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Patient factors that predict response to intensive phonomotor treatment

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Abstract

Patient Factors that Predict Response to Intensive Phonomotor Treatment

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Phonomotor treatment is a phonologically based, intensive training program associated with gains in naming trained items, untrained items (generalization) and improvements in parts of discourse and quality of life indicators. The purpose of this study was to examine links between pretreatment individual factors and phonomotor treatment outcome measures in 26 persons with aphasia. Age, months post onset (MPO), severity of aphasia, severity of anomia, and severity of phonological impairment were assessed prior to treatment and compared to gains immediately and at a 3 month follow-up. Though age and MPO appear to predict immediate improvement, they do not predict maintenance of learned skills following treatment termination and therefore should not be used to inform enrollment decisions. Baseline lexical retrieval ability predicted trained and untrained real word confrontation naming 3 months following treatment termination. These results lend support for the importance of considering residual lexical-semantic abilities when enrolling participants into phonomotor treatment.

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Introduction

Aphasia is an acquired language disorder that affects approximately 25% to 45% of stroke survivors (McClung, Gonzalez Rothi & Nadeau, 2010) and is associated with lower quality of life ratings, poorer functional outcomes, greater mortality, and greater cost of care compared to stroke survivors who do not have aphasia (Ellis, Simpson, Bonhila, Maudlin & Simpson, 2012; Laska, Hellblom, Murray, Kahan & von Arbin, 2001). Damage to cortical networks limits access to language processing units located at the levels of phonology, syntax, and lexical semantics, resulting in heterogeneous deficit profiles that may involve receptive and/or expressive language. Anomia, or naming difficulty, is a regular and devastating consequence of both focal and diffuse damage in the left hemisphere that results from either incorrect or incomplete activation of semantic or phonological information (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997). Due to its prevalence, various treatments for anomia have been extensively researched. The overarching goal of anomia therapy is to improve production of words that were trained in therapy, maintain those changes over time, and achieve generalization to words and linguistic behaviors that were untrained.

In a hallmark meta-analysis on phonological, semantic, and mixed treatment approaches, Wiseburn and Mahoney (2009) noted large standard deviations in response to language treatment despite evidence for overall efficacy. These authors attributed this to the influence of moderator variables. Confounding intra-individual (e.g., type of lesion, age, pre-stroke depression, etc.) and extra-individual (e.g., psychosocial support, presence of supportive caregiver, etc.) factors almost certainly impact success in any anomia treatment program. However, to date, the impact of these factors on treatment outcomes is not well understood, is often analyzed post-hoc rather than being the primary focus of investigation, and is often considered in relation to participation in

intervention generally, rather than in relation to the nature of a specific intervention protocol. Not only is understanding the impact of individual factors important in discerning the efficacy of a specific language intervention, but it is also ethical to consider how to best allocate treatment in today's healthcare climate. Predicting response to treatment based on factors that can be assessed prior to implementation is a powerful tool in selecting participants that will benefit from therapeutic activities that require a large commitment of time and monetary resources.

Importantly, outlining the impact of such factors will also inform expectations of patients and their families. To this end, the purpose of the proposed study is to retrospectively examine links between 5 relevant patient factors and treatment outcome measures on n=26 persons with aphasia (PWA) who completed 60 hours of intensive phonomotor treatment.

Phonomotor Treatment

A myriad of treatment protocols have been designed to enhance and restore damaged language networks through restorative therapy. Phonomotor treatment is one such treatment that has been developed over the past 15 years and was specifically designed to achieve generalization and maintenance goals (Kendall, Conway, Rosenbek & Gonzalez-Rothi, 2003; Kendall et al., 2006a; Kendall, Rodriguez, Rosenbek, Conway & Gonzalez-Rothi, 2006b; Kendall et al., 2008, Kendall, Oelke, Brookshire & Nadeau, 2015; Raymer, Haley & Kendall, 2002). This intensive, phonologically based protocol has been systematically investigated in a series of phase I and phase II trials (Kendall et al., 2003; Kendall et al., 2006a; Kendall et al., 2006b; Kendall et al., 2008; Kendall et al., 2015). Results thus far provide evidence of improvement in naming trained items, untrained items (generalization) and importantly, evidence of improvements in parts of discourse and quality of life indicators (Kendall et al., 2003; Kendall et al. 2006a; Kendall et al., 2008; Kendall et al., 2015). Phonomotor treatment is theoretically

motivated and aims to increase activation and connectivity throughout the entire language network through training at the level of phonology.

