due to impaired phonological processing, particularly in repetition. Although other subcategories of aphasia indeed include verbal STM deficits, those which composite phonological scores indicate a reliance on the higher levels of processing (Martin & Saffran, 1997). The most compelling evidence of the involvement of STM in language processing comes from error patterns in deep to phonological dysphasia (Butterworth & Warrington, 1995; Martin et al , 1996; Majerus & Van der Linden, 2001; Ablinger, Abel, & Huber, 2008). Despite the critical role repetition plays in communication, few treatment approaches developed for PWA have targeted STM and language processes (Martin, Kohen, & Kalinyak-Fliszar, 2010; Kalinyak-Fliszar et al., 2011; Berthier et al., 2014; Salis, Kelly, & Code, 2015). Studies using repetition within treatment methods have, however, reported that targeting the activation and maintenance of representations for repetition led to generalized gains in other areas of phonological as well as semantic language processing abilities (Francis et al., 2003; Schwartz et al., 2006; Kalinyak-Fliszar et al., 2011; Salis, 2012; Berthier et al., 2014). et al., 2011; Salis, 2012; Berthier et al., 2014).

Purpose of the Dissertation

Through an investigation of speech error patterns caused by damaged STM in PWA, the objectives of this dissertation research were three-fold:

- To add to the knowledge base on deep dysphasia and phonological dysphasia and extend the characteristic presentation of this ;

- To determine the characteristic profile of recovery in deep dysphasia, providing further evidence that deep dysphasia is an impairment that exists at the most severe point along a continuum of recovery which in milder form demonstrates phonological dysphasia.
- To evaluate the efficacy of treatment approaches developed on the basis of Dell and O'Seaghdha's (1992) two-step interactive activation model of word production and using repetition to improve verbal STM and word processing.

The functional relationship between language processing and STM as extended to the IA model (Martin & Saffran, 1997) served as the theoretical framework for this research. To best understand how the rehabilitation of STM can be improved, the subcategory of aphasia most closely identified as demonstrating a marked deficit in STM was studied. Treatment approaches in deep-phonological dysphasia have not been considered by researchers. A key objective of this dissertation research was to provide evidence that a damaged language processing system can be repaired directly through the context of an auditory-verbal STM task.

Approaches to Deep Dysphasia in the Literature

Deep dysphasia is a rare subcategory of aphasia first identified by Michel and Andreewsky (1983). The authors proposed this diagnostic label to identify individuals who demonstrated patterns in repetition analogous to the error patterns in reading associated with deep dyslexia (Morton, 1980; Goldblum, 1981). The hallmark features of repetition in deep dysphasia and reading in deep dyslexia are greater accuracy on words than nonwords (lexicality effect), greater accuracy for high-image than for low-image words (imageability effects), and the occurrence of semantic errors in single-word reading or repetition (Howard & Franklin, 1988; Katz & Goodglass, 1990; Martin & Saffran, 1992). Critically, case studies of deep dysphasia have shown that profoundly reduced auditory-verbal STM capacity was the underlying cause of error patterns (Katz & Goodglass, 1990; Martin & Saffran, 1992; Trojano, Stanzione, & Grossi, 1992; Martin, Dell, Schwartz, Saffran, & Gagnon, 1994; Butterworth & Warrington, 1995; Martin, Saffran, & Dell, 1996; Majerus & Van der Linden, 2001; Ablinger, Abel, & Huber, 2008; Tuomiranta et al., 2014). The profoundly reduced auditory-verbal STM capacity was attributed to a rapid decay of the phonological representation (Katz & Goodglass, 1990) or both the phonological and semantic representations of the word to be repeated (Martin, et al., 1996).

The seminal case of MR, Michel and Andreewsky (1983) used the influential logogen model of word processing (Morton & Patterson, 1980) to account for the deficit pattern in this syndrome. In this model, input can be auditory via the spoken word or visual via the written word; interaction between levels in the model is assumed. Within this model, Michel and Andreewsky postulated that deep dysphasia resulted from disruption of the sublexical input-output phoneme route and in the connection from input auditory to output logogens. In analyzing their case study of MK, Howard and Franklin (1988) also invoked the logogen model and postulated two loci of impairment to account for MK's repetition pattern (imageability effects, semantic errors and inability to repeat nonwords): the sublexical route and the direct lexical route between the auditory input lexicon and the phonological output lexicon. These two impairments left only a semantic route to support repetition of words. According to this hypothesis, semantic representations of words activated by input phonological and lexical activation supported activation of output word forms in the output lexicon.

Other researchers have proposed involvement of auditory-verbal STM in deep dysphasia. For example, Katz and Goodglass (1990) reported a case study of SM, who presented with a deep dysphasia pattern of word repetition. The authors proposed that impairment of phonemic memory affected word repetition and developed a box and arrow model to explain three possible routes of word repetition (1990). This model suggests that word repetition impairment could be due to impairment in three possible routes of word repetition: (1) a non-semantic route where word form is affected, (2) a nonlexical route to explain word and nonword repetition, and (3) a lexical-semantic route, where repetition via access to word meanings that activate word forms in the output lexicon.

These early accounts agreed that multiple loci of impairment were necessary to account for the poor repetition of words and nonwords and the semantic errors in repetition characteristic of deep dysphasia. Katz and Goodglass's addition of a processing component (phonemic memory impairment) illustrates the beginning of a shift away from representational accounts to explain aphasia. The theoretical framework for the present study is an interactive activation model of word processing (Dell & O'Seaghdha, 1992) that views aphasia as a processing impairment that affects access to and/or maintenance of activated semantic, lexical, and phonological representations of words over the course of comprehending, repeating, and producing words.

Another pattern of impairment in aphasia is identical to deep dysphasia but for one feature—semantic errors in single-word repetition. The term "phonological dysphasia" has been used to describe this pattern (e.g., Wilshire & Fisher, 2004).The overlap in symptoms of deep and phonological dysphasia has led to the hypothesis that they share the same root cause, impaired maintenance of activated representation of words, but differ in severity of that impairment, with deep dysphasia being more severe. Furthermore, although semantic errors do not occur in single-word repetition in this group, they are present in multiple-word and sentence repetition tasks (Saffran & Marin, 1977; Martin et al., 1996; Trojano, Stanzione & Grossi, 1992).

Evidence that these two syndromes (deep and phonological dysphasia) lie on a severity continuum comes from multiple sources: a longitudinal study (Martin et al., 1996) of changing error patterns in repetition and verbal STM associated with recovery from deep dysphasia; reports of semantic errors in repetition of word strings (Trojano et al, 1992; Martin et al., 1996; Reilly et al., 2012) and sentences (Saffran & Marin, 1975), as well as observations of associations between verbal span size and severity of naming and word recognition impairment (Martin & Gupta, 2004).

A common feature across deep-phonological dysphasia profiles is an imageability effect in recognition (Howard & Franklin, 1988; Martin & Saffran, 1992; Weekes & Raman, 2008), oral reading (Martin & Saffran, 1992; Majerus et al., 2001; Weekes & Raman; 2008), and repetition of low-image (LI) words (Howard & Franklin, 1988; Katz & Goodglass, 1990; Butterworth & Warrington, 1995; Hanley, Dell, Kay & Baron, 2004; Majerus et al., 2001; Gold & Kertesz, 2001; Weekes & Raman; 2008). An imageability effect is correlated with superior semantic processing abilities when compared to phonological processing (Martin & Saffran, 1997). Semantic errors in single-word repetition can be understood within Dell and O'Seaghdha's two-step interactive activation model of word production (here inafter, the IA model) as the incorrect selection of a primed semantically related competitor during a period of rapid global decay (Martin & Saffran, 1992). In the context of serial recall tasks, the initial words in a list receive the greatest amount of semantic feedback (Martin & Ayala, 2004). In the performance of multiple-word repetition, reduced recency or increased accuracy for items at the beginning of the word list has been frequently reported (Trojano et al., 1992; Martin & Saffran, 1997; Majerus, 2001; Wilshire & Fisher, 2004). This pattern of errors is referred to as a primacy effect in serial recall, due to rapid global decay. The effect of primacy indicates that the first word is more likely to be repeated correctly than the seccond word (Martin & Saffran, 1997). In Martin et al.'s (1996) longitudinal report of recovery in deep dysphasia, imageability influenced NC's repetition accuracy across positions in serial recall.

A frequency effect, less often reported, has also been identified in recognition (Howard & Franklin, 1988; Martin & Saffran, 1992; Weekes & Raman, 2008), oral reading (Katz & Goodglass, 1990; Majerus et al., 2001; Gold & Kertesz, 2001; Weekes & Raman; 2008), and repetition of low-frequency (LF) words (Howard & Franklin, 1988; Butterworth & Warrington, 1995; Hanlet et al., 1997; Majerus et al., 2001; Gold & Kertesz, 2001; Weekes & Raman, 2008). It appears that a frequency effect may decrease as recovery occurs along the deep-phonological dysphasia continuum. Milder cases do not report significant frequency effects in reading (Jefferies, Sage & Lambon Ralph, 2007), repetition (Wilshire & Fisher 2004), and repetition with a filled delay (Martin et al., 1996). Evidence from studies of deep-phonological dysphasia have revealed an influence of imageability (HI>LI), frequency (HF>LF), and modality (visual>auditory).

In some cases, imageability and/or frequency have been reported to influence success in visual processing tasks such as oral reading (Nolan & Carmazza, 1982; Toumiranta et al., 2014).

As previously noted, auditory-verbal STM has been clearly identified as an area of impairment in deep-phonological dysphasia, but treatment paradigms aimed to improve language function within this population of PWA have not been proposed. The presentation of deep-phonological dysphasia is characterized by an advantage in visual processing, when compared to auditory processing of the same stimuli (Howard & Franklin, 1988; Martin & Saffran, 1992; Wilshire & Fisher, 2004; Ablinger et al., 2008).

The most pervasive impairment across this continuum is the limitation of auditory-verbal STM capacity. This limitation has been attributed to a rapid decay of the phonological representation (Katz & Goodglass, 1990), rapid decay of both phonological and semantic representations (Martin et al., 1996), or weak connection weights between the phonetic and phonological input levels (Ablinger et al., 2008). As an individual's recovery continues toward a mild presentation of phonological dysphasia, the pervasive impairment of phonological auditory-verbal STM remains (Martin & Ayala, 2004).

It has been noted that the presentation of deep to phonological dysphasia exhibits some variability. The traditional Western Aphasia Battery-Revised (*WAB-R;* Kersetz, 2006) aphasia classification that most suitably fits the profile of deep dysphasia would be more severe than Wernicke's aphasia presentation as described by Michel and Andreewsky (1983), Howard and Franklin (1988), Martin and Saffran (1992). With recovery and a less severe phonological dysphasia presentation, a traditional aphasia classification would most likely be Conduction aphasia (Martin & Saffran, 1992;

Wilshire & Fisher, 2004; Huber, Ablinger, Abel & Huber, 2008; McCarthy et al., 2013). As a person with phonological dysphasia further recovers, differential performance across visual and auditory maintenance tasks is likely to persist, as intact visual processing abilities are consistent with this continuum (Ablinger, et al., 2008). Verbal STM may still be affected, even in cases where traditional aphasia classification is reported as non-aphasia/normal (McCarthy et al., 2014).

A marked advantage in the visual input processing of words over auditory processing characterizes the presentation of deep-phonological dysphasia (Howard & Franklin, 1988; Martin & Saffran, 1992; Wilshire & Fisher, 2004; Ablinger et al., 2008). Underlying this deficit is a severe impairment in the ability to maintain activation of semantic and phonological representations in STM (Martin & Saffran, 1992; Wilshire & Fisher, 2004; Ablinger et al., 2008). To compensate for the rapid decay due to deficits in phonological processing (Martin & Saffran, 1997; Martin & Ayala, 2004), persons with deep-phonological dysphasia employ relatively superior lexical-semantic processing (Martin & Saffran, 1992; Martin et al., 1996). Error patterns in the recovery of deep-phonological dysphasia substantiate a reliance on lexical-semantic activation and reduced STM capacity.

Theoretical Motivation

The IA model of word production (Figure 1) and its extension to word repetition (Martin et al., 1994; Figure 2) provided a theoretical framework for the treatment protocol used in this study. This model functions in an interactive, bi-directional fashion. To account for deep to phonological dysphasia, activation of semantic and phonological representations of words is governed by two parameters: connection weight (strength of activation spread) and decay rate (stability of activation strength). Activation at one level spreads to the next in the form of feedforward spreading activation and also spreads back to the preceding level as feedback.

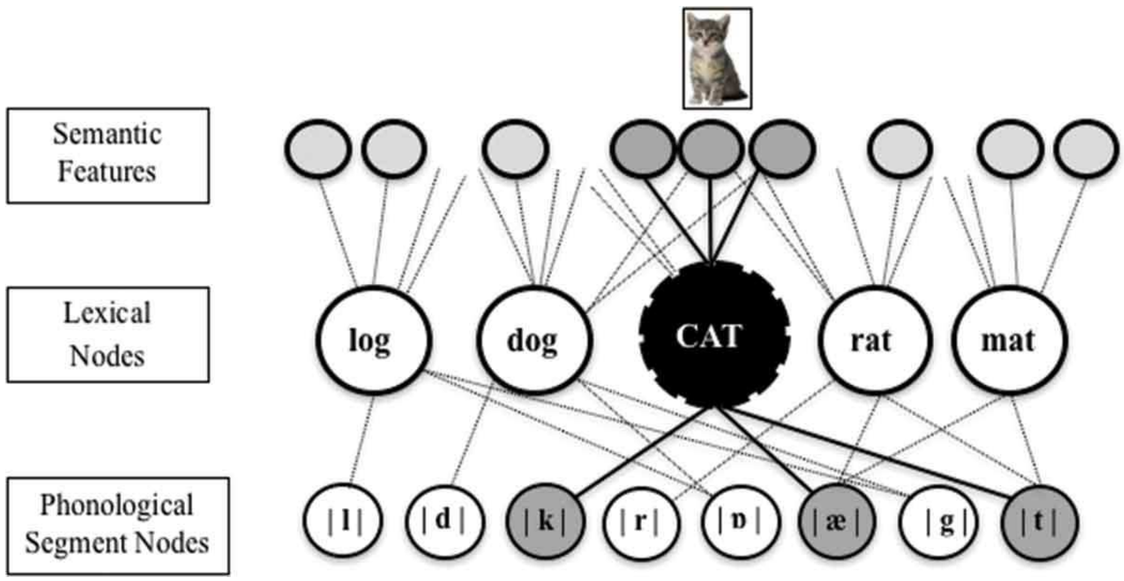

Figure 1. Lexical network structure in the spreading activation production model (Dell & O'Seaghdha, 1992).

The interactive nature of spreading activation takes place over the time-course of word retrieval (Figure 2) and ensures that later stages of word processing (whether phonological in naming or semantic in repetition) influence the earlier stages (semantic activation in naming and phonological activation in repetition).

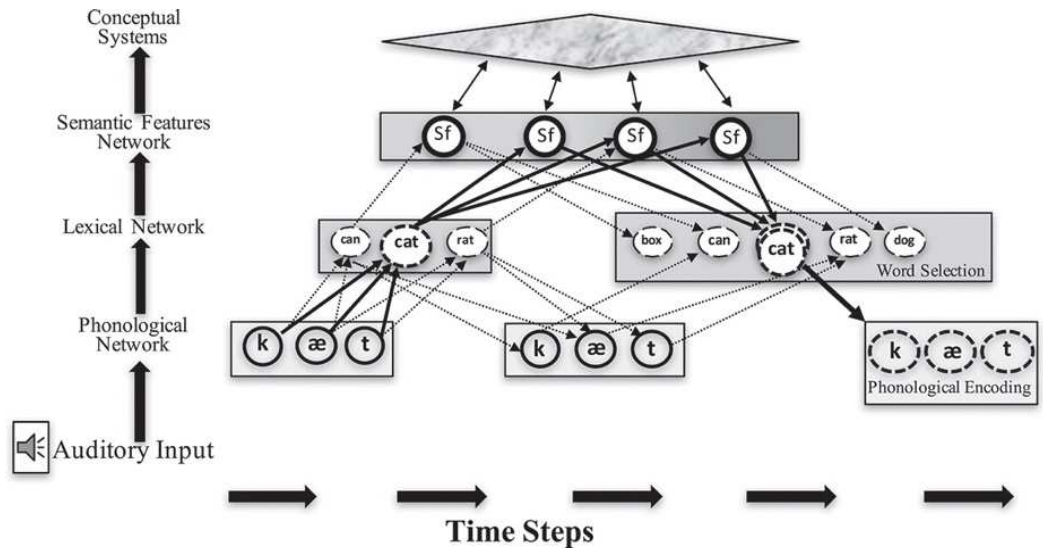

Figure 2. An interactive activation model of single-word repetition (Martin et al., 1994).

The activation of semantic and phonological representations of a word contributes to the strength of the word (lexical) nodes through the feed forward-feedback process and eventually determines which word node is highest in activation when the intended word is retrieved. Sometimes the word that is retrieved is the intended ("target") word (e.g., "cat") and sometimes it is another word node in the lexicon, often semantically (e.g., "dog"), phonologically (e.g., "mat") or both semantically and phonologically (e.g., "rat") related to the target. Impairment to one or both of the processing parameters—connection weight and decay rate—can alter the balance of semantic and phonological input to the activation of the target word and its competitors and lead to the wrong word being selected.

Schwartz and colleagues (1994) modeled the naming error pattern observed in a case study of FL, who demonstrated fluent speech and a high rate of nonwords in his production. The model was extended to repetition in the case study of NC, who demonstrated deep dysphasia (Martin & Saffran, 1992; Martin, et al., 1994). Martin and Saffran (1992) proposed that a global rate of decay account for the unique symptom of deep dysphasia, namely semantic errors in repetition of single words. Martin et al. (1994) used the IA framework to model NC's error patterns in naming and repetition in a computer simulation of word retrieval by increasing the decay rate of activated nodes, but maintaining the normal levels of connection strength. A notable achievement of this modeling study was that a single lesion to the decay rate parameter was able to simulate the high rate of semantic errors in repetition.

The IA Model and the Severity Continuum

The IA model was used in another study to address co-occurring changes in error patterns and auditory-verbal STM span that were observed over the course of NC's recovery (Martin et al., 1996). As noted, NC initially demonstrated the classic features of deep dysphasia, lexicality and imageability effects and semantic errors in single-word repetition (Martin & Saffran, 1992); his auditory-verbal STM word span was less than one item, whether the span task required a repetition or pointing response. As NC recovered, he no longer made semantic errors in single-word repetition and his word span increased to two or three words. This pattern of recovery suggested an association between increased decay rate and rates of semantic errors. A simulation of this pattern in the IA model demonstrated a significant positive correlation between the severity of the decay rate impairment and the presence of semantic errors in repetition. It is the presence of semantic errors in single-word repetition that distinguishes deep dysphasia from phonological dysphasia. In two follow-up studies of NC's recovery, Martin et al. (1996)

tested the severity continuum hypothesis by reducing the rate of decay toward normal levels (though still abnormally high). This adjustment in the model parameters led to a pattern of symptoms associated with what eventually would be termed phonological dysphasia (Wilshire & Fisher, 2004).

As a further test of the severity continuum hypothesis, Martin et al. (1996) tested the prediction that adding memory load to a word repetition task would lead to a re-emergence of semantic errors. Memory load was added either by imposing a five-second delay before a repetition response or by increasing the number of items to be repeated. As predicted, the result was an increase in error rates overall and an increase in semantic errors. This pattern was simulated with two manipulations of the computer simulation. First, the decay rate was increased, but to a lesser degree than the extremely high rate that led to semantic errors in single-word repetition. Second, performance with this parameter setting was examined at different time-steps to simulate the effects of time passage that would happen in the repetition task if a five-second delay was imposed before responding or if two words were to be repeated.

On the basis of these behavioral and computer simulation data, Martin et al. (1996) proposed that NC’s repetition performance at earlier and later stages of recovery in deep dysphasia could be characterized as two points on a functional severity continuum of a single cognitive ability, maintenance of the activation of semantic and phonological representations in auditory-verbal STM. The researchers further hypothesized that two variables—auditory-verbal STM span and task demands on that span capacity—would predict the point of breakdown on this severity continuum and indicate where semantic errors would appear in the repetition error pattern. If verbal span were severely limited (e.g, less than one word), then semantic errors and imageability effects in single word repetition would expected to be present. If span capacity were greater than a single item (e.g., two to three words), semantic errors would not be present and imageability effects would be reduced in single-word repetition. Data from the study of NC's recovery bore out these predictions (Martin et al., 1996). Semantic errors and imageability effects reappeared when cognitive load was increased during testingm which was demonstrated with a delayed interval prior to repetition as well as an increase in repetition word span size (Martin et al., 1996). The case study of NC provided evidence that auditory-verbal STM capacity and the size of imageability effect in repetition interact with the degree to which the limits of verbal span capacity are stressed by the number of stimuli or delay in response time.

The literature base reporting a classification of deep dysphasia or phonological dysphasia is limited; a report published in 2008 indicated fewer than twenty studies (Ablinger et al., 2008). Moreover, mild phonological dysphasia has not been considered in detail, and evidence guiding recovery in deep dysphasia is needed in the research base to inform best clinical practice.To gain insight into the pattern of deficit presentation characteristic of persons with chronic auditory-verbal STM impairment and to bring greater clarity to the profile of recovery along the deep-phonological dysphasia continuum, the present research undertook a systematic review of case studies reporting a repetition pattern consistent with deep-phonological dysphasia (see Chapter 2). The analysis of case studies in the literature base provided the historical foundation of the theoretical and empirical understanding of deep and phonological dysphasia that framed this dissertation research.

CHAPTER 2

A SYSTEMATIC REVIEW OF THE DEEP TO PHONOLOGICAL DYSPHASIA LITERATURE BASE

The literature base documenting deep and phonological dysphasia is highly relevant to better understanding of recovery in aphasia. The pattern of errors reported as characteristic of this ‘syndrome’ has provided some of the clearest evidence that this presentation of aphasia is the result of underlying damage to both language and STM processes (Martin & Saffran, 1992; Ablinger et al., 2008). Best practice in aphasia rehabilitation now considers the importance of interventions targeting damaged cognitive processes in conjunction with language processes. In the longitudinal case study of deep dysphasic NC, it was proposed that a changing pattern of errors in repetition was mediated by severity of verbal STM (Martin et al., 1996). As previously discussed, this important study led the authors to hypothesize that deep (most severe) and phonological (less severe) dysphasia were the same impairment, but reflected two different points on a severity continuum.(Martin et al., 1996).

The most recent study reporting on the existing research base of deep to phonological dysphasia determined it consisted of fewer than 20 studies (Ablinger et al.. 2008). Nevertheless, the progression of symptoms in a subtype of aphasia known for severe deficit in verbal STM is of great interest. Understanding the pattern of errors characteristic to a subcategory of aphasia has the potential to improve treatment and promote recovery (Martin et al., 1996; Martin & Saffran, 1997; Dell et al., 2007). The current systematic review cast a wider net than past reviews in order to gather evidence of a severity continuum mediated by severity of impairment of auditory-verbal STM capacity. In an attempt to determine if additional studies in the literature base existed that could be used to provide evidence of this severity continuum, this systematic review examined all case studies reporting a profile consistent with deep to phonological dysphasia.

Deep Dysphasia and Deep Dyslexia

In 1983, Michel and Adreewsky characterized deep dysphasia as a severe impairment of repetition analogous to the error pattern noted in the severe aquired reading impairment (Marshall & Newcombe, 1978) deep dyslexia. First described by Beringer and Stein (1930), this impairment was studied across the twentieth century (Goldstein, 1948; Marshall & Newcombe, 1978; Friedman, 1996), deep dyslexia is the most severe presentation of this acquired neurological impairment characterized by inability to read single words and the occurrence of semantic paralexias during those attempts (Glosser & Friedman 1990). The first published review of deep dyslexia was by Marshall and Newcombe (1978); this review was then expanded by Morton (1980). Then, Friedman (1996) conducted the largest review of the literature to date and examined eleven cases with the aim of increasing understanding of the progression of symptoms in deep dyslexia and phonological dyslexia. Friedman used a pattern of errors to provide evidence that these impairments were the same, mediated on a continuum of severity (1996). In 2007, Jefferies, Sage, and Lambon-Ralph completed an investigation of deep to phonological dyslexia in order to test Friedman's theory. This study investigated the performance of twelve individuals and concluded that the results constituted further evidence of the existence of a continuum.

What sets deep dyslexia apart from the otherwise similar phonological dyslexia is the occurrence of semantic errors in single-word reading vs. multiple-word reading. The error patterns of acquired dysphasia and acquired dyslexia appear to differ in a way that provides insight into the underlying impaired modality. The presence of semantic paraphasias/paralexias categorizes the distinction between both deep and phonological dysphasia and deep dyslexia and phonological dyslexia (Glosser & Friedman, 1990).

With the goal of further defining acquired dysphasia, a cursory review of the historical background of acquired dyslexia was completed. Exploring the history of research informing understanding of deep to phonological dyslexia provided guidance for proceeding with an investigation of acquired dysphasia. Additionally, the disparity in the available research bases of these two acquired language impairments illustrated the challenges that early researchers in dysphasia faced. Over fifty years of research in deep dyslexia as well as evidence from thirteen case studies exploring treatment approaches for this impairment preceded Friedman's hypothesis of a severity continuum in 1996. That same year, Martin et al. (1996) presented the single case of NC, a detailed and elegant description of the evolving pattern of errors in recovering deep dysphasia. Given the exceptionally small literature base, the authors used a weight/decay model in which the single parameter of decay could be manipulated to predict patterns of errors in deep dysphasia along a continuum. The importance of the study of NC was the evidence that it provided supporting severe auditory-verbal STM impairment and language processing impairment occurring in tandem.

Phonological dysphasia was introduced as a classification by Wilshire and Fisher (2004). Studies that followed lacked clear of the notion of a severity continuum. Jefferies, Sage, & Lamdon Ralph (2007) posited that deep and phonological dysphasia shared a phonological impairment due to damage to the primary auditory system, but the authors did not extend this hypothesis or address the presence of a severity continuum. In fact, participants were excluded from their study on the basis of severity (too mild and too severe). Ablinger et al. (2008) conducted a nine-month longitudinal case study of JR, a person with deep dysphasia. Although JR presented with significant recovery across the four time points measured, the study did not discuss the premise of a continuum or use JR's performance to justify a revised theoretical model. The first use of the terminology "deep to phonological dysphasia continuum" was within a case series study of individuals characterized in an analysis completed by Berthier et al. (2014), who cited the above references, although none of these studies had adopted the terminology of a "continuum" (Martin et al., 1996; Wilshire & Fisher, 2004; Jefferies et al., 2007).

The Current Systematic Review

Following the lead of research completed in the field of deep to phonological dyslexia, this investigation conducted the first systematic review of case studies describing individuals presenting with the characteristic markers of deep to phonological dysphasia. Of particular concern in previous research was the ambiguity of relevant studies that appeared to allude to a continuum of severity, but avoided consistency using this particular terminology. A primary purpose of this systematic review was to analyze and describe cases presenting with symptoms of deep to phonological dysphasia. The notion that dysphasia exists on a continuum from deep to phonological is central to the predictions of this dissertation. The characteristics of this disorder (imageability effects, frequency effects, and rate of semantic errors in repetition) and changes in these symptoms as severity of auditory-verbal STM impairment improves drove the following predictions:

- Deep and phonological dysphasia are two points on a continuum of severity mediated by auditory-verbal STM. Word span size will serve as a quantifiable variable and predictive marker of severity along this continuum.
- Severity of auditory-verbal STM impairment will predict the presence of semantic errors in deep dysphasia. Semantic errors will negatively correlate with increased word-span in repetition tasks.
- Severity of auditory-verbal STM impairment in deep-phonological dysphasia will predict imageability and frequency effect size in verbal span. Both effects will diminish in degree of severity with recovery in deep to phonological dysphasia, but if demand on verbal span is stressed, the presence of both effects will reappear.

Method

Search Terms. Seminal case studies defining characteristics of deep-phonological dysphasia were applied in the development of operational search terms for this review (Katz & Goodglass, 1990; Martin & Saffran, 1992; Trojano et al., 1992; Butterworth & Warrington, 1995; Martin et al., 1996; Majerus et al., 2001; Ablinger et al., 2008; Tuomiranta, Gronholm-Nyman, Kohen, Rautakoski & Martin, 2011).

Population-related search constructs were developed to capture the broad population in question (*adult* OR *acquired* OR "geriatric not *child"*) and more specific diagnoses (*dysphasia* OR *"deep dysphasia"* OR *"phonological dysphasia"* OR *aphasia*).

Table 1
Search terms [123]

Construct Related Search Terms	Population Related Search Terms	Topic Related Search Terms
auditory	acquired	abstract
"auditory verbal"	adult	assess*
AVSTM	aphasia	concrete
memory	NOT child	diagnos*
phonological	"deep dysphasia"	eval*
"short term memory"	geriatric	frequency
"short-term memory"	"phonological dysphasia"	imageability
		lexicality

[1] *Databases used:* PubMed, EbscoHost Research Databases (Including: Academic Search Premier, MEDLINE, PsycARTICLES, Psychology and Behavioral Sciences Collection, PsycINFO).

[2] *Journals used:* Aphasiology, NeuroCase

[3] *Boolean Phrase:* (adult OR acquired OR geriatric) NOT child AND (dysphasia or "deep dysphasia" or "phonological dysphasia" or aphasia) AND (memory or "short-term memory" or "short term memory" or "AVSTM" or auditory or "auditory-verbal" or phonological) AND (frequency or imageability or lexicality or concrete or abstract) AND

See Table 1 for a complete list of the search terms used. Both deep dysphasia and phonological dysphasia include the diagnostic criteria of reduced auditory-verbal STM and effects of lexicality, imageability, and frequency in repetition (Howard & Franklin, 1988; Martin & Saffran, 1992; Wilshire & Fisher, 2004; Abel, Huber & Dell, 2009; Ablinger, Abel & Huber, 2008). In past studies (Martin & Ayala, 2004), auditory-verbal STM had been referred to as AVSTM, which was included in the criteria. These markers were used to develop construct-related search constructs (*memory* OR "*short-term memory"* OR *"short term memory"* OR *AVSTM* OR *auditory* OR *"auditory-verbal"* OR *phonological*) as well as topic-related search constructs (*frequency* OR *imageability* OR *lexicality* OR *concrete* OR *abstract* AND *eval** OR *diagnos** OR *assess** OR "*case study"*). Terms used to define inclusion criteria produced the final Boolean phrase: (adult OR acquired OR geriatric) NOT child AND (dysphasia OR "deep dysphasia" OR "phonological dysphasia" OR aphasia) AND ("memory" OR "short-term memory" OR "short term memory" or "AVSTM" or "auditory" OR "auditory-verbal" OR 'phonological') AND (frequency OR imageability OR lexicality OR concrete OR abstract) AND (eval* OR diagnos* OR assess* OR "case study").

Literature Search. The following databases were used to identify relevant articles: PubMed, EbscoHost Research Databases (Including: Academic Search Premier, MEDLINE, PsycARTICLES, Psychology and Behavioral Sciences Collection, PsycINFO). The journals *Aphasiology* and *NeuroCase* were used to identify relevant articles because both were known to include articles of interest due to preliminary research in this area. Within this search, if articles included citations referencing studies with the potential to meet inclusion criterion that were not previously identified, these studies were also reviewed.

Inclusion Criteria. The critical threshold for inclusion was a marked auditory-verbal STM impairment defined as a word-span less than 4 items. Errors in repetition word span also had to meet one or more of three classic markers of deep to phonological dysphasia: imageability effect, frequency effect and/or lexicality effect. Cases were required to have been published between 1980 and 2015 and written in English. Study participants were also required to be adults (defined as age 18 or older), with an acquired neurological deficit resultant in dysphasia.

Experimental Design. Descriptive statistics were employed to report the following demographic information in this systematic review: age, years post-onset, education level, gender, etiology, cor, responding neurostructural presentation, and traditional aphasia classification as defined by the Western Aphasia Battery-Revised (*WAB-R*; Kertesz, 2006). For each study, reference information included author(s), year of publication, and identifying label (in most cases a combination of two letters). Additionally, measures of auditory-verbal STM span included performance on word, digit, and letter repetition when provided in the study. Repetition performance was assessed for an imageability effect, a frequency effect, and a length effect. Percentage of semantic errors in single and multiple words were collected (if reported). In the context of the entire sample size, the mean, median, and standard deviation of each listed variable were reported to identify patterns in performance. The purpose of this portion of the data analysis was to calculate the range and average trends in variables underlying deep-phonological dysphasia presentation.

Data Analysis. In order to test the above predictions, inferential statistics were performed using SPSS predictive analytics software (Statistical Package for the Social Sciences, IBM, 2013). Severity of auditory-verbal STM impairment was quantified using a severity scale of repetition performance on word span tasks. In order to organize a large number of studies which met inclusion critierion, but reported word repetition abilities as severely or profoundly impaired, specific points on the continuum of deep to phonological dysphasia were defined. As seen in Table 2, word span repetition performance was categorized in seven groups, I to VII, according to severity of auditory-verbal STM impairment. Severity Level I reflected the most profound deficit of auditory-verbal STM impairment (unable to repeat single words). Level II most closely characterized the profile of individuals with deep dysphasia (single-word repetition >0.80). Level III was the first to capture points on the proposed contrinuum that would fit the classification of phonological dysphasia (single-word repetition accuracy for one-word span ≥ 0.80, but inability to repeat two words). Level IV included many persons with phonological dysphasia (single-word repetition >0.80; two-word span repetition < 0.80). The last three levels demonstrated what would be expected during recovery in phonological dysphasia: Level V (accuracy for two-word span ≥ 0.80). Level VI (for three-word span ≥ 0.80); and, finally, Level VII demonstrated the maximum level of performance considered for inclusion (accuracy for three-word span ≥ 0.80).

Table 2.
Severity of auditory-verbal short-term memory impairment

Word Span	Category	Criteria
Unable	I	Unable to repeat single words, accuracy = 0.00
<1 word	II	Accuracy for repetition of single words < 0.80
1 word	III	Accuracy for repetition of single words ≥ 0.80
>1 word; <2 words	IV	Single word repetition > 0.80; Two-word span < 0.80
≥ 2 words	V	Accuracy for two-word span repetition ≥ 0.80
≥ 3 words	VI	Accuracy for three-word span repetition ≥ 0.80
≥ 4 words	VII	Accuracy for four-word span repetition ≥ 0.80

Multiple linear regression was used to describe the relationship between the dependent variable (auditory-verbal STM severity) and the independent variables defined in each prediction. In order to examine the prediction that severity of auditory-verbal

STM could be employed to the presence of semantic errors, case studies were divided into two groups for linear regressions by word span: less than a single word (deep dysphasia) and greater than a single word (phonological dysphasia). In a second multiple regression analysis across the two groups, severity of auditory-verbal STM was used to examine the relationship between this repetition word span and presence of semantic errors. A final analysis examined the relationship between the severity of auditory-verbal STM and imageability and frequency effect, to determine if the measures of word span could predict the severity of these effects.

Results

A review of the literature base from 1980 to 2015 identified 428 articles; these were all assessed for possible inclusion. Thirty-six case studies of deep and phonological dysphasia met inclusion criteria; 27 of these cases represented one-time point (single report of participant) and 9 cases reported more than one-time point (longitudinal data reporting the performance of an individual at more than one point of testing); a total of 44 time points were recorded. All the sample cases demonstrated severe deficit in repetition. The main reason for excluding articles was the absence of report of repetition performance.

Table 3 provides demographic information. Participants included 24 males, 9 females, and 2 whose sex was not reported. The average age was 53.9 years old (minimum=22 years old and maximum=83 years old). Average time post-onset was 35.93 months or 3 years (minimum <1 month and maximum = 168 months). Dominating etiology was a left CVA (.73), which for most of the participants involved the left temporal region (.72). Twenty-three cases (0.63) reported classical aphasia taxonomy labels. Dominating these descriptions were Wernicke's Aphasia (.43) and Conduction Aphasia (.26).

TABLE 3. Summary of background information.

First Author (Year)	Case Study	Age, Gender	ime Post Ons	Etiology	Classification of Aphasia	Language
Nolan (1982)	B.L.	57 y/o M	72 months	Lt. CVA- infarct in lt. temporal, posterior frontal and parietal lobes	Broca's aphasia, dysarthria, deep dyslexia	*english (us)*
Michel (1983)	M.R.	52 y/o M	72 months	TBI- infarct in lt. prefrontal and middle temporal lobes	Wernicke's aphasia, deep dysphasia	*french*
Metz-Lutz (1984)	G.L.	24 y/o F	0 months	Lt. CVA- occlusive vasular lesion in lt. MCA	Wernicke's aphasia (initial); pure word deafness (2 months post-onset)	*french*
Freidrich (1984)	E.A.	52 y/o F	49 months	Lt. CVA-posterior temporo-parietal lesion	Conduction aphasia (4 years post onset)	*english (us)*
Duhamel (1986)	N.Z.	64 y/o M	168 months	TBI- infarct in lt. posterior temporal lobe and	Wernicke's aphasia (initial); mild fluent aphasia (as reported by	*french*
Howard (1988)	M.K.	42 y/o M	24 months	Lt. CVA- infarct in lt. parietal region,	Wernicke's aphasia	*english (us)*
Marshall (1988)	M.C.H.	M	unknown	Lt CVA	Wernicke's aphasia	*english (uk)*
Katz (1990)	S.Z.	71 y/o M	120 months	Lt. CVA- infarct in lt. temporal lobe including 75% of Wernicke's area	Fluent aphasia characteristic of deep dysphasia	*english (us)*
Vallar (1990)	E.R.	34 y/o F	0 months	Lt. ischemic CVA- temporoparietal region and insular region	Excellent fluent speech with phonemic paraphasias, selective deficit of auditory-verbal STM span	*italian*
Coslett (1991)	W.T.	30 y/o F	.5 month	Lt. CVA-infarct in lt. posterior superior temporal lobe involving Wernicke's area	Wernicke's aphasia	*english (us)*
Martin (1992)	N.C.	28 y/o M	0-3 months	Lt. MCA aneurysm clipped via craniotomy, lt. temporoparietal region	Wernicke's aphasia, word deafness, deep dysphasia	*english (us)*
Trojano (1992)	S.C.	33 y/o M	25 months	Hypodense area in lt. temporal and parietal regions	Phonemic deafness	*italian*
Cardebat (1993)	P.	22 y/o M	2 months	Lt. side ischemic CVA, lt. temporoal parietal region infarct	Fluent aphasia with severe auditory comprehension deficit indicating pure word deafness	*french*
Franklin (1994)	D.R.B.	64 y/o M	108 months	Lt MCA infarct	Fluent speech, repetition is severely impaired, only able to repeat words he can comprehend	*english (uk)*
DePartz (1995)	A.M.	64 y/o M	1-24 months	Lt parieto-occipital CVA	Severely impaired repetition, fluent speech	*french*
Butterworth (1995)	M.E.G.	59 y/o F	0-24 months	Focal seizures, lt. posterior temporoparietal low attenuation with lt. MCA infarct.	Jargon aphasia with very poor comprehension (initial) to fluent speech with decreased vocabulary (24 months)	*english (uk)*
Valois (1995)	E.A.	72 y/o M	120 months	Lt temporo-parietal region of the left hemisphere	Wernicke's aphasia- fluent spontaneous speech but severe deficit in auditory comprehension and repetition	*french*
Martin (1996)	N.C.	30 y/o M	12-24 month	Lt. MCA aneurysm clipped via craniotomy, lt. temporoparietal region	Wernicke's aphasia, phonologically based STM deficit	*english (us)*
Cappa (1996)	G.M.	28 y/o M	0 months	Lt temporal pole hemmorhage	Severe conduction aphasia	*italian*
Tyler (1997)	Dr.O.	60 y/o M	36 months	Lt MCA	Fluent with jargon, word finding difficulties	*english (uk)*
Hanley (1997)	P.S.	late 40's, M	36-48 month	Lt. CVA in lt. temporal region	Auditory repetition deficit similar to deep dysphasia, but with no semantic errors in repetition	*english (uk)*
R. Martin (1999)	M.S.	30 y/o M	6-36 months	Herpes encephalitis resultant in lt. temporal damage	Anomic aphasia with surface dyslexia and dysgraphia	*english (us)*
Croot (1999)	C.B.	57 y/o M	unknown	Progressive aphasia- Atrophy in persylvian region with mild lt. temporal lobe	Nonfluent primary progressive aphasia	*english (uk)*
Knott (2000)	F.M.	55 y/o F	0-40 months	Hypo-perfysion of the left temporal regions	Progressive fluent anomic aphasia	*english (uk)*
Majerus (2001)	C.O.	75 y/o M	60 months	Progressive aphasia- perisylvian and focal left temporal cerebral compromise	Mixed primary progressive aphasia with nonfluent speech output	*french*
Tree (2001)	P.W.	60 y/o F	12 months	No abnormalities upon intial imaging scans	Progressive fluent aphasia with a severe anomic impairment	*english (uk)*
Gold (2001)	M.M.B.	not reported	12 months	Lt. CVA involving posterior MCA, posterior superior temporal area	Conduction aphasia, surface dyslexia	*english (us)*
Basso (2003)	A.M.	59 y/o M	1-24 months	Lt. CVA with lt frontal-temporal-insular lesion.	Global aphasia (initial) moderate nonfluent aphasia (24 months)	*italian*
				Lt. CVA with small region of hypodensity in	Borderline Wernickes/conduction aphasia	
Jefferies (2007)	Dysphasic 1	54 y/o M	14 months	Lt. CVA in temporo-parietal region	Fluent aphasia with frequent phonological jargon, with impaired comprehension and repetition.	*english (uk)*
Jefferies (2007)	Dysphasic 2	70 y/o F	60 months	Large lt. CVA in temporo-parietal region	Fluent aphasia with impaired verbal comprehenson and repetition.	*english (uk)*
Weekes (2008)	B.R.B.	67 y/o M	not specified	Lt. CVA resultant in medium lt. parietal-occipital infarct	Fluent but empty speech, deep dysphasia in Turkish and English	*turkish*
Ablinger (2008)	J.R.	46 y/o M	1 month; 8 m	Lt. CVA-infarct in lt. middle and posterior temporal gyrus, Wernicke's area	Global aphasia (initial), deep dysphasia	*german*
Berthier (2012)	J.V.A.	not reported	84 months	Lt. CVA-infarct in lt. temporoparietal lobe	Conduction aphasia	*spanish*
De-Torres (2013)	J.A.M.	46 y/o M	12 months	Large intracerebral hemmorhage, damage in rt. Segment of AF and IFOF	Conduction aphasia	*spanish*
McCarthy (2014)	L.T.	34 y/o F	36 months	Lt. CVA-infarct in lt. temporal and parietal lobes, posterior insula	Conduction aphasia, phonological dysphasia	*english (us)*
Tuomiranta (2014)	A.A.	60 y/o F	33 months	Subarachnoid hemmorhage due to ruptured aneurysm in lt. MCA; lt. temporal infarct.	Global aphasia (until 3 months post-onset), deep dysphasia, anomia	*finnish*

Table 4.
Further classifying auditory-verbal short-term memory span in single word repetition

Span Accuracy, Single Word Repetition <	Sub-Categorized Single Word Span
0.01-0.20	II a
0.21-0.40	II b
0.41-0.60	II c
0.61-0.79	II d

Twenty cases met the inclusion criterion for this analysis in deep dysphasia—a word span of less than one. This provided a rich sample size to test whether the severity of auditory-verbal STM impairment could be used to predict the presence of semantic errors in deep to phonological dysphasia. A regression analysis was performed to determine if accuracy of single-word span was predictive of the amount of semantic errors and imageability. A linear regression revealed that the rate of semantic errors negatively correlated with word span size ($F(1,20) = -4.21$, $p < 0.01$) (smaller word span resulted in a higher rate of semantic errors). Furthermore, the average of semantic errors in each category decreased as span accuracy improved on single words, as noted in Table 4. Span size IIa had an average of 0.23 semantic errors; span size IIb, an average of 0.15 semantic error; span size IIc, an average of 0.11 errors; and span size IId, an average of 0.03 errors. This systematic decline provided further evidence of a severity continuum (See Table 5).