Intensive. Phonomotor treatment includes intensive training (i.e., 60 hours of training across 6 weeks). Many have stressed the importance of intensive training in order to maximize efficacy. Specifically, intensive language therapy over a short period of time is associated with positive outcomes in patients with aphasia (Bhogal, Teasell, & Speechley, 2003; Denes, Perazzolo, Piani & Piccione, 1996; Wenke et al., 2014).

Phonologically based. Phonomotor treatment includes training of phonemes and 1, 2, and 3 syllable real and non-word phoneme sequences (See appendix A for a complete description of the treatment protocol). Most anomia treatments, such as semantic feature analysis (SFA), capitalize on a top-down process of word retrieval where the strengthening of semantic concepts facilitates access to associated items at the lexical and phonological levels of language. In contrast, phonomotor treatment utilizes a bottom-up process, where enhancing phonological knowledge using multi-modal input results not only in strengthened representations, but also strengthens connections to related items at other levels of language (e.g., lexical-semantics). This is supported by Dell's (1986) interactive activation theory, which postulates that the process of word retrieval follows a bidirectional selection process using semantic, word form and phonologic levels of knowledge.

According to this model, input at any level activates a bi-directional cascading effect of activation to related representations at all levels of language. For example, training of the phoneme sequence "ch" may activate the lexemes "chair," "chimpanzee," or "challenge," and will also spread to related concepts at the level of semantics. Activation permeates throughout the entire language network and target items at each level and closely related "neighbors" are

activated. The item receiving the strongest activation is selected. Input targeting any level of the network will trigger a similar pattern of activation throughout the network. For example, a picture of a chair may trigger this pattern of activation beginning at the level of semantics. This theory is supported by the types of errors that PWA make: following stroke, reduced or incomplete activation results in predictable, rule based errors that are often related phonologically (e.g., “chase” for “chair”) or semantically (e.g., “couch” for “chair”) to the target item.

Multi-modal. The tasks of phonomotor treatment are delivered using multi-modal input (e.g., auditory, motor, orthographic, tactile-kinesthetic, and conceptual) modified from the Lindamood Phoneme Sequencing Program (Lindamood & Lindamood, 1998) and based on Nadeau’s (2001) parallel-distributed processing (PDP) model of phonology. Nadeau’s model proposes that phonologic representations are distributed patterns of connectivity within and between auditory, articulatory motor, orthographic, and semantic/conceptual domains. In a damaged network, these connections exhibit properties of graceful degradation and probabilistic selection, resulting in errors that are not novel or bizarre, but rather that remain rule-bound. Connections between the units, both within and across domains, can be strengthened through multimodal learning. Distributed phonologic representations are thought to be rapidly and simultaneously engaged during verbal and written language tasks, and input into any domain of the phonologic network (e.g., auditory, orthographic, etc.) should lead to engagement of other domains. The tasks of phonomotor treatment are designed to capitalize on this interconnectivity, and training enhances all facets of phonological knowledge and, theoretically, their connections to other levels of the language network. See Figure 1 for a representation of Phonomotor Treatment tasks.

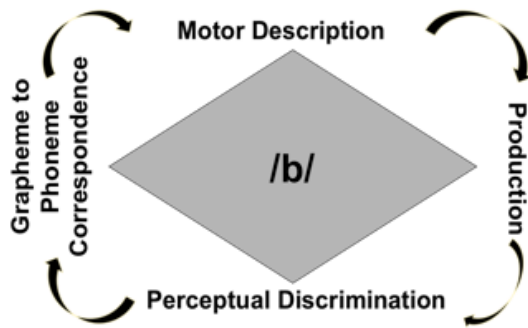


Figure 1. Visual representation of phonomotor treatment multi-modal training tasks.