Table 5.
Auditory-verbal short-term memory span as related to semantic errors

Study #	First Author (Year)	Case Study	Auditory-Verbal STM span (IIa-IId)	Nouns- Average Across I/F Reports	Semantic Errors				
					Single Words SE Average	Single Words HI	Single Words LI	Single Words Adjectives	Single Words- Verbs
1	Michel (1983)	MR	II a	0.11	0.25	0.24	0.25	0.24	0.27
2	Jefferies (2007)	Dysphasic 1	II a	0.15	0.22				
3	Martin (1992)	N.C.	II b	0.29	0.19	0.10	0.03		
4	Ablinger (2008)	J.R. T1 (1 month post)	II b	0.30	0.01				
5	Wilshire (2004)	M.S.	II b	0.30	0.06				
6	Marshall (1988)	M.C.H.	II b	0.33	0.20				
7	Cappa (1996)	G.M. 1993	II b	0.35	0.15				
8	Majerus (2001)	C.O. May 1994	II b	0.35	0.21				
9	Metz-Lutz (1984)	G.L.	II b	0.36	0.32				
10	Franklin (1994)	D.R.B.	II b	0.39	0.20				
11	Howard (1988)	M.K.	II c	0.43	0.08	0.08	0.07		
12	Butterworth (1995)	M.E.G. 1986	II c	0.44	0.29				
13	Valois (1995)	E.A.	II c	0.44	0.11				
14	Tree (2001)	P.W.	II c	0.49	0.01				
15	Ablinger (2008)	J.R. T2 (3 months post)	II c	0.51	0.00				
16	Croot (1999)	C.B. Sept. 1996	II c	0.52	0.06				
17	Hanley (1997)	P.S.	II c	0.56	0.00				
18	Duhamel (1986)	N.Z.	II c	0.58	0.48		0.36		
19	Basso (2003)	A.M. Feb.-Mar. 2000	II c	0.60	0.18				
20	Ablinger (2008)	J.R. T3 (8 months post)	II d	0.66	0.00				
21	Trojano (1992)	S.C.	II d	0.67	0.05	0.10	0.00	0.00	0.00
22	Knott (2000)	F.M.	II d	0.67	0.00				
23	Basso (2003)	A.M. April-May 1999	II d	0.68	0.12				
24	Gold (2001)	M.M.B.	II d	0.71	0.01				
25	Jefferies (2007)	Dysphasic 2	II d	0.73	0.03				
26	Cappa (1996)	G.M. 1994	II d	0.77	0.04				

Although the terminology used to describe the impairment ranged from deep dysphasia, phonological dysphasia, to short-term memory impairment, to auditory-verbal STM impairment, all reported cases demonstrated a severe deficit in repetition.The most notable initial findings indicated a high occurrence of imageability effects in repetition across the stages of recovery (.92) and a high occurrence of semantic errors (.67). Twenty-seven cases met the criteria for inclusion. (Eliminated were GL, MCH, P, MEG, GM, DrO, AM, JVA). A pattern was observed in which imageability effects negatively correlated with size of auditory-verbal STM (F (1,27) =-3.95, p <0.01). The findings in Table 6 identified a high occurrence of imageability effects in repetition across the stages of recovery consistent with the prediction of continued errors. By contrast, the occurrence of a frequency effect was not found to be significant (F (1,20) =-1.34, p <0.21). Only twenty cases met that criterion for inclusion, as frequency effect was less reported. (See Table 7).

Table 6

Systematic review of literature repetition performance and imageability effect

Study #	First Author (Year)	Case Study	Auditory-Verbal STM span (I-VII)	Repetition Performance- Auditory						
				Nouns- Average Across I/F Reports	High Imageability Noun Accuracy	Low Imageability Noun Accuracy	Difference in Accuracy (HI - LI)	Imageability Ratio (HI : LI)	(HI ÷ LI)	Normalized Difference Score
1	Nolan (1982)	B.L.	III	0.83	0.85	0.80	0.05	17:16	1.06	*0.06*
2	Michel (1983)	M.R.	II	0.11	0.60	0.06	0.54	10:01	10.00	*0.90*
3	Duhamel (1986)	N.Z.	II	0.58	0.75	0.40	0.35	15:8	1.88	*0.47*
4	Howard (1988)	M.K.	II	0.42	0.60	0.29	0.31	2:1	2.07	*0.52*
5	Katz (1990)	S.Z.	II	0.38	0.63	0.13	0.50	63:13	4.85	*0.79*
6	Vallar (1990)	E.R.	V	0.69	0.91	0.53	0.38	91:51	1.72	*0.42*
7	Coslett (1991)	W.T.	III	0.81	0.98	0.65	0.33	98:65	1.50	*0.34*
8	Martin (1992)	N.C.	II	0.30	0.53	0.07	0.46	53:7	7.58	*0.87*
9	Trojano (1992)	S.C.	II	0.67	0.70	0.45	0.25	14:9	1.56	*0.36*
10	Franklin (1994)	D.R.B.	II	0.39	0.77	0.03	0.74	77:3	25.67	*0.96*
11	DePartz (1995)	A.M. 24 months	III	0.87	0.93	0.73	0.20	93:73	1.27	*0.22*
12	Valois (1995)	E.A.	II	0.44	0.63	0.13	0.50	63:13	4.85	*0.79*
13	Martin (1996)	N.C. 12-18 months post	III	0.85	0.85	0.48	0.37	85:48	1.77	*0.44*
14	Hanley (1997)	P.S.	II	0.56	0.73	0.39	0.34	73:39	1.87	*0.47*
15	R. Martin (1999)	M.S.	VI*3-word*	0.83	0.83	0.83	0.00		0.00	*0.00*
			4-word	0.55	0.70	0.40	0.30	7:4	1.75	*0.43*
16	Croot (1999)	C.B. March 1996	III	0.85	0.87	0.73	0.14	87:73	1.19	*0.16*
		C.B. September 1996	II	0.55	0.60	0.35	0.25	12:7	1.71	*0.42*
17	Knott (2000)	F.M.	II	0.67	0.71	0.63	0.08	71:63	1.13	*0.11*
18	Majerus (2001)	C.O. May 1994	II	0.35	0.35	0.60	-0.25	7:12	1.71	*-0.71*
19	Tree (2001)	P.W.	II	0.49	0.65	0.37	0.28	65:37	1.76	*0.43*
20	Gold (2001)	M.M.B.	II	0.71	0.73	0.57	0.16	73:57	1.28	*0.22*
21	Wilshire (2004)	M.S.	II	0.30	0.38	0.23	0.15	38:23	1.65	*0.39*
22	Jefferies (2007)	Dysphasic 1	II	0.15	0.30	0.00	0.30		0.00	*1.00*
23	Jefferies (2007)	Dysphasic 2	II	0.73	0.83	0.63	0.20	83:63	1.32	*0.24*
24	Weekes (2008)	B.R.B. English	II	0.10	0.20	0.00	0.20		0.00	*1.00*
		B.R.B. Turkish	II	0.29	0.55	0.03	0.52	55:3	18.33	*0.95*
25	Ablinger (2008)	J.R. T1 (1 month post)	II	0.30	0.53	0.33	0.20	53:33	1.61	*0.38*
		J.R. T2 (3 months post)	II	0.51	0.64	0.40	0.24	8:5	1.60	*0.38*
		J.R. T3 (8 months post)	II	0.66	0.81	0.50	0.29	81:50	1.62	*0.36*
		J.R. T4 (10 months post)	III	0.81	0.90	0.73	0.17	90:73	1.23	*0.19*
26	McCarthy (2014)	L.T. Pre-Treatment	V*2-word*	0.40	1.00	0.86	0.14	50:43	1.16	*0.14*
		L.T. Post-Treatment	VI*3-word*	0.20	1.00	0.16	0.84	25:4	1.64	*0.84*
27	Tuomiranta (2014)	A.A.	II	0.43	0.53	0.33	0.20	53:33	1.61	*0.38*

Table 7.
Systematic review of literature frequency effect

Study #	First Author (Year)	Case Study	Auditory-Verbal STM span (I-V	Repetition Performance- Auditory					
				High Frequency Nouns	Low Frequency Nouns	Difference in Accuracy (HI LF)	Frequency Ratio (HI LF)	(HF ÷ LF)	Normalized Difference Score
1	Friedrich (1984)	E.A.	V	0.65	0.50	0.15	6:5	1.30	*0.23*
2	Howard (1988)	M.K.	II	0.48	0.35	0.13	48:35	1.37	*0.27*
3	Vallar (1990)	E.R.	V	0.69	0.65	0.04	69:65	1.06	*0.06*
4	Coslett (1991)	W.T.	III	0.82	0.79	0.03	82:79	1.04	*0.04*
5	Martin (1992)	N.C.	II	0.28	0.33	-0.05	28:33	0.84	*-0.18*
6	Trojano (1992)	S.C.	II	0.87	0.67	0.20	87:67	1.30	*0.23*
7	DePartz (1995)	A.M. 24 months	III	0.96	0.88	0.08	12:11	1.09	*0.08*
8	Valois (1995)	E.A.	II	0.74	0.21	0.53	74:21	3.52	*0.72*
9	Martin (1996)	N.C. 12-18 months post	III	0.76	0.57	0.19	4:3	1.33	*0.25*
10	Hanley (1997)	P.S.	II	0.58	0.54	0.04	29:27	1.07	*0.07*
11	R. Martin (1999)	M.S.	VI *3-word*	0.98	0.67	0.31	98:67	1.46	*0.32*
			4-word	0.77	0.34	0.43	77:34	1.75	*0.56*
12	Knott (2000)	F.M.	II	0.71	0.63	0.08	71:63	1.13	*0.11*
13	Majerus (2001)	C.O. May 1994	II	0.50	0.20	0.30	5:2	2.50	*0.60*
14	Gold (2001)	M.M.B.	II	0.74	0.40	0.34	37:20	1.85	*0.46*
15	Wilshire (2004)	M.S.	II	0.37	0.27	0.10	37:27	1.37	*0.27*
16	Jefferies (2007)	Dysphasic 1	II	0.23	0.08	0.15	23:8	2.88	*0.65*
17	Jefferies (2007)	Dysphasic 2	II	0.70	0.75	-0.05	14:15	0.93	*-0.07*
18	Weekes (2008)	B.R.B. English	II	0.13	0.08	0.05	13:8	1.63	*0.38*
		B.R.B. Turkish	II	0.38	0.20	0.18	19:10	1.90	*0.47*
19	Ablinger (2008)	J.R. T1 (1 month post)	II	0.35	0.34	0.01	35:34	1.03	*0.03*
		J.R. T2 (3 months post)	II	0.64	0.40	0.24	8:5	1.60	*0.28*
		J.R. T3 (8 months post)	II	0.74	0.58	0.16	37:29	1.28	*0.22*
		J.R. T4 (10 months post)	III	0.89	0.71	0.18	89:71	1.25	*0.20*
20	McCarthy (2014)	L.T. Pre-Treatment	V *2-word*	1.00	1.00	0.00	1:1	0.00	0.00
		L.T. Post-Treatment	VI *3-word*	1.00	1.00	0.00	1:1	0.00	0.00

A regression analysis (Table 8) was performed to determine if rate of semantic errors and imageability effect could be predicted from accuracy of word repetition. Twenty-two cases met the inclusion criterion for this analysis—word span of more than 1. A linear regression revealed a negative correlation between semantic errors and word span size (F (1,20) =-4.21, p <0.01 with smaller word span resulting in higher rate of semantic errors.

Table 8.
Cases reporting imageability effect, span size and rate of semantic errors

Study #	First Author (Year)	Case Study	Auditory-Verbal STM span (I-VII)	Nouns-Average Across I/F Reports	Semantic Errors-Single Word Average	Imageability Effect (HI÷LI)
1	Michel (1983)	M.R.	II a	0.11	0.25	10.00
2	Jefferies (2007)	Dysphasic 1	II a	0.15	0.22	0.00
3	Martin (1992)	N.C.	II b	0.29	0.19	7.58
4	Ablinger (2008)	J.R. T1	II b	0.30	0.01	1.60
5	Wilshire (2004)	M.S.	II b	0.30	0.06	1.65
6	Majerus (2001)	C.O. May 1994	II b	0.35	0.21	1.71
7	Franklin (1994)	D.R.B.	II b	0.39	0.20	25.67
8	Howard (1988)	M.K.	II c	0.43	0.08	2.07
9	Valois (1995)	E.A.	II c	0.44	0.11	4.85
10	Tree (2001)	P.W.	II c	0.49	0.01	1.76
11	Ablinger (2008)	J.R. T2	II c	0.51	0.00	1.60
12	Croot (1999)	C.B. Sept. 1996	II c	0.52	0.06	1.71
13	Hanley (1997)	P.S.	II c	0.56	0.00	1.87
14	Duhamel (1986)	N.Z.	II c	0.58	0.48	1.88
15	Ablinger (2008)	J.R. T3	II d	0.66	0.00	1.62
16	Trojano (1992)	S.C.	II d	0.67	0.05	1.56
17	Knott (2000)	F.M.	II d	0.67	0.00	1.13
18	Gold (2001)	M.M.B.	II d	0.71	0.01	1.28
19	Jefferies (2007)	Dysphasic 2	II d	0.73	0.03	1.32
20	Coslett (1991)	W.T.	III	0.81	0.10	1.50
21	Ablinger (2008)	J.R. T4	III	0.81	0.00	1.23
22	Martin (1996)	N.C. 12-18 months post	III	0.85	0.04	1.77

Discussion

The purpose of this review was to determine if a characteristic profile of recovery along the deep-phonological dysphasia continuum could be established through the evidence base within the existing literature. The review identified concrete inclusion criteria from different cases, and a comprehensive picture of the pattern of recovery emerged from the examination of multiple aspects of patient language performance. An important finding was the commonality of specific impairment with respect to LI words.

The presented research provided the opportunity to test a model-based treatment approach based on the predictions of the IA model as developed by Dell and colleagues (Dell & O'Seaghdha, 1992, Martin & Saffran, 1992; Martin et al., 1994) and its extension in Martin and Saffran's activation-maintenance hypothesis (Martin & Saffran, 1997).

Results were consistent with the literature that noted pervasive impairment of verbal STM as predictive of severity along a continuum of deep-phonological dysphasia (e.g., Martin & Saffran, 1992; Martin et al., 1994, Foygel and Dell, 2000; Hanley et al, 2004; Dell et al., 2007). A characteristic error pattern was the presence of semantic errors. The consistent report of an imageability effect in these findings was encouraging, but these errors should in the future be reviewed in the context of auditory-verbal STM performance.

The pattern of semantic error rates and imageability effects in repetition were systematically related to auditory-verbal STM span. Auditory-verbal STM capacity was not found to be a significant predictor of frequency effect.The well-known and prominent marker of semantic errors was an unexpectedly subtle error pattern in even the most severe cases. Semantic errors in repetition were not as common as many other speech errors. To put this into perspective, Dell et al. (2007) examined a total of 6,575 errors in repetition produced by sixty-five PWA and reported zero occurrences of semantic errors. When seminal articles of deep dysphasia were examined for overall presence of semantic errors and single-word repetition, the percentages were relatively low. Howard and Franklin (1988) reported MK presenting with 0.08 semantic errors; Trojano (1992) reported SC presenting with 0.05 semantic errors; Martin and Saffran (1992) reported NC presenting with 0.19 semantic errors.

The prominent marker of semantic error production was less obvious in testing for deep dysphasia than for deep dyslexia. This differential has hindered identification of deep dysphasia deficits. Dell et al. (2007) explained how the two-step model of lexical access could not include more than two percent semantic errors due to the assumption of perfect recognition for auditory input. Along with the rarity of the disorder, the testing limitation might account for the few articles available. Howard and Franklin (1988) compared deep dysphasia to the likelihood of simultaneously presenting with dental, viral, abdominal and podiatric ailments.

It is important to note observations that have drawn significant distinctions between these two modality specific impairments. Karanth (2000) reported that while deep dyslexia was the third major type of acquired dyslexia, the rarity of deep dysphasia in its purest form presented a challenging disadvantage to researchers seeking to find appropriate participants. Karanth concluded that the identification of deep dyslexia in the literature covered a wide range of errors characterized as semantic (2000). Categorization could include visual semantic errors (milk->depot, hike-> hitchhike), (dogma->dog, woman) and/or visual and semantic errors: sympathy: orchestra->sympathy “symphony”, stream->steam “train”) Marshall & Newcombe, 1978; Saffran, Schwartz, & Marin, 1976).

This examination of the literature base also raised challenging practical and theoretical questions about the extent to which clinical intervention can influence the pattern of recovery in this population. As typically observed in deep and phonological dysphasia and consistent with the presentation of NC, imageability effects in repetition of single and multiple words remained a marker across the continuum of dysphasia; HI words were repeated more accurately than LI words. The review findings on imageability effects in repetition served as a key theoretical motivation for this dissertation and led to the focus on the one feature common to aphasia profiles wherever they fall on the severity continuum.

CHAPTER 3

THE EFFECTS OF SEMANTIC CONTEXT ON DEEP TO PHONOLOGICAL DYSPHASIA: A TREATMENT STUDY

Findings from the literature base were used to inform understanding of recovery along a continuum of deep to phonological dysphasia. The greatest practical ramification of the preceding findings within the foundational literature was an unanswered question: What treatment approaches best promote improved performance for this population during recovery? The literature, when investigated systematically, provided irrefutable evidence that this impairment exists on a continuum of severity. This dissertation research then undertook a single-case study and a broader four-condition, multi-participant facilitation investigation with the goal of developing and testing appropriate treatment approaches. The profound contrast between superior visual processing in contrast to auditory processing and a pronounced imageability effect were consistent markers of this impairment continuum. Deep-phonological dysphasia has been recognized as a phonological impairment where impaired maintenance of activation across levels of processing is subjected to rapid decay, thus restricting auditory STM (Martin et al., 1996; Dell et al., 1997).

In the clinical setting, it is common to note a patient's strengths and weaknesses and attempt to use these strengths to compensate for areas of impairment. In the consideration of an effective treatment approach, a visually supported system was considered. Ultimately, a strictly auditory approach was hypothesized to be a direct and relevant method. The strength of visual processing was not forgotten. The present research investigations, however, focused on strictly auditory tasks and whether they could be used to manipulate the integrity of the visual processing system. This focus resulted in the development of a treatment approach aimed at improving imageability effect, a trademark impairment of this continuum, and was first employed in the following single-subject case study with participant LT.

The primary purpose of the LT study was to investigate whether LT's ability to access and maintain activation of LI words could be improved by creating contexts (adjective-noun phrases) that enhanced the imageability of LI words. Specifically, the study sought to determine if pairing LI words in semantically cohesive adjective-noun phrases (e.g., long *distance*; social *exclusion*) would facilitate their repetition in the context of that phrase and later when presented in word pairs for repetition (e.g., *distance*- *exclusion*).

Imageability effect had been manipulated previously in a naming treatment experiment in which Kiran, Sandberg and Abbot (2008) provided evidence that training abstract (LI) words showed greater generalization to untrained concrete (HI) words than the reverse. This result followed the principle of the complexity account of generalization between trained and untrained items—that is, training more complex (abstract) words leads to greater generalization to untrained less complex words (concrete) words. (See also Kiran & Thompson, 2003.)

In the LT study, the rationale for manipulating imageability of abstract word stimuli derived from the assumption in the IA model that there is interaction between lexical and semantic levels of word representation. Manipulating imageability of abstract words by narrowing their semantic interpretation in an adjective-noun phrase should make them temporarily more accessible, but importantly this improved access should carry over to repetition of low-image words without the phrasal context. Specific predictions of the LT study include:

- Training repetition of LI-LF nouns in semantically cohesive LI-LF adjective-noun phrases (e.g., long *distance*; social *exclusion*) will improve accuracy of repetition of these same nouns when they are presented as word pairs (e.g., *distance exclusion*).
- Treatment effects for repetition of LI-LF pairs will be less robust when training repetition of LI-LF adjective-noun phrases that are not semantically cohesive (e.g., *purple agility*).
- Improvements in repetition of LI-LF pairs will generalize to improvements in repetition of untrained LI-LF pairs.

Method

The treatment involved repetition of abstract word pairs (modifier-noun phrases) created in a way that increased the semantic and syntactic cohesiveness of words in the pair. For example, to improve the repetition of the word pair "distance– exclusion," the participant was provided the phrases "long distance" and "social exclusion." The goal of this manipulation was to increase the probability of accessing the abstract words' lexical and semantic representations by enriching their semantic-syntactic context. It was hypothesized that this increase in accessibility would be maintained when the words were repeated without the contextual phrase.

Participant. The participant was LT, a 34 year-old, right-handed, college-educated female. She experienced a left middle cerebral artery infarct involving the left temporal and parietal lobes, and posterior insula in October, 2009. LT's employment history included work as a teacher, poet, writer, and actress. She was approximately 36 months post-onset at the beginning of this study. Prior to participation in the treatment study, LT gave written informed consent as approved by the Institutional Review Board (IRB) of Temple University. As per study guidelines, LT passed an audiometric pure-tone, air conduction screening at 25 decibels hearing level (dB HL) at 1K, 2K, and 4K hertz (Hz) bilaterally.

Pre-Treatment Assessment. LT was administered a number of standardized and laboratory-developed assessments to determine aphasia type and language profile. (Results can be found in Table 9.) Unlike many reported cases of deep-phonological dysphasia (e.g., Howard & Franklin, 1988; Martin & Saffran, 1992), LT presented with minimal impairment of picture naming, scoring .85 (51/60), with mainly non-responses and two semantic paraphasias on the long form of the *Boston Naming Test* (BNT; Goodglass, Kaplan & Weintraub, 1983). To measure auditory comprehension, the complex ideational material subtest of the *Boston Diagnostic Aphasia Examination* (BDAE, Goodglass et al., 1983) was used. LT's pattern of responses on the BDAE revealed decreased accuracy as a function of difficulty of the auditory comprehension task. In contrast, spontaneous language was preserved and was judged as grammatical and free of paraphasias. Although the *Western Aphasia Battery-Revised* (WAB-R; Kertesz, 2006) was not administered immediately prior to testing, it was notable that

LT's aphasia classification was conduction aphasia, with an aphasia quotient (AQ) of 88.6 (88.6/100).

LT's ability to discriminate words from nonwords was tested using the *Auditory Lexical Decision Test* (Martin & Saffran, 2002). Her performance was greater than 2 standard deviations (*SD)* above the mean performance of persons with aphasia when tested in Aphasia Rehabilitation Research Laboratory at Temple University (ARRL) on recognition of words $z = 2.67$, n = 21, .88 ± .06, and nonwords $z = 2.01$, n = 21, .91 ± .07, indicating a relatively spared ability to map phonemes onto lexical representations. Lexical comprehension of abstract, concrete, and emotional concepts was tested using the *Shallice Test of Abstract, Concrete and Emotional Concepts* (Shallice & McGill, unpublished). Here, LT demonstrated a significant advantage in the identification of concrete words compared to abstract words (86% compared to 40%, $p = 0.04$).

Table 9.
LT's performance on standardized language evaluation: Pre-and interim treatment.

Measure	*Pre treatment*	*Interim*
Boston Naming Test[1] (*n* = 60)	0.85	0.95
Boston Diagnostic Aphasia Evaluation[2]		
Complex Ideational Material (*n* = 12)	0.67	0.83
Auditory Lexical Decision[3]		
Words (*n* = 40)	0.93	
Nonwords (*n* = 40)	1.00	
Shallice Test of Abstract, Concrete and Emotional Concepts[4]		
Abstract (*n* = 30)	0.40	0.50
Concrete (*n* = 30)	0.86	0.80
Emotional (*n* = 15)	0.73	0.80

[1] Kaplin et al. (1983) proportion correct.
[2] Goodglas and Kaplan (1983) proportion correct.
[3] Martin, Schwartz, and Kohen (2006) proportion correct.
[4] McGill and Shallice (1978) proportion correct.

Pre-Treatment Cognitive Measures. Repetition span subtests of the *Temple Assessment of Language and (Verbal) Short-Term Memory in Aphasia* (*TALSA*, Martin, et al., 2010) were used to assess digit and word span capacity. Results are reported in Table 9. All span measures reflect serial order recall. For digit span, performance was within 1 SD below the mean performance of persons with aphasia (PWA) tested in ARRL for pointing z= -.59, n = 38, 3.24 ± 1.74 and repetition z= -.44, n = 38, 3.54 ±1.68.

Measures of verbal span on *TALSA* subtests provided a refined diagnosis of LT's impairments. (See Table 10.) LT presented with a moderate to severe auditory-verbal repetition deficit influenced by lexicality and imageability effects. Performance was similar on measures of pointing word span, z= -.56, n = 38, 2.88 ± 1.21, and repetition word span z= -.50, n = 37, 3.06 ± 1.33. Word span was more than1 SD below the mean score of PWA tested at ARRL, z= -.96, n = 34, 2.70 ± 1.35. Nonword span was also below average z= -.54, n = 34, 1.52 ± .95. When span was varied for imageability and frequency, accuracy was lowest for HI-LF words z= -.86, n = 35, 2.37 ± 1.21 and LI-LF words z= -.70, n = 35, 2.20 ± 1.33. In word repetition span tasks, errors included semantic and phonological paraphasias and unrelated word errors. On a probe memory span task that manipulated semantic and phonological characteristics of words in span, LT's semantic span was close to the mean of PWA tested in the ARRL, z= -.21, n = 34, 3.44 ± 1.52. Probe memory phonological span was an area of strength, with LT scoring over 2 SD above the mean, z= 1.52, n = 34, 3.80 ± 2.04.

Table 10.
LT's performance on TALSA span measures with language variations.

	Pre	Post
Digit and Word Span[1]		
Digits (ISO)		
Pointing	2.20	2.60
Repetition	2.80	*4.20*
Words (ISO)		
Pointing	2.20	2.40
Repetition	2.40	*3.20*
Word and Nonword Repetition Span [2]		
Word	1.40	1.20
Nonword	1.00	1.00
Repetition span for words varied for frequency (F) and Imageablility (I)[3]		
HI	2.67	2.33
LI	1.67	1.00
HF	1.33	*2.00*
LF	1.33	1.33
Probe memory Span [4]		
Semantic	3.12	*4.00*
Phonological	6.56	6.76

[1] Maximum string length = 7 items
[2] Maximum string length = 5 items
[3] Maximum string length = 5 items
[4] Maximum string length = 7 items
HI-HF: high image, high frequency LI-HF: low image, high frequency
HI-LF: high image, low frequency LI-LF: low image, low frequency

Pre-Treatment Evaluation of Functional Communication. The *Communicative Effectiveness Index* (*CETI*; Lomas et al., 1989) was used to quantify the perceptions of LT and her primary caregiver (mother) of LT's functional communication abilities before and after her stroke on a 1-10 scale. Both mother and daughter rated the various aspects of communication requiring intact auditory processing as poor to fair (range 3 -7; mean = 4.5). This index provided functional examples of the impact LT's aphasia had on her everyday life. Conversational situations noted to be difficult for her included initiation, participation, spontaneous topic change, fast pace of speech, and multiple conversational partners.

Experimental Stimuli

Stimuli were selected from a corpus of words that varied in frequency and imageability assembled in the ARRL. The stimuli consisted of 30 LI-LF noun pairs that were four to six syllables in length. Words in pairs were neither semantically nor phonologically related. Frequency and imageability ratings were verified through use of the MRC Psycholinguistic database (Wilson, 1988). Three sets of HI-HF noun pairs, ten pairs per set, were assembled and assigned to two treatment conditions and a response generalization condition:

Set 1 (Treatment 1, TX1): "semantically + syntactically cohesive" (SEM+SYN) adjective-noun phrases (e.g., high rating).

Set 2 (Treatment 2, TX2): "syntactic only" (SYN only) adjective-noun phrases that are not semantically cohesive (e.g., purple agility).

Set 3 (Response Generalization): "limited exposure" condition including ten noun pairs to assess response generalization.

Selection of adjectives for the adjective-noun phrases followed the procedures and criteria for selection of the nouns.

Experimental Design

A single-subject multiple-baseline multiple probe design was used to analyze acquisition, maintenance, follow-up, and generalization effects of treatment. The dependent variable was accuracy of repetition of LI-LF pairs in probes. During the baseline phase, the 30 LI-LF noun pairs were continuously measured in probes in randomized order with no visual support until a stable baseline was achieved. A stable baseline was defined as no more than .20 variability between two consecutive probes within three consecutive trials, a moderately conservative criterion used by Wambaugh, et al., (2007) and others (Wambaugh & Ferguson, 2007; Kiran, et al., 2013).

During the acquisition phase of TX1, Set 1 probes identical to those in baseline were administered prior to the start of each treatment session in randomized order, while LI-LF pairs in Set 2 (for TX2) were maintained in baseline at a reduced probing schedule, every other probe session. The LI-LF pairs in Set 3, the limited exposure set, were probed every fourth session to assess response generalization. After the acquisition phase for TX1, the probing schedule was switched so that Set 2 items (TX2) were continuously probed and LI-LF pairs in Set 1 (TX1 Items) were probed every other probe session in maintenance. Criterion for acquisition of LI-LF pairs was .80 correct across two consecutive probes. Set 1 LI-LF noun pairs were probed every other probe session in maintenance. Follow-up probes for TX1, TX2, and response generalization conditions were administered three, six, and eight weeks following the end of all treatment. Pre-treatment language evaluations were re-administered between treatment conditions. At the completion of treatment, subtests from the *TALSA* (Martin, et al., 2010) were re-administered.

Each treatment session included the repetition of 60 phrase primes in total. Treatment followed an implicit priming protocol. Implicit, masked priming, refers to tasks which immediately and automatically activates the language processing system (Silkes, Dierkes & Kendall, 2013). The subject was instructed to repeat adjective-noun phrase primes (e.g., “common fallacy”) three times following successive verbal presentation. Following repetition of the target primes, the target LI-LF word pair (e.g., rating-fallacy) was presented for repetition one time. Ten repetitions of LI-LF word pairs occurred within one session. The treatment program consisted of two treatment conditions:

- Treatment Condition One (TX1; SEM+SYN): LI-LF nouns in pairs from Set 1 were combined with adjectives to form semantically cohesive adjective-noun phrases (e.g., long *distance*; social *exclusion*) to be used as primes for the LI-LF pair targets (e.g., *distance-exclusion*).
- Treatment Condition Two (TX2; SYN only). Adjective-noun phrases were formed from LI-LF pairs in Set 2 for use as primes. Adjective-noun phrases were not semantically cohesive (e.g., purple *agility).*

The order of presentation of the phrase primes for each noun in the pair was alternated across treatment sessions using an ABBA design (e.g., treatment session one: AB - "high rating" followed by "common fallacy"; treatment session two: BA- "common fallacy" followed by "high rating"; treatment session three: AB- "high rating" followed by "common fallacy" and so on). Sessions were held two times per week and lasted between 45 and 60 minutes. Each included repetition of 10 to 30 LI-LF probes followed by the treatment, which required a total repetition of 60 LI-LF adjective-noun pairs. (See Appendix A for an example of the treatment protocol.)

Reliability and procedural fidelity measures were employed throughout all conditions. Primary observers were licensed speech and language pathologists and secondary observers were laboratory research assistants. All primary and secondary observers worked in the ARRL and were trained in the data collection protocol as well as proper response coding and provided operational definitions to support these procedures.

Primary observers handwrote all participant responses in real time using a pre-constructed checklist, and all sessions were audio-recorded. Inter-rater reliability was established using independent secondary observers present in real time within the session and audio recordings. Independently written transcriptions by a secondary observer within the treatment room were collected in 15 of 40 sessions across conditions. The result was 1.00 agreement among examiners. Following all sessions, a secondary observer listened and re-transcribed responses that were audio recorded in probe testing, with 1.00 (770/770 items) agreement with the other examiners.

Effect Sizes. To estimate the strength of treatment effects in each condition, effect sizes were calculated according to the guidelines of Beeson and Robey (2006). For TX1 and TX2, effect sizes were calculated using the mean of all baseline probes and the mean of last three treatment probes. They were also calculated for follow-up effects using the mean of all baseline probes and the mean of the three follow-up probes.

Results and Discussion

Data Analysis. The proportions of LI-LF pairs repeated correctly in probes during each treatment condition and in all phases of treatment are shown in Figure 3. LT demonstrated stable repetition performance across TX1, TX2, and response generalization probes prior to the beginning of treatment, as defined by .20 or less accuracy across three sessions for all three conditions. By baseline session ten, LT's proportion correct of stimuli was within .20 across baselines eight, nine, and ten. Across these sessions, proportion correct of TX1 stimuli averaged .25; for TX2 stimuli, .30; and for response generalization stimuli, .55. Her level of performance met the study criterion for baseline stability across all conditions.

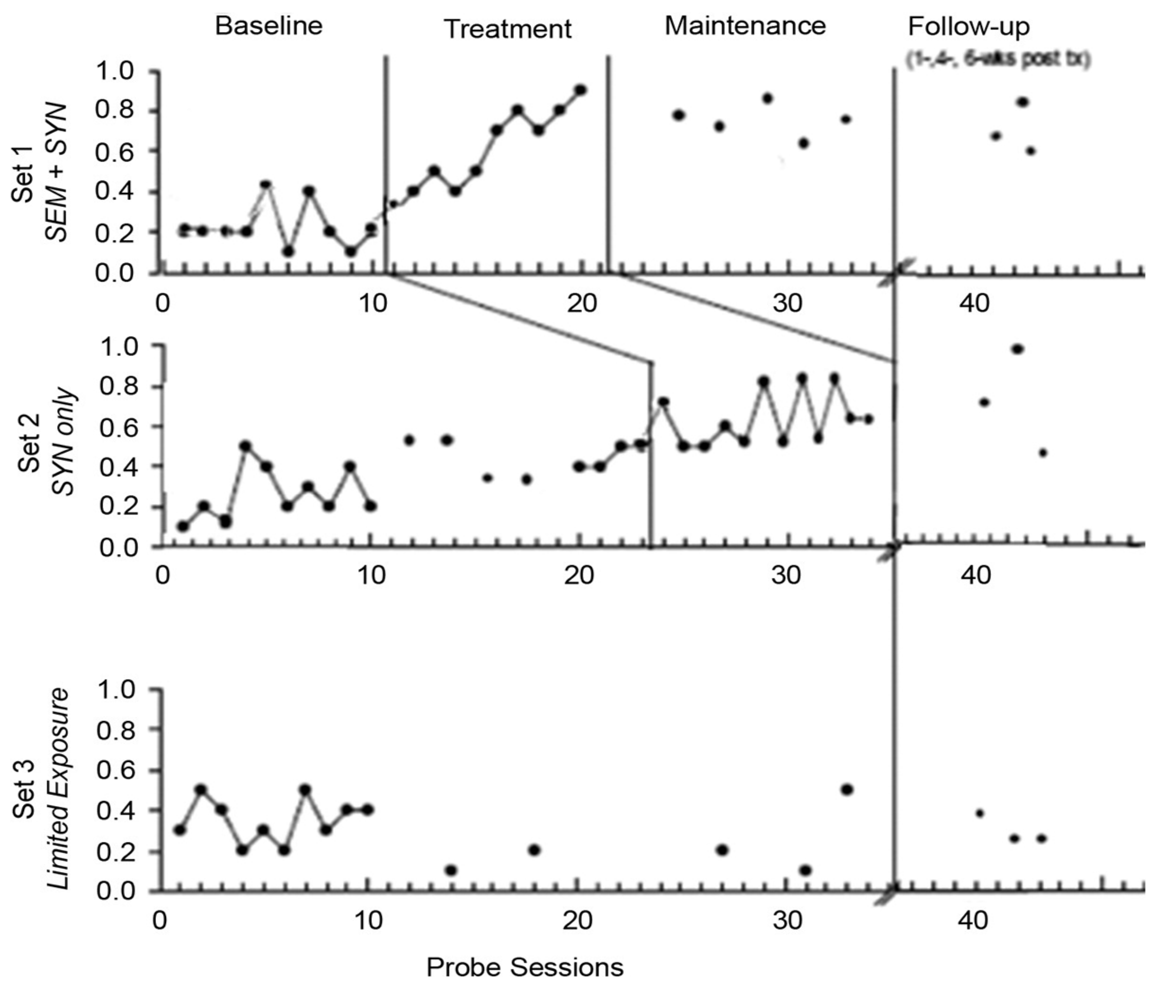

Figure 3. Proportion correct on LI-LF probe trials in for SYN + SEM, SYN only and limited exposure treatment stimuli across phases of treatment.

LT's proportion of correct repetitions of LI-LF pairs in TX1probes demonstrated steady improvement. Her ability to repeat treatment word pairs during probe testing increased by .70 in TX1, and behavioral criterion was met by probe 10. Baseline testing was extended before application of treatment to TX2 LI-LF pairs to re-establish stable accuracy levels. Four baseline probes were conducted, resulting in mean repetition performance of .45, which was a .19 increase from baseline performance levels. Despite this modest increase, LT's proportion of correct repetitions of LI-LF pairs in probe testing was variable, and the behavioral criterion was not met.

Given LT's variable performance during the TX2 condition, a semi- replication of the TX1 condition was introduced using the stimuli from TX2. Semantically cohesive adjective-noun phrases were created for each TX2 LI-LF word. Unexpectedly, in baseline testing LT reached criterion on repetition of the noun pairs by the third baseline probe. As a result, there was no need to continue this attempt at replication of the SEM-+SYN treatment. Although not shown in Figure 3, these data were obtained following the end of TX2 and before the first follow-up probe, three weeks after the last TX2 probe.

Accuracy for the response generalization stimuli remained in the baseline range with no evident improvement. During TX2, effects of TX1 remained above baseline levels but below final acquisition levels.

All probes were administered three weeks, six weeks, and eight weeks following the end of the TX2 condition. Thus, TX1 ended approximately 15 weeks prior to the final all probe. Despite this lapse in time following TX1, accuracy levels for these pairs remained at the same behavioral criterion level as the last probe within the treatment condition during the three-week follow-up probe. Accuracy then declined by .20 in subsequent follow-up probes, resulting in mean repetition performance of .80. Accuracy for the TX2 stimuli was variable, as it was during treatment. No change in accuracy for response generalization stimuli was observed.

Effect sizes. Effect sizes are reported in Table 11. The effect size for TX1 was more than two times the effect size for TX2, indicating that semantic coherence of the adjective-noun phrase was a key ingredient of the priming effect of the adjective noun phrases. Effect sizes in the follow-up phase were lower than in the treatment phase, but the effect size for TX1 was greater than TX2.

Table 11.
Effect sizes for treatment and maintenance phrases of treatment one and treatment two.

Condition	Treatment	Follow-Up
Treatment condition one: *SYM+SYN*	5.80	3.92
Treatment condition two: *SYN only*	2.77	2.16

During the baseline testing between TX1 and TX2, some interim language evaluations were re-administered. Results of these tests are reported in Table 11. LT's pre-treatment performance on a test of *Auditory Lexical Decision* (Martin &Saffran, 2002) was within normal range (Table 9) and did not require re-administration. Lexical comprehension of abstract, concrete, and emotional concepts using the *Shallice Test of Abstract, Concrete and Emotional Concepts* (T. Shallice and J. McGill, unpublished) revealed a small increase in accuracy for abstract words. LT demonstrated improved auditory comprehension on the complex ideational material subtest of the *Boston Diagnostic Aphasia Examination* (*BDAE*, Goodglass et al., 1983), with a .16 increase in accuracy. Picture naming improved by .10 on the *Boston Naming Test* (*BNT*; Goodglass et al., 1983). Although not administered immediately prior to treatment, the post-treatment aphasia quotient for LT improved 6 points, from 88.6 to 94.5. according to the *WAB-R* (Kertesz, 2006). This result was notable because LT's post-treatment aphasia classification as measured by the aphasia quotient changed from a diagnosis of conduction aphasia to normal or non-aphasic.

Performance on repetition span subtests of the *TALSA* (Martin et al., 2010) following treatment are reported in Table 10. Most notable, for repetition of digit span, performance was improved more than1SD above the mean performance of persons with aphasia, from a span of 2.80 to a span of 4.20. With respect to the repetition of words, LT also demonstrated an increase in accuracy with performance falling just under mean performance of PWA in the ARRL. Performance on probe memory spans manipulating semantic and phonological characteristics revealed modest improvements in accuracy on each span. Results on other measures of span were unremarkable.

The Communicative Effectiveness Index (CETI; Lomas et al., 1989) was administered after post-testing to determine the perceptions of LT and her mother concerning LT's functional communications. LT's mother's ratings showed improvement across categories and demonstrated an overall increase of .23. Most notably, LT's own ratings increased to 10.0. She reported that she perceived her functional communication abilities across categories to be as efficient as they were before her stroke. Anecdotally, LT and her mother reported that following the conclusion of the treatment study LT felt comfortable speaking on the telephone, as opposed to alternative means of visual electronic communication.

Implications for Future Treatment. Treatment outcomes indicated that increasing the semantic cohesiveness of low-frequency and low-imageability words improved this participant's ability to repeat those words in the context of the adjective-noun word pair and also in isolation. This study was initially developed to extend current understanding of damaged language processing and damaged STM in PWA. While the literature base has confirmed that in PWA damaged language processing and damaged STM recover in tandem, there is a need for treatment approaches that target both areas.

CHAPTER 4

IMPROVING ACCESS TO WORDS OF LOW IMAGEABILITY ON A CONTINUUM OF IMPAIRMENT: A FACILITATION STUDY EXAMINING THE EFFECTS OF SEMANTIC CONTEXT

The case study of LT discussed in Chapter 3 pioneered the use of a treatment paradigm developed to improve auditory-verbal STM capacity as a function of the language processing system. Evidence from this single-case study indicated that manipulating lexical and semantic influence within an adjective-noun phrase enhanced LT's semantic processing as well as auditory-verbal STM (McCarthy et al., 2014; McCarthy et al., 2016). Specifically, embedding these words within a cohesive phrase generalized and increased the likelihood of successful repetition later without the semantic and syntactic context.