Generalization. Theoretically, there is also support for generalization. Phonological knowledge, comprised of phonemes and phoneme sequences, has extensive underlying regularities that occur in a variety of linguistic contexts. Phonological processing is a core language function that drives the decoding and production of sounds, and allows us to understand and produce meaningful language (Nadeau, 2001). In theory, treatment targeting this limited set of sequences and patterns that occur in English words strengthens connections within and between representations at all levels of language (e.g., phonology, lexical-semantics) and results in improvements in naming and discourse production. Additionally, it facilitates broad generalization within the language network if these sequences and patterns can be strengthened and restored. Evidence for improvement in naming trained items following phonological intervention is widely supported in the literature (Lorenz & Ziegler, 2009; Miceli, Amitrano, Capasso, & Caramazza, 1996; Wiseburn & Mahoney, 2009), however, evidence for generalization has been mixed (Miceli et al., 1996; Nettleton & Lesser, 1991). Thus far, results from phonomotor treatment trials provide evidence of generalization, which is promising (Kendall et al., 2015).

Patient Factors Related to Response to Treatment

Initial results of phonomotor treatment trials are promising, however, an important next step and what remains to be known is who responds to this type of treatment and who does not. Clear themes are evident among studies that have examined individual patient factors that predict recovery and response to treatment. Intra-individual factors that have a higher degree of support in the literature include initial severity of impairment, severity of impairment within different language domains (e.g., phonology, auditory comprehension), cognitive status (e.g., memory, attention, executive functions), pre- or post-morbid depression, and lesion characteristics (e.g., volume, location) (El Hachioui et al., 2013; McClung et al., 2010; Watila & Balarabe, 2015). Although extra-individual factors reflect a largely neglected area of study compared to intra-individual factors, supported extra-individual factors include presence of a supportive caregiver; patient or caregiver depression; presence of familial, community, and social supports; and presence and quality of language rehabilitation (McClung et al., 2010; Watila & Balarabe, 2015). Intra-individual factors with mixed support in the literature include age, gender, time post onset, multilingualism, handedness, occupational status, educational status and socioeconomic status (McClung et al., 2010; Nettleson & Lesser, 1991; Persad, Wozniak & Kostopoulos, 2013; Watila & Balarabe, 2015).

Aphasia research aimed at identifying patient factors that predict response to anomia treatment is challenged by the nature of the population: sample sizes are generally small and participants are heterogeneous in regards to factors such as lesion characteristics and familial support, yet homogeneous in regards to factors such as multilingualism and socioeconomic status. Furthermore, there is a complex interplay between stroke characteristics (e.g., lesion site and size), aphasia characteristics (e.g., severity of impairment) individual factors (e.g.,

depression) and extra-individual factors (e.g., social support), which makes it hard to understand the impact of any one factor in isolation from others. Additionally, studies examining patient factors that predict response to anomia treatment are highly susceptible to limited statistical power due to the need to explore a multitude of factors in the context of a limited sample size. Therefore, it is vitally important to carefully select a limited number of patient factors that are theoretically and empirically supported.

In this study, 5 patient factors that relate to aphasia recovery and anomia treatment outcomes will be examined: age, months post onset (MPO), and pre-treatment severity of aphasia, naming impairment, and phonological impairment. Cognition (e.g., memory, attention, executive functions), presence of pre- or post-morbid depression, and psychosocial support have emerged as an important predictor of treatment success, however the current study did not have ample data to include these variables. Furthermore, even though factors that predict both spontaneous recovery *and* response to treatment are important to understand, this distinction is often not explicitly discussed or delineated in the literature pertaining to predictors of recovery. Although the focus of this study is on response to treatment, background pertaining to spontaneous recovery as well as response to treatment (where applicable) has been reviewed and thus, will be discussed here in order to provide context for the current study.

Age. Treatment aimed at restoring access to impaired language networks relies on brain alterations or changes, commonly referred to as neuroplasticity. Changes can be biochemical, physiologic, or structural in nature (Papathanasiou, Coppens, & Potagas, 2013). Human and animal models suggest that cortical reorganization varies depending on a number of factors such as age, extent of injury, and participation in rehabilitative therapies (Levin, 2003; Shih & Cohen, 2004). Historically, the prevailing thought was that brains beyond the point of nervous system

development were incapable of cortical reorganization (Shih & Cohen, 2004). More recently, this myth has been dispelled in both animal and human models (Kempermann, Gast, & Gage, 2002; Park & Reuter-Lorenz, 2009). However, what remains unclear is the neuroplastic potential of older versus younger subjects and the effects of confounding personal or environmental variables. As a result, age is commonly included as a variable of interest in studies that aim to identify predictors of spontaneous recovery and response to treatment following stroke.