The phase of the research reported in the current chapter is an extension of the original single-case study. The main object of this research was to further test paradigms developed to improve auditory-verbal STM capacity as a function of the language processing system. The primary question was whether increasing semantic cohesiveness was an effective method for the treatment of repetition impairments in aphasia. The facilitation studies reported in this chapter were designed to test the usefulness of treatments that control for the manipulation of stimuli characteristics and modality of presentation.

The following predictions were developed to quantify the efficacy of this treatment:

- Training repetition of LI nouns in semantically and syntactically cohesive LI adjective-noun phrases (e.g., business casual) or sentences (e.g., The affair is business casual) will significantly improve performance in repetition of these same nouns when they are presented as unrelated noun pairs/triplets for serial recall (e.g., casual-poverty/-wisdom) following a ten-minute delay.
- Immediate and delayed facilitation effects of training repetition of LI adjective-noun phrases (e.g., rude agility) or sentences (e.g., Calcium is a rude agility) that are not semantically cohesive will have a significantly smaller effect on performance on repetition of these same nouns when they are presented as unrelated noun pairs/triplets for serial recall in comparison to the effects of the matching condition which employed semantic enhancement.
- Training repetition of LI nouns in semantically related serial recall span tasks of pairs/triplets (e.g., faith-hope/devotion) demonstrates an approach that will complete repetition priming and semantic priming. Immediate improved performance in repetition of these same nouns when presented as unrelated noun pairs/triplets for serial recall is expected.
- Treatment facilitation effects will generalize to improved performance on all-stimuli post-test/*TALSA* (Martin, et al., 2010) post-tests, when compared to all baseline levels as determined by stimuli-pre-test/*TALSA*(Martin, et al., 2010) pre-test.

Method

Participants: **Inclusion and Recruitment**. Potential research participants were evaluated in the Eleanor M. Saffran Center for Cognitive Neuroscience within the Department of Communication Sciences and Disorders at Temple University. Initial contact with participants was made in two ways: (a) from a laboratory pool of participants (experimental and control) who had previously participated in the Center's studies and had agreed to be contacted for future studies and (b) via referral from physicians, speech language pathologists, or other clinicians. Participants were fully consented prior to enrollment.

The study goal was to recruit an equal number of males and females, aged 21 to 80, that were representative of the racial demographics of the Philadelphia area. Participants were required be at least six months post-onset of left CVA (cerebrovascular accident). Background testing completed prior to the facilitation study included the *TALSA* (Martin, et al., 2010). Performance on this assessment revealed participants that demonstrated difficulty with repetition span tasks and was used to determine if the participant was appropriate for the two-word or three-word condition of this study. Relevant standard participant demographic information was defined as age, education, sex, race, time post-onset, and etiology of acquired neurological deficit. This information was collected during the first session. Following the completion of data collection, these data were analyzed in order to characterize the sample of participants through the use of common descriptive statistics. Background history results included measures of central tendency (mean, median) and variation (standard deviation, interquartile range).

Pre- and Post-Test Facilitation Study Assessment. Pre and post-facilitation test background testing included a repetition span subtest varying frequency and imageability from the *TALSA* assessment battery (Martin et al., 2010). This testing revealed sensitivity to the repetition of HI versus LI words and also provided information on word-span capacity. If a participant's performance on this standardized language evaluation was identified as appropriate for candidacy in this facilitation study, continued assessment was conducted.

Level of repetition impairment determined if a second screening tool would be administered, depending on whether the participant met qualifications for participation in the two-word or three-word version of the facilitation study. A second screening tool, developed specifically for this facilitation study, measured performance accuracy on the repetition of all trained and untrained stimuli used in the facilitation study, varied across word order position. At the conclusion of the facilitation study, these measures were re-administered. Post-test performance assessed change in the participant's ability to repeat trained versus untrained stimuli in isolation. Post-testing on the *TALSA* (Martin, et al., 2010) determined if there was a difference in repetition performance of words varied for imageability and frequency.

Facilitation Study Design: Experimental Stimuli

Experimental stimuli were selected from a corpus of 102 LI-LF nouns developed specifically for the investigation. The *TALSA* (Martin, et al., 2010) subtest varied for frequency, and imageability served as the primary pre-test that determined eligibility for participation in study. It was logical to create a corpus of experimental stimuli using the properties of LI ("abstract") targets within the word repetition span subtest of the *TALSA* battery. List lengths one through six of the TALSA subtest consist of 76 LI-LF laboratory developed noun targets. Performance on this measure was a primary pre-testing tool.

Frequency, imageability, and syllable length of the *TALSA* (Martin, et al., 2010) items were used to control syllable length and phonological similarity in addition to maintaining imageability ratings consistent with the *TALSA* LI-LF repetition span task items. To maintain consistency, LF words were included. In terms of syllable length, there were 31 one-syllable (0.30), 48 two-syllable (0.47), and 23 three-syllable items (0.23). The 60-item experimental stimuli set mean frequency was 7.69 (SD=7.55), following Pastizzo and Carbone (2007); rating and mean imageability was 391.12 (SD=23.64), following the Coltheart (1981) rating system. Low imageability words were defined as ± ¾ SD of the mean frequency used on *TALSA* (Martin, et al., 2010) stimuli (min 341, max 430). Sixty items were selected as experimental stimuli; these were previously reviewed. Noun lists from the 60-word corpus were exclusive to an assigned ondition. (See Table 12 for the itemization in detail.)

Table 12

Experimental stimuli

Item	Trained Noun Target	Untrained Noun Target	Label	Relevant Stimuli Information Imageability	Frequency	Syllables
1	Habit		Condition One- Trained Target *A*	418	12	2
2	Routine		Condition One Trained Target *B*	341	6	2
3	Tribute		Condition One- Trained Target *C*	386	4	2
4	Compliment		Condition One- Trained Target *D*	496	1	3
5	Vow		Condition One- Trained Target *E*	389	1	1
6	Pledge		Condition One- Trained Target *F*	408		1
7		Alter	Condition One- Generalization Target A	413	16	2
8		Bury	Condition One- Generalization Target B	401	1	2
9		Comfort	Condition One- Generalization Target C	421	13	2
10		Devotion	Condition One- Generalization Target D	411	2	3
11		Mood	Condition One- Generalization Target E	394	16	1
12		Saint	Condition One- Generalization Target F	394		1
13	Dispute		Condition Two- Trained Target *A*	421	5	2
14	Graphic		Condition Two Trained Target *B*	352	18	2
15	Impulse		Condition Two- Trained Target *C*	396	5	2
16	Loyalty		Condition Two- Trained Target *D*	411	6	3
17	Pat		Condition Two- Trained Target *E*	386	21	1
18	Fare		Condition Two- Trained Target *F*	384	2	1
19		Clever	Condition Two- Generalization Target A	387	9	2
20		Recruit	Condition Two- Generalization Target B	412	5	2
21		Wasteful	Condition Two- Generalization Target C	373	1	2
22		Zodiac	Condition Two- Generalization Target D	415		3
23		Scent	Condition Two- Generalization Target E	421		1
24		Myth	Condition Two- Generalization Target F	359	25	1
25	Halt		Condition Three- Trained Target *A*	417	2	1
26	Pause		Condition Three- Trained Target *B*	347	7	1
27	Talent		Condition Three- Trained Target *D*	399	2	2
28	Skill		Condition Three- Trained Target *E*	266	27	1
29	Loan		Condition Three- Trained Target *G*	430	5	1
30	Debt		Condition Three- Trained Target *H*	284	7	1
31		Shame	Condition Three- Generalization Target A	419	9	1
32		Blunt	Condition Three- Generalization Target B	404	1	1
33		Sincere	Condition Three- Generalization Target D	407	4	2
34		Ease	Condition Three- Generalization Target E	327	2	1
35		Bawl	Condition Three- Generalization Target G	417		1
36		Ate	Condition Three- Generalization Target H	364	23	1
37	Recess		Condition Three- Trained Target *C 3-word only*	415		2
38	Ambition		Condition Three- Trained Target *F 3-word only*	346	6	3
39	Frugal		Condition Three- Trained Target *I 3-word only*	367		2
40		Humane	Condition Three- Generalization Target C 3-*word only*	383	2	2
41		Unstable	Condition Three- Generalization Target F *3-word only*	356	10	2
42		Suspect	Condition Three- Generalization Target I *3-word only*	377	30	2
43	Kale		Condition Four- Trained Target *A*	391		1
44	Guilt		Condition Four- Trained Target *B*	381	3	1
45	Patience		Condition Four- Trained Target *D*	363	4	2
46	Hire		Condition Four- Trained Target *E*	394	1	1
47	Cure		Condition Four- Trained Target *G*	397	18	1
48	Dull		Condition Four- Trained Target *H*	373	3	1
49		Fraud	Condition Four- Generalization Target A	381	3	1
50		Aim	Condition Four- Generalization Target B	383	9	1
51		Sable	Condition Four- Generalization Target D	419		2
52		Apt	Condition Four- Generalization Target E	295	4	1
53		Brave	Condition Four- Generalization Target G	427		1
54		Firm	Condition Four- Generalization Target H	404	56	1
55	Stylish		Condition Four- Trained Target *C 3-word only*	407		2
56	Liberty		Condition Four- Trained Target *F 3-word only*	392	10	3
57	Hazard		Condition Four- Trained Target *I 3-word only*	394	1	2
58		Token	Condition Four- Generalization Target C *3-word only*	416	1	2
59		Gender	Condition Four- Generalization Target F *3-word only*	376	77	2
60		Merit	Condition Four- Generalization Target I *3-word only*	380	4	2

Table 13. Experimental Stimuli Defined, 2-word/3-word

	Condition One	Condition Two	Condition Three	Condition Four
	Semantic +Synactic (Related)	Synactic-only (Unrelated)	Semantically Structured (Related)	Structured-only Word Span(Unr
Trained Stimuli: Word Condition 4) Trained Target: (A-F) Rating [Imag.]; Rating [Freq.]; # of Syllab	1 Habi Condition One Trained Ta (Imag. 418; Freq. 12; 2syl.)	1 Dispute Condition Two Tr Target A (Imag. 4 2syl.)	1 Halt Condition Three Trai (Imag. 417; Freq. 2; 1syl.)	1 Habit Condition One Trained T (Imag. 418; Freq. 12; 2syl.)
	2 Routine Condition One Trained (Imag. 341; Freq. 2; 2syl.)	2 Graphic Condition Two Tr Target B (Imag. 2syl.)	2 Pause Condition Three Train (Imag. 347; Freq. 7; 1syl.)	2 Routine Condition One Trained (Imag. 341; Freq. 2; 2syl.)
	3 Tribute Condition One Trained T (Imag. 386; Freq. 4; 2syl.)	3 Impulse Condition Two Tr Target C (Imag. 3 2syl.)	3 Talent Condition Three Tra (Imag. 399; Freq. 2; 2syl.)	3 Tribute Condition One Trained (Imag. 386; Freq. 4; 2syl.)
	4 Compliment Condition One Traine (Imag. 496; Freq. 1; 2syl.)	4 Loyal Condition Two Tr D (Imag. 411; Fre	4 Skill Condition Three Train (Imag. 266; Freq. 27; 1syl.)	4 Compliment Condition One Train (Imag. 496; Freq. 1; 2syl.)
	5 Vow Condition One Trained Tar (Imag. 389; Freq. 4; 2syl.)	5 Pat Condition Two Tra (Imag. 386; Freq. 21; 1syl.)	5 Loan Condition Three Traine (Imag. 430; Freq. 5; 1syl.)	5 Vow Condition One Trained Ta (Imag. 389; Freq. 4; 2syl.)
	6 Pledge Condition One Trained T (Imag. 408; 1syl.)	6 Fare Condition Two Tr F (Imag. 384; Fre	6 Debt Condition Three (Imag. 284; Freq. 7, 1syl.)	6 Pledge Condition One Trained (Imag. 408; 1syl.)
			7 Pledge Condition One Trained T (Imag. 408; 1syl.)	7 Pledge Condition One Trained (Imag. 408; 1syl.)
			8 Pledge Condition One Trai (Imag. 408; 1syl.)	8 Pledge Condition One Tr (Imag. 408; 1syl.)
			9 Pledge Condition One Trained T (Imag. 408; 1syl.)	9 Pledge Condition One Trained (Imag. 408; 1syl.)
Generalization Stimuli: Word: Condition (1-4) Generalizatio F) (Imagability Rating Frequency Rating [Freq.]; [#syl.])	1 Alter Condition One Generalizat (Imag. 413; Freq. 16; 2syl.)	1 Clever Condition Two Ge Target A (Imag. 3 2syl.)	1 Sham Condition Three Generali (Imag. 419; Freq. 9; 1syl.)	1 Alter Condition One Generaliza (Imag. 413; Freq. 16; 2syl.)
	2 Bury Condition One Generalizat (Imag. 413; Freq. 16; 2syl.)	2 Recruit Condition Two Ge Target B (Imag. 2syl.)	2 Blunt Condition Three Generaliz (Imag. 404; Freq. 1; 1syl.)	2 Bury Condition One Generaliza (Imag. 413; Freq. 16; 2syl.)
	3 Comfort Condition One Generaliz (Imag. 421; Freq. 13; 2syl.)	3 Wasteful Condition Two Generalization Target C 373; Freq. 1; 2syl.)	3 Sincere Condition Three Generali (Imag. 407; Freq. 4; 2syl.)	3 Comfort Condition One General C (Imag. 421; Freq. 13;
	4 Devotion Condition One General D (Imag. 411; Freq. 2; 2	4 Zodiac Condition Two Ge Target D (Imag. 4	4 Ease Condition Three Generaliza (Imag. 327; Freq. 2; 1syl.)	4 Devotion Condition One Genera D (Imag. 411; Freq. 2;
	5 Mood Condition One Generaliza (Imag. 394; Freq. 16; 1syl.)	5 Scent Condition Two Gen Target E (I	5 Bawl Condition Three Generaliza (Imag. 417; 1syl.)	5 Mood Condition One Generaliz (Imag. 394; Freq. 16; 1syl.)
	6 Saint Condition One Generalizat (Imag. 394; 1syl.)	6 Myth Condition Two Gen Target F (Imag. 3 1syl.)	6 Ate Condition Three Generaliza (Imag. 364; Freq. 23, 1syl.)	6 Firm Condition Four Generaliz (Imag. 404; Freq. 56, 1syl.)
			7 Pledge Condition One Trained T (Imag. 408; 1syl.)	7 Pledge Condition One Trained (Imag. 408; 1syl.)
			8 Pledge Condition One Trai (Imag. 408; 1syl.)	8 Pledge Condition One Tr (Imag. 408; 1syl.)
			9 Pledge Condition One Trained T (Imag. 408; 1syl.)	9 Pledge Condition One Trained (Imag. 408; 1syl.)
Within Facilitation Ex	*"Practice* Routine"	*"Eager* Graphic"	"Skill-Ambition"	"Fraud-Kale"
	"Practice Routine"	*"Eager* Graphic"	"Skill-Ambition"	"Fraud-Kale"
	"Practice Routine"	*"Eager* Graphic"	"Skill-Ambition"	"Fraud-Kale"
				10 second pause						10 second pause							10 second pause						10 second pause		
	"Solemn Vow" ___________	*"Morbid* Fare" ___________	"Loan-Debt" ___________	"Saint-Hazard" ___________
	"Solemn Vow" ___________	*"Morbid* Fare" ___________	"Loan-Debt" ___________	"Saint-Hazard" ___________
	"Solemn Vow" ___________	*"Morbid* Fare" ___________	"Loan-Debt" ___________	"Saint-Hazard"___________
				10 second pause						10 second pause							10 second pause						10 second pause		
	"Routine- Vow" _____________	"Fare- Graphic" _____________	"Fare- Graphic" _____________	"Fare- Graphic" ___________
				30 second pause						30 second pause							30 second pause						30 second pause		
	Repeat -- 3 Total Sets in each treatm (Set Defined as the Above: Repea sec.] Repeat Phrase E Pause, Repeat Noun Pair x1 [30	Repeat -- 3 Total Sets in each segment Set Above: Repeat Phrase A Repeat Phrase Bx3 [10sec Pause, Repeat Noun Pair	Repeat -- 3 Sets in 3 treatment seg Set Defined as the Above: Repeat Phr x3; [10 sec.] Pause, Repeat Noun Pair x1 [30	Repeat -- 3 Sets in 3 treatment se Segment Defined as the Abov Repeat Unrelated 2-word span A x Repeat Phrase Bx 3 [10sec.] Pause, Repeat Unrelated Noun Pair
	Repetition Trials During Facilitation: S Noun Phrase Prime: 54 Repetitions across 3 c primes per cycle). Practice Probe: 2-word unrelated noun repetition span: 9 across 3 cycles (3 proves per cycle).	Repetition Trials During Facilita Adjective-Noun Phrase Prime: 54 Repetit across 3 cycles. (18 primes per c Practice Probe: 2-word unrelated nou repetition span: 9 Repetitions ac (3 probes per cycle).	Repetition Trials During Facilitation: S Adjective-Noun Phrase Prime: 81 Repetitions ac cycles. (27 primes per cycle). Practice Probe: 2-word unrelated noun repet 9 Repetitions across 3 cycles (3 probes	Repetition Trials During Facilitation: Adjective-Noun Phrase Prime: 81 Repetitions a cycles. (27 primes per cycle). Practice Probe: 2-word unrelated noun repe span: 9 Repetitions across 3 cycles (3 cycle).

Table 14. Experimental Stimuli Precise Definition: Two-word span- Condition One, Condition Two, Condition Three, and Condition Four

	Condition One	Condition Two	Condition Three	Condition Four
Condition Format Approach **Abbreviation**	Semantic +Synactic (Related) Faciliting Repetition via: Se Noun Phrase **FSC1: 2-w** **SEM+SYN**	Synactic-only (Unrelated) Faciliting Repetition via: Sen Noun Phrase **FSC2: 2-word SYN-only**	Semantically Structured (Related) Facilitation repetition via: Repetition span task **FSC3: 2-Word SEM+SPAN**	Structured-only Word Span (Unrelated) Facilitating repetition via: Stuctured Repetition Span Task **FSC4: 2-Word SYN+SPAN**
Linguistic Structure: Within F Condition	*Adjective*-Noun	*Adjective*-Noun	Noun - Noun	Noun - Noun
Presentation: Wi Facilitation Condition	*Research SLP:* 1 . Verbally states SEM + SYN adjective-no for immediate repetition. 2 . Three opportunities provided to repeat S adjective-noun phrase. 3. Repeat above steps 1-2 , new SEM + SYN targeted. 4. Two-word noun span targeting trained L pair: Participant has one opportunity to repe accurately.	*Research SLP* 1 . Verbally states SYN-only adjective-noun immediate repetition. 2 . Three opportunities provided to repeat SY adjective-noun phrase. 3. Repe above steps 1-2 , new SYN-only phrase targe 4. Two-word noun span targeting trained LI pair: Participant has one opportunity to repea accurately..	*Research SLP:* 1 . Verbally states SEM+SPAN two-word span st immediate repetition. 2 . Three opportunities provided to correctly repe SEM+SPAN. 3. Repeat 1,2. New SEM + SPAN pair targeted. 4. Two-word noun span targeting trained LI-LF nouns pair: Pa one opportunity to repeat accurately.	*Research SLP:* 1 . Verbally states SYN+SPAN using unrelated two-wo for immediate repetition. 2 Three opportunities provided to correctly repeat SY 3. Repeat 1, 2 with new SYN + SPAN pair targeted. 4. Two-word noun targeting trained LI-LF nouns pair: Participant has c opportunity to repeat accurately.
Pre-Test Accuracy	*Pre-Test Administered:* 1. Pre Test Immediately Before Tx	*Pre-Test Administered:* 1. Pre-T Immediately Before Tx	*Pre-Test Administered:* 1. Pre-Te Immediately Before Tx	*Pre-Test Administered:* 1. Pre-Test Immediately Before Tx
Number of Stimuli Traine	12 LI-LF Nouns: Untrained: 6 items Adjectives Items: 6 items	12 LI-LF Nouns: Untrained: 6 items Adjectives Items: 6 items	12 LI-LF Nouns: Untrained: 6 items	12 LI-LF Nouns: Untrained: 6 items
Variation of Monosyllabic, Bisyll **Word Presentation** *Incudes* Traine and Untrained Items	one-syllable: 4 two-syllable:6	one-syllable: 4 two-syllable:6	one-syllable: 10 two-syllable:2	one-syllable: 10 two-syllable:2
Post-Test Accuracy	*Probe Tests Administered:* 1. Immediate Post-Test 2. 1 min.delay Post-Test	*Probe Tests Administered:* 1. Immediate Post-Test 2. 1(min.delay Post-Test	*Probe Tests Administered:* 1. Immediate Post-Test 2. 10 min.delay Post-Test	*Probe Tests Administered:* 1. Immedi Post-Test 2. 10 min.delay Po

Table 15. Experimental Stimuli Precise Definition: Three-word span- Condition One, Condition Two, Condition Three, and Condition Four

	Condition One	Condition Two	Condition Three	Condition Four
Condition Format Approac **Abbreviation**	Semantic +Synactic (Related Faciliting Repetition via: Noun-Adjective-Noun Phras **FSC1: 3-word S**	Synactic-only (Unrelated) Faciliting Repetition via: Noun-Adjective-Noun Phrase **FSC2: 3-word SYN-only**	Semantically Structured (Re Facilitation repetition via: word Semantic+ Repetition s **FSC3: 3-Word SEM+S**	Structured-only Word Span (Unre Facilitating repetition via: word Stuctured Repetition Span T **FSC4: 3:-Word SYN+SPA**
Linguistic Structure: Within F Condition	Noun-*Adjective*-Noun	Noun-*Adjective*-Noun	Noun - Noun - Noun	Noun - Noun - Noun
Presentation: Wi Facilitation Condition	*Research SLP:* 1 . Verbally states SEM + SYN noun-adjec sentence for immediate repetition. 2 . Three opportunities provided to repeat SYN noun-adjective-noun sentence 3. Repeat above steps 1-2 , new SEM + SY targeted. 4. Three-word noun span targeting trained nouns triplet. Participant has one opportun repeat accurately.	*Research SLP:* 1 . Verbally states SYN-only noun-adjective- sentence for immediate repetition. 2 . Three opportunities provided to repeat S noun-adjective-noun sentence 3. Repeat above steps 1-2 , new SYN only se targeted. 4. Three-word noun span targeting trained L triplet Participant has one opportunity to repe accurately.	*Research SLP:* 1 . Verbally states SEM+SPAN usin three-word span stimuli for immediate repetition. 2 . Three opportunities provided to c repeat SEM+SPAN. 3. Repeat 2 with new SEM + SPAN triplet targ 4. Three-word noun span targeting trai nouns triplet Participant has one opp to repeat accurately.	*Research SLP:* 1 . Verbally states SYN+SPAN using unrelat word span stimuli for immediate repetition. 2 . Three opportunities provided to correctly SYN+SPAN. 3. Repeat 1 with new SYN + SPAN triplet targeted. 4. Three-w noun span targeting trained LI-LF nouns trip Participant has one opportunity to repeat acc

In each condition, nouns were divided into two equal groups, half selected as trained stimuli and half to be used for untrained generalization items. Of the experimental stimuli selected, half were used as probes to determine the facilitative effects of four conditions and half as generalization items. All were balanced for syllable length, and words in pairs were neither phonologically nor semantically related. Conditions One and Two matched four 1-syllable words, six 2-syllable words, and two 3-syllable words. Conditions Three and Four matched ten 1-syllable words and two 2-syllable words at the two-word level as well a ten 1-syllable words, seven 2-syllable words, and one 3-syllable words at the three-word level. Prior to each condition, a pre-test of the current condition's stimuli and matching stimuli for generalization was administered. Figure 4 provides a conceptual framework of the protocol.

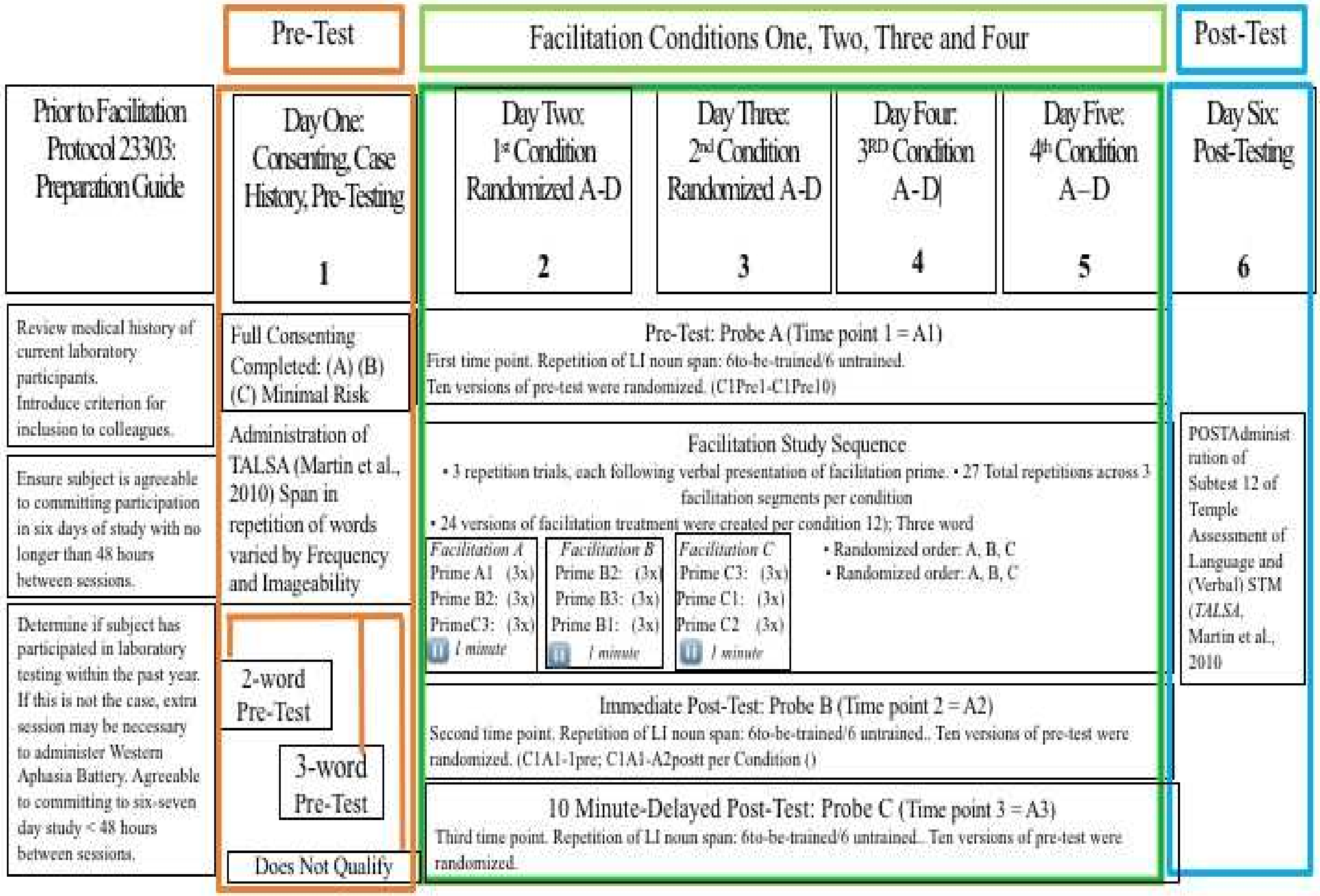

Figure 4. Conceptual Framework of Facilitation Study Session One-Session Six.

Dependent Variable.

The facilitation study employed a case series design and used repeated measures analysis. The primary dependent variable of interest was accuracy on repetition probe span tasks on two-item or three-item lists. A second dependent variable of interest was accuracy of recall on recall tasks presented immediately following treatment, serial recall as well as in any order. Baseline accuracy of LI pairs was measured in the pre- and post-test screening tools. The facilitation program consisted of four facilitation conditions targeting two-word or three-word repetition (Table *). Conditions were constructed to demonstrate a variation of semantic and/or syntactic context and were formed using abstract noun pairs or noun triplets:

- Facilitation Condition One (C1; SEM+SYN): LI pairs/triplets were trained through the repetition of semantically and syntactically cohesive LI adjective-noun phrases (e.g., practiced routine; solemn pledge) or sentences (e.g., A habit is a practiced routine; A vow is a solemn pledge).
- Facilitation Condition Two (C2; SYN only): LI pairs/triplets were trained through the repetition of syntactically structured LI adjective-noun phrases (e.g., eager graphic; modified fare) or sentences (e.g., A dispute is an eager graphic; A pat is a modified fare). The participant was informed that this repetition task was nonsensical.
- Facilitation Condition Three (C3; SEM+SYN SPAN): LI pairs/triplets were trained through the repetition of semantically related two/three-word serial order tasks (e.g., faith-hope; wisdom-knowledge-information).

- Facilitation Condition Four (C4; SYN only SPAN): LI pairs/triplets were trained through the repetition of unrelated LI two- or three-word serial order tasks (e.g., stern spirit; rude agility; fact- stern-spirit; calcium-rude-agility).

Participant Algorithm for Administration. To control for the possibility of an effect of order of condition administered, treatment order, pre-/post-test order, or a learning effect, a randomized algorithm was developed. This list of order of administration was generated prior to recruitment. Ten versions of the pre-test, immediate post-test, and delayed post-test were created for each condition. Additionally, three versions of each treatment administration were created to ensure randomization. (See Table 15 for the master algorithm for administration.) A structured record ensured that the examiner did not have control of order of condition and stimuli presented. This procedure was expected to provide a more interesting analysis of the data as it reflected performance on multiple treatment variations.

Table 16.
2016-2017 Participant Algorithm for Administration

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10	Subject 11	Subject 12
Participant ID	KC3	EH4	XH-46	EC-25	UP-35	MI-10	IU-19	QH-22	EL-5	NF-54	KT-53	KM-38
Date Initiated	7/7/16	7/7/16	7/7/16	8/25/16	8/25/16	8/27/16	9/20/16	9/22/16	10/2/16	1/4/16	1/4/16	1/19/16
Consented	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TALSA 12 Pre-Test	1, 2, 3	1, 2, 3	1, 2	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2	1, 2, 3	1	1, 2, 3
All Word Pre-Test	3-word	3-word	2-word	3-word	3-word	3-word	3-word	3-word	2-word	3-word	2-word	3-word
Condition[1]	4	2	4	1	3	1	4		3	3	3	1
Pre-test Version[2]	3	5	9	10	7	4	5		6	2	6	2
Treatment Version[3]	A	B	A	C	B	B	B		A	C	B	A
Post-test Version A[4]	2	3	7	10	5	10	7		5	6	4	9
Post-test Version B[5]	2	5	8	1	3	5	9		10	2	7	8
Condition[1]	2	4	2	3	2	4	1			4	1	4
Pre-test Version[2]	6	10	6	8	5	3	10			9	6	1
Treatment Version[3]	C	B	C	A	C	B	C			C	C	A
Post-test Version A[4]	7	2	7	3	3	6	1			10	8	5
Post-test Version B[5]	5	3	5	8	9	4	10			1	10	2
Condition[1]	1	3	1	2	4	3	2			1	2	4
Pre-test Version[2]	8	5	8	5	6	9	5			7	9	5
Treatment Version[3]	C	B	C	A	B	C	A			B	A	C
Post-test Version A[4]	5	7	5	4	7	3	4			1	9	2
Post-test Version B[5]	4	5	4	3	8	5	3			5	9	6
Condition[1]	3	2	3	4	1	2	3			2	4	2
Pre-test Version[2]	7	4	8	5	4	4	7			10	7	1
Treatment Version[3]	A	C	C	B	A	B	A			C	A	B
Post-test Version A[4]	6	5	7	7	3	7	3			7	10	2
Post-test Version B[5]	8	5	8	9	4	5	7			3	1	3
All Word Post-Test	3-word	3-word	2-word	3-word	3-word	3-word	3-word			3-word	2-word	3-word
TALSA 12 Post-Test	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3, 4	1, 2, 3	1, 2, 3, 4			1, 2, 3	1	1, 2, 3
Date Completed	7/14/16	7/15/16	7/15/16	9/2/16	9/2/16	9/2/16	9/28/16	9/22/16	10/3/16	1/18/17	1/18/17	1/26/17

[1] *Conditions randomized:* 1, 2, 3, 4
[2] *Pre-tests randomized:* 10 versions per condition
[3] *Treatments randomized:* 3 versions per condition
[4] *Post-test A:* Tested immediately, 10 versions per condition
[5] *Post-test B:* Following a 10 minunte delay, 10 versions per condition

Scoring System. Tests were scored within facilitation by the examiner, as well as after administration via audio recording. A second reviewer examined the results and any disagreement in results was resolved via discussion. Change from pre-test was defined as the proportion of word and list accuracy at post-test (immediate and 10-minute delay) subtracted by these values at pre-test. Paired t-tests were used to determine statistically significant differences in change from pre-test within each of the four conditions separately. The null hypothesis assumed that the true mean difference was equal to 0, and the upper-tailed alternative hypothesis assumed that the true mean difference was greater than 0. Additionally, repeated measures analysis of variances (ANOVA) was used to determine if there were statistically significant differences in change from pre-test between Conditions One and Two and between Conditions Three and Four. A Bonferroni correction for pairwise comparisons was applied to the *p*-values and confidence intervals. The null hypothesis stated there were no differences in change from pre-test between Conditions One and Two or between Conditions Three and Four. This test allowed for comparisons in single-factor studies, as all participants in the facilitation study completed all conditions.

For categorical variables, measures included frequencies and percentages. Because the small sample size might limit the statistical significance of the results, effect sizes to demonstrate a direct treatment effect were calculated to assess the magnitude of change from pre-test to post-test performance scores on all-stimuli as well as *TALSA* (Martin, et al., 2010) performance. Magnitude of effect sizes was interpreted based on benchmarks specific to lexical retrieval in aphasia studies. These benchmarks were developed by Robey & Beeson (2005) and intended to extend application of Busk and

Serlin's (1992) calculation of Cohen's (1988) *d* statistic to PWA. Aphasia effect size benchmarks within multiple participant studies were as follows: small: >4.0, medium: >7.0, large: >10.1 (Robey & Beeson, 2005).

Simple regression models were used to determine whether the robustness of response to treatment was predicted by the size of imageability effect in pre-tests or size of span. Due to the small sample size, these regression models were exploratory in nature, and Beeson & Robey (2005) effect sizes were calculated to determine the magnitude of change. Lastly, a *post-hoc* power calculation was conducted using the obtained sample size (n=10) to determine the power to detect differences in change from pre-test. Statistical significance was taken at the 0.05 level.

Results

Ten participants with aphasia presented with chronic auditory-verbal STM impairment and the general results of this treatment approach indicated that all participants improved in repetition abilities. Analyses were driven by the previously defined research predictions and addressed performance before and after the facilitation study in serial order (ISO) or in any order (IAO), as well as comparisons between the semantically enhanced conditions and the syntactically well-formed conditions. All analyses were conducted using the software program Statistical Package for the Social Sciences (*SPSS,* IBM corp., 2013).

Participants. Descriptive statistics included measures of central tendency (mean, median) and variation (standard deviation, interquartile range) for these measures. Relevant participant demographic information can be viewed in Table 16. Nine participants (0.90) had more than 12 years of formal education. Sex (6 males, 4 females) was more evenly distributed when compared to distribution of race (8 African American, Caucasian [0.20] and time post-onset (122 months [*SD*=88*, range* =27-341]*).* The measure of word span repetition performance developed for the systematic review (Table 2) was determined to be an appropriate tool to use in this study. Auditory-verbal STM impairment was categorized in seven groups, I (most severe) to VII (least severe) , according to severity of auditory-verbal STM impairment to severity of auditory-verbal STM impairment. The sample size had a range of severity of auditory-verbal STM impairment: 8 participants (0.80) were characterized as severity level V (accuracy for two-word span ≥ 0.80), 1 participant (0.10) was categorized as level IV (single-word repetition >0.80; two-word span repetition < 0.80), and 1 participant was (0.10) be categorized as level I (single-word repetition >0.80). Three participants qualified for the two-word condition and seven participants qualified for the three-word condition.

Given a range of deficits spanning from more phonologically impaired to more semantically impaired, it was critical to review results ISO and IAO. Tables 17, 18 and 19 ISO provide examples of one-, two-, and three-word *TALSA* (Martin, et al., 2010) pre-testing scoring on items and lists. Tables 20, 21, and 22 IAO provide examples of one-, two-, and three-word *TALSA* (Martin, et al., 2010) pre-testing scoring on items and lists.

Table 17.
Participant demographic information

ID #	Subject	Age	Education	Sex	Race	Date of Onset	Etiology	Date Enrolled	Time Post Onset	Severity of auditory-verbal STM impairment	Completed
KC3	1	56	15 years	M	AA	10/1/01	Lt. CVA,seizures	7/7/16	177 months	V	Y
EH4	2	52	13 years	F	AA	10/5/04	Lt. MCA CVA	7/7/16	141 months	V	Y
XH-46	3	48	7 years	M	AA	3/1/14	Lt. CVA	7/7/16	27 months	IV	Y
EC-25	4	69	18 years	F	AA	3/23/88	Aneurysm clip, seizures	8/25/16	341 months	V	Y
UP-35	5	53	14 years	M	AA	3/25/08	Lt. CVA	8/25/16	101 months	V	Y
MI-10	6	65	19 years	F	AA	6/6/07	Lt. posterior temporal-occipital CVA; Lt occipital AVM	8/27/16	110 months	V	Y
1U-19	7	72	17 years	M	C	2/7/07	Lt. parieto-ocipital CVA, Lt. MCA CVA	9/20/16	115 months	V	Y
QH-22	8	55	18 years	M	C	1/1/08	Lt. ICH and craniotomy	9/22/16	104 months	VII	N
EL-5	9	53	13 years	F	AA	3/22/94	Lt. CVA, thrombc embolic	10/2/16	183 months	IV	N
NF-54	10	56	14 years	F	AA	1/6/14	Lt. CVA	1/4/17	36 months	V	Y
KT-53	11	67	18 years	M	AA	3/1/14	Lt. MCA CVA	1/4/17	31 months	I	Y
KM-38	12	74	18 years	M	CC	7/22/04	Lt. MCA CVA	1/19/17	145 months	V	Y

Table 18.
TALSA Pre-/post-test performance 1-item/list ISO/IAO

ID #	Subject	Pre-Test ISO				Post-Test ISO			
		Imageability		Frequency		Imageability		Frequency	
		HI	LI	HF	LF	HI	LI	HF	LF
KC3	1	1.00	0.60	0.70	0.90	1.00	1.00	1.00	1.00
EH4	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
XH-46	3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EC-25	4	1.00	0.90	1.00	0.90	1.00	1.00	1.00	1.00
UP-35	5	1.00	0.90	0.90	1.00	1.00	1.00	1.00	1.00
MI-10	6	1.00	0.90	1.00	0.90	1.00	1.00	1.00	1.00
1U-19	7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NF-54	8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KT-53	9	0.30	0.00	0.30	0.40	0.50	0.20	0.30	0.40
KM-38	10	0.90	0.80	0.70	1.00	1.00	1.00	1.00	1.00

ID #	Subject	Pre-Test IAO				Post-Test IAO			
		Imageability		Frequency		Imageability		Frequency	
		HI	LI	HF	LF	HI	LI	HF	LF
KC3	1	1.00	0.60	0.90	0.60	1.00	1.00	1.00	1.00
EH4	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
XH-46	3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EC-25	4	1.00	0.90	1.00	0.90	1.00	1.00	1.00	1.00
UP-35	5	1.00	0.90	0.90	1.00	1.00	1.00	1.00	1.00
MI-10	6	1.00	0.90	1.00	0.90	1.00	1.00	1.00	1.00
1U-19	7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NF-54	8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KT-53	9	0.30	0.00	0.30	0.40	0.50	0.20	0.30	0.40
KM-38	10	0.90	0.80	0.70	1.00	1.00	1.00	1.00	1.00

Table 19.

TALSA Pre-/post-test performance 2-item ISO/IAO

ID #	Subject	Pre-Test Item ISO				Pre-Test List ISO				Post-Test Item ISO				Post-Test List ISO			
		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency	
		HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF
KC3	1	0.75	0.70	0.75	0.70	0.50	0.50	0.50	0.50	0.95	0.95	0.90	0.90	0.90	0.90	0.90	0.90
EH4	2	1.00	0.90	0.90	0.90	1.00	0.80	0.90	0.90	1.00	0.90	0.95	0.95	0.90	0.90	0.90	0.90
XH-46	3	0.30	0.15	0.30	0.15	0.30	0.10	0.30	0.10	0.70	0.90	0.80	0.80	0.60	1.00	0.80	0.80
EC-25	4	0.85	0.90	0.85	0.90	0.80	0.90	0.80	0.90	0.85	0.70	0.80	0.95	0.70	0.80	1.00	0.50
UP-35	**5**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MI-10	6	0.95	0.85	0.85	0.95	0.90	0.70	0.70	0.90	1.00	0.95	1.00	0.95	1.00	0.90	1.00	0.90
1U-19	7	1.00	0.95	1.00	0.95	1.00	0.90	1.00	0.90	1.00	0.90	0.95	0.95	0.80	1.00	0.90	0.90
NF-54	8	1.00	0.95	1.00	0.95	1.00	0.90	1.00	0.95	0.80	1.00	0.90	0.90	1.00	0.90	1.00	0.90
KT-53	9	0.95	0.85	0.85	0.95	0.90	0.70	0.70	0.90	1.00	0.95	1.00	0.95	1.00	0.90	1.00	0.90
KM-38	10	0.90	0.90	0.95	0.85	0.80	0.80	0.90	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

ID #	Subject	Pre-Test Item IAO				Pre-Test List IAO				Post-Test Item IAO				Post-Test List IAO			
		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency	
		HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF
KC3	1	0.75	0.70	0.75	0.70	0.50	0.50	0.50	0.50	0.95	0.95	0.95	0.95	0.90	0.90	0.90	0.90
EH4	2	1.00	0.90	1.00	0.90	1.00	0.90	1.00	0.90	1.00	0.90	0.95	0.95	0.90	0.90	0.90	0.90
XH-46	3	0.95	0.85	0.95	0.85	1.00	0.80	1.00	0.80	0.95	0.95	1.00	1.00	0.90	0.90	1.00	0.80
EC-25	4	0.90	0.95	0.90	0.95	0.80	0.90	0.80	0.90	0.95	1.00	1.00	0.95	0.90	0.90	1.00	0.80
UP-35	**5**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MI-10	6	0.95	0.85	0.85	0.95	0.90	0.70	0.70	0.90	1.00	0.95	1.00	0.95	1.00	0.90	1.00	0.90
1U-19	7	1.00	0.95	1.00	0.95	1.00	0.90	1.00	0.90	0.80	1.00	0.90	0.90	1.00	1.00	1.00	1.00
NF-54	8	1.00	0.95	1.00	0.95	1.00	0.95	1.00	1.00	1.00	0.93	1.00	0.93	1.00	0.90	1.00	0.90
KT-53	9	0.95	0.85	0.95	0.85	1.00	0.80	1.00	0.80	0.95	0.95	1.00	1.00	0.90	0.90	1.00	0.80
KM-38	10	0.90	0.90	0.95	0.85	0.80	0.80	0.90	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 20.