Spontaneous recovery. Age as a predictor of spontaneous recovery has received mixed results in the literature. El Hachoui et al. (2013) examined the functional linguistic outcomes of 147 stroke patients at one-year post onset. Results indicated that age was a significant predictor of recovery, with younger participants having an advantage. Wagle et al. (2011) found similar results. Younger age, intact cognitive skill, and activities of daily living (ADL) pre-stroke were associated with a greater degree of recovery in their sample of 163 stroke patients who were followed for 13 months post-stroke. Laska et al. (2001) followed 119 aphasic patients over the course of 18 months, and results included a significant effect for age, with younger patients recovering a greater degree of language skill during this period of recovery.

In contrast, Lazar et al. (2010) examined language recovery over a shorter period of time during the acute phase (e.g., 90 days following first-time stroke) in a smaller sample of 21 stroke patients. Age was not identified as a significant predictor of improvement, with both younger and older individuals exhibiting gains predicted primarily by the initial severity of their deficits. It is unclear whether this lack of significance was due to a shorter time interval, smaller sample of participants, or other variables. Pedersen, Vinter, and Olson (2004) followed a larger sample of 270 participants over the course of one year following stroke, and found that age, gender, and handedness were not related to language outcomes. Similarly, Pedersen, Jorgensen, Nakayama,

Raaschou and Olsen (1995) followed 880 stroke patients over the course of 6 months following injury, and found that only initial severity of impairment, but not age, was related to language recovery. Although not specific to stroke patients, a study by Levin (2003) provides insight into the interplay between age and lesion characteristics. Participants with closed-head traumatic brain injury (TBI) were assessed for signs of neural reorganization, and age emerged as an advantage only when the injury was focal, rather than diffuse. Further research examining age in relation to spontaneous recovery is needed to understand the complex dynamics of this variable.

Response to intervention. Treatment efficacy studies frequently examine the relationship between age and degree of improvement. It is well established that age is a significant predictor when measuring improvement through activities of daily living (ADLs) (Carod-Artal, Medeiros, Horan & Braga, 2005; Kong & Lee, 2014; Paolucci et al., 2001; Wagle et al., 2011).

Assessments designed to measure ADLs, such as the Barthel Index (BI) or the Functional Independence Measure (FIM) often include some measure of functional communication, but rarely analyze communication and language in isolation from other, age-related variables such as ambulation or bladder management. Therefore, studies relying solely on ADL assessment as an outcome measure are of limited use when examining the influence of age on language recovery following intervention.

Many treatment efficacy studies have looked at the relationship between age and language outcomes using “pure” language measures. Overall, it is unclear whether age is a significant predictor of recovery. Van de Sandt-Koenderman et al. (2008) outlined a multi-axial system aimed at guiding selection of participants for aphasia treatment. In their sample of 58 participants who received 40 hours of treatment, age at time of onset was a significant predictor of improvement, with an advantage for younger participants. These authors did not expect this

result, and cautioned that older age alone should not be an exclusion factor, especially because confounds such as motivation and general health likely influence improvement potential.

Marshall, Tompkins, and Phillips (1982) examined 110 participants' response to a one-month treatment program. These authors split participants into groups who experienced either marked, fair, or poor gains following treatment. The participants who made marked gains were significantly younger than those classified as making poor gains. Similarly, Lendram, McGuirk and Lincoln (1988) looked at language gains made by 87 PWA following 24 weeks of treatment provided within the first year following stroke. Age was classified by decade, and results indicated an advantage for younger patients, with older patients achieving lower levels of overall ability. In contrast, Seniow, Litwin, and Lesniak (2009) examined response to treatment in a sample of 47 PWA. Age did not emerge as a significant factor related to language improvement, but it is important to note that these authors excluded participants older than 65 years in order to control for cognitive decline associated with aging. In this case, a lack of variability in age may have contributed to nonsignificant findings. Code, Torney, Gildea-Howardine, & Willmes (2010) examined 8 participants' response to a one-month intensive treatment. All individuals made significant progress regardless of age, and interestingly, the oldest participant made the most progress overall. Pickersgill and Lincoln (1983) examined age in relation to response to treatment, and found that age was largely unrelated to treatment outcomes. Interestingly, they did report that older age may be associated with poorer recovery in the group of patients classified as having severe aphasia, but not in the group with moderate aphasia. Persad et al. (2013) completed a retrospective analysis of participants' responses to two intensive aphasia treatment programs. Results indicated that age was not a significant predictor of improvement on measures of language ability or importantly, functional communication.