TALSA Pre-/post-test performance 3-item ISO/IAO

ID #	Subject	Pre-Test Item ISO				Pre-Test List ISO				Post-Test Item ISO				Post-Test List ISO			
		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency	
		HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF
KC3	1	0.53	0.53	0.63	0.43	0.20	0.00	0.20	0.00	0.67	0.37	0.53	0.50	0.40	0.20	0.30	0.10
EH4	2	0.93	0.87	0.83	0.70	0.70	0.20	0.50	0.40	0.93	0.73	1.00	0.93	0.80	0.30	0.60	0.50
XH-46	3																
EC-25	4	0.40	0.29	0.35	0.13	0.20	0.00	0.20	0.00	0.43	0.37	0.67	0.13	0.20	0.10	0.30	0.00
UP-35	5	0.83	0.70	0.70	0.83	0.50	0.80	0.80	0.50	0.87	0.73	0.77	0.83	0.70	0.50	0.50	0.70
MI-10	6	0.47	0.47	0.53	0.40	0.10	0.10	0.10	0.10	0.77	0.60	0.77	0.50	0.50	0.40	0.70	0.20
1U-19	7	0.80	0.83	0.80	0.83	0.60	0.70	0.90	0.40	1.00	0.93	0.93	1.00	0.80	1.00	1.00	0.80
NF-54	8	0.93	0.87	1.00	0.80	0.70	0.60	1.00	0.30	0.93	0.87	1.00	0.80	1.00	0.70	1.00	0.70
KT-53	9																
KM-38	10	0.53	0.47	0.70	0.50	0.60	0.30	0.60	0.40	0.73	0.53	0.70	0.50	0.60	0.40	0.70	0.30

ID #	Subject	Pre-Test Item IAO				Pre-Test List IAO				Post-Test Item IAO				Post-Test List IAO			
		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency		Imageability		Frequency	
		HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF	HI	LI	HF	LF
KC3	1	0.53	0.63	0.63	0.53	0.40	0.20	0.20	0.10	0.73	0.63	0.83	0.53	0.40	0.30	0.60	0.10
EH4	2	0.93	0.87	0.83	0.70	0.70	0.20	0.50	0.40	0.93	0.73	1.00	0.93	0.80	0.40	0.70	0.50
XH-46	3																
EC-25	4	0.57	0.47	0.50	0.37	0.20	0.00	0.20	0.00	0.67	0.53	0.77	0.43	0.20	0.10	0.30	0.00
UP-35	5	0.90	0.80	0.80	0.90	0.50	0.80	0.80	0.50	0.93	0.90	0.90	0.93	0.80	0.70	0.70	0.80
MI-10	6	0.57	0.57	0.63	0.50	0.10	0.10	0.10	0.10	0.92	0.75	0.00	0.65	0.60	0.40	0.70	0.30
1U-19	7	0.80	0.83	0.80	0.83	0.60	0.70	0.90	0.40	1.00	0.93	0.93	1.00	0.80	1.00	1.00	0.80
NF-54	8	0.97	0.92	1.00	1.00	0.97	0.92	1.00	1.00	1.00	0.93	1.00	0.93	1.00	0.90	1.00	0.90
KT-53	9																
KM-38	10	0.73	0.53	0.87	0.80	0.70	0.30	0.60	0.40	1.00	0.70	0.93	0.67	0.80	0.40	0.80	0.40

Prediction 1: Training repetition of LI nouns in semantically and syntactically cohesive LI adjective-noun phrases (e.g., business casual) or sentences (e.g., The affair is business casual) will significantly improve performance in repetition of these same nouns when they are presented as unrelated noun pairs/triplets for serial recall (e.g., casual-poverty/-wisdom) following a ten-minute delay.

Prediction 1- Analysis 1: Effect of Semantically Cohesive Phrases or Sentences. Condition One trained repetition of LI nouns in semantically and syntactically cohesive LI adjective-noun phrases or sentences. The first research prediction was specific to performance before and following a ten-minute delay after the facilitation. Sample t-tests were conducted to analyze ISO/IAO performance on words and lists. The training did not have a significant immediate effect on repetition performance for lists (Tables 22, 23). Results showed a small effect of word repetition IAO (M=0.75, SD=0.22); t(9) = -3.780, p = .004. These data were also supported by a small-medium effect size of 5.69 (Beeson & Robey, 2005).

Prediction 1: Analysis 2: Delayed Effect of Semantically Cohesive Phrases or Sentences. Two paired-sample t-tests focused on comparing pre-test performance and delayed post-test performance on words and on lists repeated accurately in any order. In words and lists, a significant difference was found in both ISO and IAO (Table 22).

Table :21.

Summary of paired t-test results and effect sizes pre-/post-facilitation administration: Prediction 1

	T1 Label (ISO/IAO)	T1 Mean	T1SD	T2 Label	T2 Mean	T2 SD	T Value	*df*	Sig. (2-tailed)*	Effect size	Beeson and Robey, 2005	T1 Label Defined (ISO/IAO)	T2 Label Defined (ISO/IAO)
Prediction 1													
	ISO.C1A1W	0.59	0.27	**ISO.C1A2W**	0.64	0.30	-1.38	9	.202	6.81	medium	**Pre-test performance on Condition One words ISO**	**Immediate post-test performance on Condition One words ISO**
	C1A1W	0.50	0.27	C1A2W	0.75	0.22	-3.78	9	.004	5.69	small	Pre-test performance on Condition One words IAO	Immediate post-test performance on Condition One words IAO
	ISO.C1A1L	0.45	0.31	**ISO.C1A2L**	0.52	0.34	-1.18	9	.268	5.05	small	**Pre-test performance on Condition One lists ISO**	**Immediate post-test performance on Condition One lists ISO**
	C1A1L	0.45	0.32	C1A2L	0.52	0.35	-1.18	9	.268	3.78	small	Pre-test performance on Condition One lists IAO	Immediate post-test performance on Condition One lists IAO
	ISO.C1A1W	0.59	0.27	**ISO.C1A10W**	0.71	0.31	-2.60	9	.029	6.35	medium	**Pre-test performance on Condition One words ISO**	**Delayed post-test performance on Condition One words ISO**
	C1A1W	0.50	0.27	C1A10W	0.71	0.31	-2.18	9	.036	4.27	small	Pre-test performance on Condition One words IAO	Delayed post-test performance on Condition One words IAO
	ISO.C1A1L	0.45	0.31	**ISO.C1A10L**	0.57	0.34	-0.16	9	.036	5.54	small	**Pre-test performance on Condition One lists ISO**	**Delayed post-test performance on Condition One lists ISO**
	C1A1L	0.45	0.32	C1A10L	0.72	0.33	-2.10	9	.036	4.27	small	Pre-test performance on Condition One lists IAO	Delayed post-test performance on Condition One lists IAO

Prediction 1: Analysis 3*:* Condition One over Time. A one-way repeated measures analysis of variance was conducted in order to compare scores among participants. This analysis made it possible to determine if there was a significant change in performance between time 1 (pre-test, prior to intervention), time 2 (post-test immediately after intervention), and time 3 (ten-minute delay). There was a significant effect in Condition One for words, Wilk's Lambda = (0.90). F (2,8) = 36.490, p =.000, and for lists, Wilk's Lambda = (0.701). F(2,8) =14.293, p= .001. These results suggested that within Condition One, performance accuracy on both word and lists significantly increased over time.

Table 22.

Condition one performance ISO, IAO

ID #	Subject	Condition	In Serial Order (ISO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	C	0.33	0.00	0.33	0.00	0.00	0.00	0.67	0.25	0.34	0.25
EH4	2	D	0.56	0.33	0.66	0.81	0.10	0.48	0.81	0.66	0.25	0.33
XH-46	3	C	0.63	0.58	0.92	0.92	0.29	0.34	0.92	0.92	0.29	0.34
EC-25	4	A	0.44	0.25	0.38	0.25	-0.06	0.00	0.47	0.25	0.03	0.00
UP-35	5	D	0.81	0.66	0.78	0.58	-0.03	-0.08	0.86	0.66	0.05	0.00
MI-10	6	A	0.67	0.50	0.72	0.41	0.05	-0.09	0.88	0.75	0.21	0.25
1U-19	7	B	0.92	0.92	0.94	0.83	0.02	-0.09	1.00	1.00	0.08	0.08
NF-54	8	D	0.92	0.92	0.94	0.83	0.02	-0.09	1.00	1.00	0.08	0.08
KT-53	9	B	0.08	0.00	0.04	0.00	-0.04	0.00	0.00	0.00	-0.08	0.00
KM-38	10	A	0.55	0.41	0.78	0.58	0.75	0.41	0.23	0.00	0.20	0.00

ID #	Subject	Condition	In Any Order						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	C	0.33	0.00	0.53	0.08	0.69	0.25	0.20	0.25	0.36	0.25
EH4	2	D	0.56	0.33	0.66	0.86	0.92	0.75	0.10	0.42	0.36	0.42
XH-46	3	C	0.63	0.58	1.00	1.00	1.00	1.00	0.37	0.42	0.37	0.42
EC-25	4	A	0.44	0.25	0.72	0.33	0.61	0.25	0.28	0.00	0.17	0.00
UP-35	5	D	0.81	0.66	0.78	0.66	0.92	0.75	-0.03	0.09	0.11	0.09
MI-10	6	A	0.67	0.50	0.78	0.41	0.94	0.83	0.11	0.33	0.27	0.33
1U-19	7	B	0.92	0.92	0.94	0.83	1.00	1.00	0.02	0.08	0.08	0.08
NF-54	8	D	0.94	0.83	0.97	0.92	1.00	1.00	0.03	0.17	0.06	0.17
KT-53	9	B	0.08	0.00	0.29	0.00	0.25	0.00	0.21	0.00	0.17	0.00
KM-38	10	A	0.55	0.41	0.78	0.58	0.75	0.41	0.23	0.00	0.20	0.00

Prediction 2: Immediate and delayed facilitation effects of training repetition of LI adjective-noun phrases (e.g., rude agility) or sentences (e.g., Calcium is a rude agility) that are not semantically cohesive will have a significantly smaller effect on performance on repetition of these same nouns when they are presented as unrelated noun pairs/triplets for serial recall in comparison to the effects of the matching condition which employed semantic enhancement.

Prediction 2: Analysis 4: Immediate Effect of the Syntactically Well-Formed Facilitation Condition. Analysis of Condition One demonstrated significant improvement in post-test performance. Using the same statistical measures, Condition Two performance was investigated, comparing pre-test and immediate post-test results. As expected, treatment effects were not significant following training repetition of LI adjective-noun phrases/sentences that were not semantically cohesive. Paired-t-tests determined there was no significant change in performance in repetition IAO of these same nouns during pre-testing performance on words/lists when presented as unrelated noun pairs/triplets for immediate serial recall of words/lists. (Table 23 reports ISO and IAO performance.)

Prediction 2: Analysis 5: Delayed Effect of Syntactically Well-Formed Facilitation Condition. Whereas performance during Condition One improved following a ten-minute delay, in Condition Two there were no significant findings from paired t-tests comparing performance on words/lists in pre-testing to both immediate and delayed post-testing.

Table 23.

Summary of paired t-test results and effect sizes pre-/post-facilitation administration: Prediction 2

Prediction 2	**ISO.C2A1W**	0.63	0.29	**ISO.C2A2W**	0.64	0.30	-0.38	9	.715	1.53	no effect	**Pre-test performance on Condition Two words ISO**	**Immediate post-test performance on Condition Two words ISO**
	C2A1W	0.63	0.29	C2A2W	0.63	0.30	-0.16	9	.876	0.34	no effect	Pre-test performance on Condition Two words IAO	Immediate post-test performance on Condition Two words IAO
	ISO.C2A1L	0.46	0.30	**ISO.C2A2L**	0.49	0.36	-1.84	9	.100	1.04	no effect	**Pre-test performance on Condition Two lists ISO**	**Immediate post-test performance on Condition Two lists ISO**
	C2A1L	0.46	0.30	C2A2L	0.56	0.35	-2.60	9	.136	3.21	small	Pre-test performance on Condition Two lists IAO	Immediate post-test performance on Condition Two lists IAO
	ISO.C2A1W	0.63	0.29	**ISO.C2A10W**	0.70	0.29	-1.64	9	.136	1.57	no effect	**Pre-test performance on Condition Two words ISO**	**Delayed post-test performance on Condition Two words ISO**
	C2A1W	0.63	0.29	C2A10W	0.70	0.29	-1.84	9	.157	2.43	no effect	Pre-test performance on Condition Two words IAO	Delayed post-test performance on Condition Two words IAO
	ISO.C2A1L	0.46	0.30	**ISO.C2A10L**	0.56	0.35	-3.97	9	.003	3.33	small	**Pre-test performance on Condition Two lists ISO**	**Delayed post-test performance on Condition Two lists ISO**
	C2A1L	0.46	0.30	C2A10L	0.29	0.33	0.63	9	.100	2.74	small	Pre-test performance on Condition Two lists IAO	Delayed post-test performance on Condition Two lists IAO

Table 24.

Condition two performance ISO, IAO

ID #	Subject	Condition	In Serial Order (ISO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	B	0.61	0.25	0.67	0.33	0.06	0.08	0.61	0.33	0.00	0.08
EH4	2	A	0.31	0.25	0.58	0.41	0.27	0.16	0.50	0.41	0.19	0.16
XH-46	3	B	0.63	0.41	0.92	0.96	0.29	0.55	0.92	0.96	0.29	0.55
EC-25	4	C	0.47	0.16	0.44	0.08	-0.03	-0.08	0.58	0.16	0.11	0.00
UP-35	**5**	B	0.81	0.66	0.66	0.58	-0.15	-0.08	0.66	0.50	-0.15	-0.16
MI-10	6	D	0.72	0.58	0.86	0.66	0.14	0.08	0.86	0.66	0.14	0.08
1U-19	7	C	0.94	0.83	0.83	0.75	-0.11	-0.08	1.00	1.00	0.06	0.17
NF-54	8	C	0.97	0.92	1.00	1.00	0.03	0.08	1.00	1.00	0.03	0.08
KT-53	9	C	0.04	0.00	0	0.00	-0.04	0.00	0.04	0.00	0.00	0.00
KM-38	10	D	0.83	0.69	0.69	0.25	0.86	0.58	-0.14	-0.11	0.03	-0.11

ID #	Subject	Condition	In Any Order (IAO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	B	0.61	0.25	0.77	0.41	0.72	0.33	0.16	0.08	0.11	0.08
EH4	2	A	0.69	0.25	0.81	0.41	0.83	0.50	0.12	0.25	0.14	0.25
XH-46	3	C	0.79	0.58	0.92	0.96	0.92	0.96	0.13	0.38	0.13	0.38
EC-25	4	C	0.64	0.16	0.72	0.25	0.58	0.16	0.08	0.00	-0.06	0.00
UP-35	**5**	B	0.86	0.66	0.89	0.83	0.89	0.75	0.03	0.09	0.03	0.09
MI-10	6	D	0.89	0.66	0.92	0.75	0.92	0.75	0.03	0.09	0.03	0.09
1U-19	7	C	0.94	0.83	0.89	0.75	1.00	1.00	-0.05	0.17	0.06	0.17
NF-54	8	C	0.97	0.92	1.00	1.00	1.00	1.00	0.03	0.08	0.03	0.08
KT-53	9	C	0.17	0.00	0.17	0.00	0.13	0.00	0.00	0.00	-0.04	0.00
KM-38	10	D	0.83	0.69	0.69	0.25	0.86	0.58	-0.14	-0.11	0.03	-0.11

Prediction 3: Training repetition of LI nouns in semantically related serial recall span tasks of pairs/triplets (e.g., faith-hope/devotion) will result in immediate improved performance in repetition of these same nouns when presented as unrelated noun pairs/triplets for serial recall.

***Prediction 3: Analysis 6: Semantically Related Wo*rd Spans.** Condition Three gave participants semantically related two- and three-word serial recall span tasks. In order to investigate the benefit of training repetition of LI nouns in Condition Three, paired t-tests were completed. As predicted, a paired t-test investigating performance on words pre-test and post-testing showed significant differences, a second paired t-test investigating pre-test performance on lists found that post-test performance significantly improved (Table 26, 27 report, ISO/IAO performance.)

Prediction 3: Analyses 7: Related versus Unrelated Word Span. Condition Four presented nouns as unrelated pairs or triplets. Semantic boost was the only element differentiating Condition Four from Condition Three. A paired t-test investigating pre-testing performance on words within Condition Four (M=0.68, SD=0.20) found no significant difference in immediate post-test performance on words or lists within Condition Four ISO/IAO. Effect sizes as calculated using the Beeson and Robey (2005) method supported a medium effect between word accuracy on pre-/post- (5.04) and list accuracy on Condition Three (6.35) compared to these same effects of word (2.37) and list (2.22) within Condition Four (Table 26, 27).

Table : 25.

Summary of paired t-test results and effect sizes pre-/post-facilitation administration: Prediction 3

Prediction 3	**ISO.C3A1W**	0.58	0.27	**ISO.C3A2W**	0.65	0.27	-3.15	9	.012	2.59	small	**Pre-test performance on Condition Three words ISO**	**Immediate post-test performance on Condition Three words ISO**
	C3A1W	0.58	0.27	C3A2W	0.72	0.23	-5.64	9	c	5.04	small	Pre-test performance on Condition Three words IAO	Immediate post-test performance on Condition Three words IAO
	ISO.C3A1L	0.40	0.29	**ISO.C3A2L**	0.50	0.33	-4.71	9	.011	8.79	medium	**Pre-test performance on Condition Three lists ISO**	**Immediate post-test performance on Condition Three lists ISO**
	C3A1L	0.40	0.29	C3A2L	0.58	0.27	-4.03	9	.003	6.35	medium	Pre-test performance on Condition Three lists IAO	Immediate post-test performance on Condition Three lists IAO
	ISO.C3A1W	0.58	0.27	**ISO.C3A10W**	0.68	0.29	-6.14	9	.000	6.58	medium	**Pre-test performance on Condition Three words ISO**	**Delayed post-test performance on Condition Three words ISO**
	C3A1W	0.58	0.27	C3A10W	0.77	0.23	-5.64	9	.000	7.48	medium	Pre-test performance on Condition Three words IAO	Delayed post-test performance on Condition Three words IAO
	ISO.C3A1L	0.40	0.29	**ISO.C3A10L**	0.58	0.32	-2.34	9	.044	5.66	medium	**Pre-test performance on Condition Three lists ISO**	**Delayed post-test performance on Condition Three lists ISO**
	C3A1L	0.40	0.29	C3A10L	0.62	0.32	-2.45	9	.036	6.06	medium	Pre-test performance on Condition Three lists IAO	Delayed post-test performance on Condition Three lists IAO
	ISO.C4A1W	0.52	0.24	**ISO.C4A2W**	0.60	0.26	-1.92	9	.087	5.78	medium	**Pre-test performance on Condition Four words ISO**	**Immediate post-test performance on Condition Four words ISO**
	C4A1W	0.69	0.20	C4A2W	0.73	0.21	-1.29	9	.228	2.37	no effect	Pre-test performance on Condition Four words IAO	Immediate post-test performance on Condition Four words IAO
	ISO.C4A1L	0.36	0.24	**ISO.C4A2L**	0.67	0.27	-3.16	9	.186	0.83	no effect	**Pre-test performance on Condition Four lists ISO**	**Immediate post-test performance on Condition Four lists ISO**
	C4A1L	0.44	0.27	C4A2L	0.50	0.31	-1.03	9	.333	2.22	no effect	Pre-test performance on Condition Four lists IAO	Immediate post-test performance on Condition Four lists IAO
	ISO.C4A1W	0.36	0.24	**ISO.C4A10W**	0.92	0.22	-2.40	9	.040	5.80	medium	**Pre-test performance on Condition Four words ISO**	**Delayed post-test performance on Condition Four words ISO**
	C4A1W	0.69	0.20	C4A10W	0.76	0.23	-2.40	9	.040	2.69	small	Pre-test performance on Condition Four words IAO	Delayed post-test performance on Condition Four words IAO
	ISO.C4A1L	0.36	0.24	**ISO.C4A10L**	0.55	0.28	-2.45	9	.036	9.50	large	**Pre-test performance on Condition Four lists ISO**	**Delayed post-test performance on Condition Four lists ISO**
	C4A1L	0.44	0.27	C4A10L	0.55	0.28	-2.45	9	.036	5.50	medium	Pre-test performance on Condition Four lists IAO	Delayed post-test performance on Condition Fi

Table 26.

Condition three performance ISO, IAO

ID #	Subject	Condition	In Serial Order (ISO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	B	0.43	0.06	0.43	0.06	0.00	0.00	0.59	0.33	0.16	0.27
EH4	2	A	0.48	0.22	0.57	0.44	0.09	0.22	0.63	0.55	0.15	0.33
XH-46	3	B	0.79	0.75	0.92	0.96	0.13	0.21	0.92	0.92	0.13	0.17
EC-25	4	C	0.29	0.11	0.43	0.11	0.14	0.00	0.44	0.22	0.15	0.11
UP-35	5	B	0.77	0.50	0.85	0.78	0.08	0.28	0.85	0.66	0.08	0.16
MI-10	6	D	0.72	0.50	0.72	0.50	0.00	0.00	0.74	0.61	0.02	0.11
1U-19	7	C	0.85	0.77	0.87	0.77	0.02	0.00	0.94	0.98	0.09	0.21
NF-54	8	C	0.87	0.72	0.94	0.83	0.07	0.11	0.98	0.94	0.11	0.22
KT-53	9	C	0.04	0.00	0.08	0.08	0.04	0.08	0.00	0.00	-0.04	0.00
KM-38	10	D	0.83	0.69	0.69	0.25	0.86	0.58	-0.14	-0.11	0.03	-0.11

ID #	Subject	Condition	In Any Order (IAO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	D	0.43	0.06	0.70	0.50	0.72	0.39	0.27	0.33	0.29	0.33
EH4	2	C	0.67	0.22	0.59	0.60	0.81	0.55	-0.08	0.33	0.14	0.33
XH-46	3	2D	0.92	0.83	0.92	0.92	1.00	1.00	0.00	0.17	0.08	0.17
EC-25	4	B	0.48	0.11	0.50	0.11	0.54	0.22	0.02	0.11	0.06	0.11
UP-35	5	A	0.79	0.50	0.90	0.78	0.85	0.66	0.11	0.16	0.06	0.16
MI-10	6	C	0.78	0.61	0.78	0.61	0.89	0.72	0.00	0.11	0.11	0.11
1U-19	7	B	0.85	0.77	0.87	0.77	0.94	0.98	0.02	0.21	0.09	0.21
NF-54	8	A	0.89	0.72	0.94	0.83	0.98	0.94	0.05	0.22	0.09	0.22
KT-53	9	A	0.2	0.00	0.21	0.16	0.25	0.08	0.01	0.08	0.05	0.08
KM-38	10	C	0.72	0.33	0.80	0.55	0.76	0.61	0.08	0.28	0.04	0.28

A one-way repeated measures analysis of variance was conducted in order to compare scores and analyze change in performance between time 1 (pre-test, prior to intervention) and time 2 (post-test immediately after intervention) in Conditions Three and Four. The results of this analysis supported earlier findings and demonstrated a significant effect between condition performance for words, $F(1,9) = 5.25$, $p = .048$ and for lists, $F(1,9) = 10.258$, $p = 001$.

Prediction 4: Treatment facilitation effects will generalize to improved performance on all-stimuli post-test/TALSA post-tests, when compared to all baseline levels as determined by stimuli-pre-test/TALSA pre-test.

Prediction 4: Analyses 8: Improvements in Post-Testing Performance. A final important research question involved overall improvement from pre-testing to post-testing on two important measures. First, overall performance on a post-test containing all stimuli was predicted to be significantly improved when compared to pre-testing performance. Two paired-samples t-tests were conducted to compare pre-test and post-test performance on words and on lists repeated accurately in any order. There was a significant difference in accuracy of words and in number of lists repeated correct ISO/IAO in pre-test accuracy and post-test accuracy (Table 27, 28 report ISO/IAO performance). Effect sizes (Beeson & Robey, 2005) also supported improvement between pre-and post- test. For words, a medium effect size was found (6.58) and for lists, a very large effect size (12.70).

Table 27.

Summary of paired t-test results and effect sizes pre-/post-facilitation administration: Prediction 4

Prediction 4	**ISO.PreA1W**	0.62	0.23	**ISO.PostA2W**	0.89	0.21	-2.34	9	.044	2.19	no effect	**All Stimuli pre-test words ISO**	**All Stimuli post-test words ISO**
	PreA1W	0.63	0.23	PostA2W	0.77	0.23	-7.16	9	.000	1.17	no effect	All Stimuli pre-test words IAO	All Stimuli post-test words IAO
	ISO.PreA1L	0.34	0.23	**ISO.PostA2L**	0.87	0.27	-2.37	9	.042	2.30	no effect	**All Stimuli pre-test lists ISO**	**All Stimuli post-test lists ISO**
	PreA1L	0.34	0.23	PostA2L	0.62	0.33	-6.36	9	.000	1.22	no effect	All Stimuli pre-test lists IAO	All Stimuli post-test lists IAO
	ISO.T1A1W	0.83	0.27	**ISO.T1A2W**	0.77	0.23	-7.16	9	.000	2.22	no effect	**Pre-test performance on 1-item TALSA words ISO**	**Post-test performance on 1-item TALSA words ISO**
	T1A1W	0.83	0.27	T1A2W	0.89	0.22	-2.34	9	.043	2.18	no effect	Pre-test performance on 1-item TALSA words IAO	Post-test performance on 1-item TALSA words IAO
	ISO.T1A1L	0.77	0.26	**ISO.T1A2L**	0.90	0.15	-2.33	9	.044	4.60	small	**Pre-test performance on 1-item TALSA lists ISO**	**Post-test performance on 1-item TALSA lists ISO**
	T1A1L	0.81	0.32	T1A2L	0.87	0.27	-2.36	9	.003	8.70	large	Pre-test performance on 1-item TALSA lists IAO	Post-test performance on 1-item TALSA lists IAO
	ISO.T2A1W	0.82	0.20	**ISO.T2A2W**	0.95	0.07	-2.65	8	.029	5.71	small	**Pre-test performance on 2-item TALSA words ISO**	**Post-test performance on 2-item TALSA words ISO**
	T2A1W	0.87	0.14	T2A2W	0.95	0.07	-2.65	8	.029	8.87	large	Pre-test performance on 2-item TALSA words IAO	Post-test performance on 2-item TALSA words IAO
	ISO.T2A1L	0.70	0.14	**ISO.T2A2L**	0.85	0.16	-1.71	8	.000	4.15	small	**Pre-test performance on 2-item TALSA lists ISO**	**Post-test performance on 2-item TALSA lists ISO**
	T2A1L	0.77	0.29	T2A2L	0.90	0.16	-2.39	8	.000	6.89	medium	Pre-test performance on 2-item TALSA lists IAO	Post-test performance on 2-item TALSA lists IAO
	ISO.T3A1W	0.70	0.14	**ISO.T3A2W**	0.90	0.22	-6.37	7	.000	9.39	large	**Pre-test performance on 3-item TALSA words ISO**	**Post-test performance on 3-item TALSA words ISO**
	T3A1W	0.70	0.14	T3A2W	0.83	0.14	-6.37	7	.000	9.28	large	Pre-test performance on 3-item TALSA words IAO	Post-test performance on 3-item TALSA words IAO
	ISO.T3A1L	0.45	0.32	**ISO.T3A2L**	0.56	0.35	-3.78	7	.004	5.69	small	**Pre-test performance on 3-item TALSA lists ISO**	**Post-test performance on 2-item TALSA lists ISO**
	T3A1L	0.41	0.25	T3A2L	0.61	0.27	-4.51	7	.004	3.33	small	Pre-test performance on 3-item TALSA lists IAO	Post-test performance on 3-item TALSA lists IAO

Table 28.
Condition four performance ISO, IAO

ID #	Subject	Condition	In Serial Order (ISO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	B	0.5	0.22	0.5	0.16	0.00	-0.06	0.5	0.28	0.00	0.06
EH4	2	A	0.31	0.16	0.46	0.44	0.15	0.28	0.69	0.50	0.38	0.34
XH-46	3	B	0.58	0.58	0.83	0.92	0.25	0.34	0.92	0.92	0.34	0.34
EC-25	4	C	0.33	0.11	0.46	0.22	0.13	0.11	0.57	0.39	0.24	0.28
UP-35	**5**	B	0.59	0.67	0.75	0.55	0.16	-0.12	0.88	0.83	0.29	0.16
MI-10	6	D	0.57	0.28	0.57	0.33	0.00	0.05	0.68	0.55	0.11	0.27
1U-19	7	C	0.87	0.67	0.91	0.83	0.04	0.16	0.94	0.88	0.07	0.21
NF-54	8	C	0.81	0.50	0.91	0.83	0.10	0.33	0.81	0.55	0.00	0.05
KT-53	9	C	0.04	0.00	0.08	0.08	0.04	0.08	0.00	0.00	-0.04	0.00
KM-38	10	D	0.83	0.69	0.69	0.25	0.86	0.58	-0.14	-0.11	0.03	-0.11

ID #	Subject	Condition	In Any Order (IAO)						Improvement in Accuracy			
			Pre-Test		Post-Test A		Post-Test B		Post-Test A		Post-Test B	
			Words	Lists	Words	Lists	Words	Lists	Words	Lists	Words	Lists
KC3	1	D	0.59	0.38	0.67	0.22	0.57	0.28	0.08	-0.10	-0.02	-0.10
EH4	2	C	0.57	0.16	0.85	0.50	0.80	0.50	0.28	0.34	0.23	0.34
XH-46	3	2D	0.92	0.92	0.83	0.92	0.96	0.92	-0.09	0.00	0.04	0.00
EC-25	4	B	0.64	0.28	0.70	0.28	0.72	0.44	0.06	0.16	0.08	0.16
UP-35	**5**	A	0.83	0.67	0.85	0.61	0.91	0.83	0.02	0.16	0.08	0.16
MI-10	6	C	0.57	0.28	0.67	0.39	0.81	0.55	0.10	0.27	0.24	0.27
1U-19	7	B	0.87	0.67	0.91	0.83	0.96	0.88	0.04	0.21	0.09	0.21
NF-54	8	A	0.81	0.50	0.96	0.88	0.85	0.55	0.15	0.05	0.04	0.05
KT-53	9	A	0.25	0.00	0.21	0.00	0.21	0.00	-0.04	0.00	-0.04	0.00
KM-38	10	C	0.81	0.55	0.69	0.39	0.80	0.55	-0.12	0.00	-0.01	0.00

Prediction 4: Analyses 9: Improvements in *TALSA* Performance. Paired t-tests were conducted to compare pre-test and post-test performance on words and on lists repeated accurately within the *TALSA* (Martin, et al., 2010). There was a significant difference in improvement in accuracy of words and lists repeated correctly at each level of the *TALSA* (Martin, et al., 2010) testing. Significantly, there was an effect ISO and IAO between HI and LI words during pre-test, but not post test. LI was significantly different across pre-test to post test. This was not true for HF vs LF within or across conditions. This persisted across the three levels of the *TALSA* (Martin, et al., 2010) test (1-3 item lists).

Effect Sizes

Although no standards are available for evaluating the significance of effect sizes for repetition treatment, the relative size of treatment effects could be evaluated for Condition One (semantically cohesive adjective noun phrases/sentences) and Condition Three (semantically related word span) and compared to the results under Condition Two (adjective noun phrases/sentences that are not semantically cohesive) and Condition Four (unrelated word span). The comparative evaluation demonstrated significant improvement in accuracy for Conditions One (Table 22, 23) and Three (See Table 26, 27).

Discussion.

Results were exceptionally rich, given the variety of participant performance. This varied improved performance supported the assumptions of the interactive activation model that served as the theoretical framework of this investigation. Both Conditions One and Three demonstrated that manipulation of semantic presentation provided a significant benefit over presentations that did not include semantic enhancement. In terms of the IA model of language processing, semantically enhanced conditions activated lexical and semantic levels of processing, making maintenance for repetition more attainable for individuals with chronic auditory-verbal STM impairment. Overall, significant improvement in repetition of both words and lists was noted. By examining whether repetition improved an individual's facility with repetition, the current research established greater understanding of theory-driven treatment paradigms and provided insights that have direct implications for the treatment of chronic auditory-verbal STM impairment.

CHAPTER 5:
DISCUSSION

The preceding chapters address the presentation of deep to phonological dysphasia. Deep to phonological dysphasia is a complex impairment known for chronic and severe impairment of auditory-verbal STM (Martin et al., 1996; Wilshire & Fisher, 2004; McCarthy et al., 2016). This research expanded understanding of this population and supported the premise that the two disorders exist on a continuum of severity, as first proposed by Martin and colleagues (1996). PWA are, thus, the ideal population to investigate the efficacy of a treatment approach targeting language and STM.

It is now widely accepted that aphasia is an acquired language disorder that disrupts language processing and STM and, furthermore, that these damaged areas recover in tandem. Despite this recognition, few treatment studies have examined whether treating both language and STM provides greater gains across areas. As discussed in Chapters 1 and 2, a literature review of deep to phonological dysphasia revealed new insight into the expected pattern of recovery in this population.

This research aimed to provide additional evidence to support the hypothesis of a continuum from deep to phonological dysphasia (Martin et al., 1996) with severity determined by the degree of global decay across the phonological-lexical-semantic levels of language processing. The longitudinal case study of NC (Martin et al., 1992; 1994; 1996) is reported to be the longest case study of recovery in deep dysphasia (Ablinger et al., 1998). Results supported the premise that a predictive relationship exists between auditory-verbal STM span and imageability effect. These findings were consistent with conclusions from other studies that a relationship exists between auditory-verbal STM span and rate of sematic errors. Overall, the findings aligned with the predications of the

IA model. The pattern of semantic error rates and imageability effects in repetition were related to auditory-verbal STM span. This analysis yielded theoretical, empirical, and clinical insights into the deep-phonological dysphasia continuum.

Results of the current dissertation research provided further support for the hypothesis of a severity continuum and, by examining the role repetition plays in improving performance, sought to directly inform clinical practice. Its findings, thus, emphasized the value of a theoretically motivated approach to an essential component of functional communication.

Several conclusions can be established from its single-case study of LT and multi-participant facilitation investigations. The treatment approach embedded in this research showed a positive effect on auditory-verbal STM capacity, as evidenced by generalized improvements in post-testing measures including word span. The results, taken together, add more precision to the understanding of deep to phonological dysphasia on a continuum of recovery. As predicted, adding semantic context (in the form of adjective-noun phrases/sentences) to each word in the LI pair facilitated access to and maintenance of LI word pairs/triplets when the semantic context was removed and the LI words were repeated in isolation.

The single subject case study of LT as well as the ten-person treatment protocol showed that when semantically cohesive adjective-noun phrases were used as primes, repetition of LI word pairs in probes improved robustly during maintenance and follow-up. Similar improvement did not occur in either study when adjective-noun phrases that lacked semantic cohesion were used as primes. These results supported the hypothesis that feedback activation from the semantic network strengthens the lexical and phonological representations of words and that increasing the strength of that semantic feedback activation improves access to low image words. This strategy facilitated LT's immediate access to the words in the context of the adjective-noun phrases and generalized to isolated repetition in probes. LT's ttreatment outcomes indicated that increasing the semantic cohesiveness of low-frequency and low-imageability words improved her ability to repeat those words in the context of the adjective-noun word pair, but also in isolation.

Clinical and Research Implications

The treatment approach embedded in this research showed a positive effect on verbal STM capacity, as evidenced by generalized improvements in post-testing measures including word span. The increases, in turn, resulted from improvement of one or both parameters that mediate spreading activation—connection strength and decay rate. Thus, embedding hard-to-access LI words in more imageable adjective-noun phrases improved activation and short-term maintenance of semantic representations of words. These improvements were evident in greater accuracy in repetition of words as well as an increase in verbal span capacity. STM span for LI words increased following intervention.

The study aimed to develop a treatment that would strengthen access to LI words and thereby improve repetition of these words. The theoretical framework of the IA model of language processing and repetition in aphasia (Martin et al., 1994; Martin & Saffran, 1997) framed the predictions for this treatment approach and, in turn, served as a means by which the results could be understood. Repetition of words in an IA model is mediated by input phonological activation of the word form in the lexicon and feedback activation from semantics, which together converge on lexical nodes (the target word and competitors) in the lexical network. HI words benefit more from stronger top-down semantic feedback activation than LI words. This difference accounts for imageability effects in word repetition. Manipulation of the linguistic context of an adjective-noun phrase influenced, for example, LT's ability to activate and maintain activation of the phonological forms of these low-image words. Access was facilitated by embedding the low-image words in a context that increased imageability and the strength of semantic feedback to the lexical form of the word. This feedback increased the number of opportunities for successful activation of the word form in the lexicon, contributing to generalization of access to the LI words without the semantically enriched context.

Future Directions

Often, success was found within treatment sessions when participants were given three opportunities to respond. The first, perhaps timid or uncertain response would enhance maintenance, which would then be reinforced with another trial. By the third trial, many participants stated a correct response confidently, avoiding a rapid decay of the information to be repeated.

As the primary clinician administrating this treatment approach, verbal and nonverbal observations of participant's reactions to treatment should be briefly touched upon. During this study, a consistent observation was that a participant would react with joy in the success of giving a correct response. Informal notations made during sessions recorded the clear difference in the way a positive semantically related probe (e.g., *talent-skill-ambition)* was vocalized for repetition in comparison to a probe with negative word associations (e.g., *loan-debt-frugal*). This enthusiasm was akin to the practice of repeating positive affirmations. Positive affirmations are also intended to be repeated three times and are often composed of abstract words.In a semantically cohesive context, however, they become more imageable. Integration of the concept of mindfulness and positivity in future repetition treatments may provide a fruitful area of continued research.

Another future direction would be the exploration of other presentations of semantically cohesive adjective noun phrases that could increase the likelihood of generalization to untrained stimuli. For example, the noun “habit” could be paired with multiple adjectives in phrases that vary in length and complexity (e.g., new habit; daily habit, creature of habit; break the habit). It is possible that embedding a difficult-to-access low-image word in a variety of semantically enriching contexts may stimulate stronger and more sustained semantic activation. Improvement in repetition of LI pairs would not be linked to a single specific adjective and could promote greater response generalization to untrained LI pairs.

Clinical Relevance.

There are countless real-life situations where repetition and auditory-verbal STM capacity are essential for communicative success. For individuals with STM impairments, simply talking on the telephone can be unmanageable. Say a PWA gets a call from a doctor’s office regarding a change in medication. If the conversational context does not provide the necessary level of semantic support, abstract words used in the call may be difficult to process and repeat. Establishing the safest and highest level of independence communicating wants and needs seem superficially easy, as persons with verbal STM impairment often compensate using strengths.

Functionally, even the most rudimentary literature provided regarding the prevention of stroke is overwhelmed with abstract words that could be combined to enhance semantic meaning. Treatment of increased semantic cohesiveness could assist in recovering ability to understand verbal directions (e.g adjective-noun word pairs: “hypertensive crisis”; “medication management”; “oral intake”). The results of this dissertation research indicate that treatments that repeatedly facilitate successful attempts to access a lexical word form can potentially improve ease of access to that word without facilitation.

Limitations.

There is a caveat to the generalizability of this treatment protocol. The approach is appropriate for someone whose repetition and maintenance of words in auditory-verbal STM relies primarily on activation and short-term maintenance of semantic representations of words, relative to the ability to activate and maintain activation of phonological representations. There are individuals with aphasia, however, who show an opposite difficulty in repetition—poor access and maintenance of semantic representations of words relative to phonological representations. In theory, these individuals should demonstrate a reduced imageability effect in repetition, as recall will be based primarily on the phonological activation of words with little feedback from semantic support. This reliance on phonological activation would likely lead to a reduced auditory-verbal repetition span, but with errors that are more phonologically than semantically related. This pattern has been observed in some studies (e.g., Martin & Saffran, 1997), but remains to be tested more fully.

The repetition of abstract words (e.g. “exclusion; distance”) is most challenging for some persons with aphasia because they do not evoke a clear mental representation. In order to enhance semantic processing and auditory-verbal STM, the treatment approach investigated in this dissertation improved semantic availability by embedding an abstract word into the context of an adjective-noun phase (e.g., “social exclusion; long distance”). Often, success was found within treatment sessions when participants were given three opportunities to respond. The first, perhaps timid or uncertain response would enhance maintenance, which would then be reinforced with another trial. By the third trial, many participants stated a correct response confidently, avoiding a rapid decay of the information to be repeated.

Concluding Remarks.

This dissertation presented the first treatment approaches that specifically target the repetition impairment in chronic auditory-verbal STM deficits. Its results have extended the literature base beyond its previous focus mainly on characterizing the nature of the impairment. Outcomes of this study demonstrated two important potentials of targeted intervention. First, the view of aphasia as an impairment of processing that affects access to otherwise intact representations of words opened up a new way of thinking about treatment approaches. Following the principles and specific components of a model that embraces this view can guide future development of treatment protocols.

Second, dynamic models that focus on aphasia as an impairment of processing demonstrate that cognitive plasticity is feasible and provide the guidelines to stimulate cognitive changes. The notion of cognitive plasticity is akin to neural plasticity. Evidence for the latter comes in the form of neural changes (e.g., increased or decreased neural activity) observed in imaging studies before and after treatment (Fridriksson, 2010; Fridriksson et. al., 2012; Sandberg & Kiran, 2014; Sandberg, Bohland & Kiran, 2015).

At the cognitive-behavioral level, behavioral treatments designed on the basis of cognitive models can result in measurable changes in performance that reflect cognitive plasticity. These changes may or may not be manifested in neurological changes. It may be ideal to observe both neural and cognitive changes following treatment, and rehabilitation research should assess both these levels of change. For clinical purposes, however, the measures of cognitive change are the most direct and immediate indicators of change that signals better language function.

This research has provided an example of the use of principles of cognitive plasticity, theoretically supported by the IA model. These principles have been applied to develop and implement a treatment protocol that improved better auditory access to a class of words that are predicted by the model to be difficult to access. The success of this application, evident in the research results, demonstrates the usefulness of this approach in the development of treatment paradigms that promote comprehensive recovery of language abilities in aphasia.

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