Overall, the evidence for age as a predictor of spontaneous recovery and response to treatment is mixed. It is clear that the brain has the ability to adapt and change over the course of its life. However, confounding intra-individual and extra-individual variables (e.g., lesion characteristics, social support, etc.); the potential for change in older age; and varied research methodology complicate the understanding of this variable, warranting continued exploration of the circumstances under which age is a potent predictor of recovery.

Time post onset.

Spontaneous recovery. Time post onset (TPO) is strongly related to spontaneous recovery of function following acute stroke. It is clear that a bulk of spontaneous recovery occurs within the first 3 months following stroke (Demeurisse et al., 1980; Kertesz & McCabe, 1977; Laska et al., 2001). Relevant factors related to degree of spontaneous recovery were identified by Cramer (2008) and include the following: most spontaneous recovery occurs within the first 3 months following injury, cognitive deficits versus motor deficits are more likely to continue improving after the 3 month mark, patients with more mild deficits make quicker gains than those who have more severe deficits, and patterns of recovery within one person may vary across domains. Pedersen et al. (1995) studied language recovery following acute stroke in a sample of 881 participants. In 95% of patients with aphasia, language stabilization was reached within 2 weeks in those with initial mild aphasia, within 6 weeks in those with moderate aphasia, and within 10 weeks in those with severe aphasia. Kertesz (1988) found that a majority of language recovery occurred within the first 3 months following stroke, however, in contrast to recovery as stagnant after this point, a significant number of patients continued to improve beyond 3 months. Evidence suggests that the bulk of spontaneous recovery occurs in the first months to year

following the acute injury, however, the finding that gains are often experienced beyond a year highlights the variability in spontaneous language recovery.

Response to intervention. It is well supported in both human and animal models that quality therapeutic experience facilitates neuroplastic changes following injury (Kleim & Jones, 2008; May et al., 2007; Meinzer et al., 2004). Many language interventions and rehabilitation programs have proven effective, and there is evidence that early intervention may capitalize on periods of spontaneous recovery and maximize functional recovery (Basso, Capitani & Vignolo, 1979; Duncan et al., 2002; Laska et al., 2001). Huang, Chung, Lai & Sung (2009) examined early rehabilitation, and results were consistent with what's referred to as the "6-month gold standard," which highlights the benefit of beginning rehabilitation within this timeframe in order to maximize functional recovery. Carod-Artol et al. (2005) found similar results. In their prospective study of patients admitted to a rehabilitation setting, patients admitted later than 6 months following stroke experienced fewer gains than those admitted before this time-point. This is consistent with the results of Marshall et al. (1982). Following treatment, participants who made marked improvements began therapy earlier post onset than those who made fair or poor progress. Persad et al. (2013) examined two groups of aphasic patients who attended intensive, comprehensive treatment programs. Time post onset was related to clinical improvement in one functional communication measure (i.e., the Communication Effectiveness Index [CETI]), however, it was not related to improvement on a measure of language. In this case, participants in the chronic phase of recovery also experienced language gains. There is a clear trend towards early rehabilitation, however, many studies illustrate the potential of patients to demonstrate neuroplastic change and language gains during the chronic phase (e.g., 12 or more months post onset) (Basso, 1979; Meinzer et al., 2004). McClung et al. (2010), in their

literature review, found evidence that restorative therapy may be effective any time after the first few days following stroke up to years later. This potential of older patients is likely why TPO as a predictor of response to treatment has received mixed support, and also brings up a discussion of defining clinically significant change: even if participants further post onset do not experience the same degree of gain on outcome measures as those closer to onset, they still may make improvements that have a large impact on their real-world functional communication. Overall, more work is needed to better understand the pattern of spontaneous recovery following stroke and intricacies of intervention timing that affect success in treatment.

Severity of aphasia.

Spontaneous recovery. Initial severity of overall language impairment is widely supported as an indicator of prognosis and predictor of spontaneous language recovery following stroke, and is often measured using a comprehensive language measure that covers multiple domains (e.g., Western Aphasia Battery-Aphasia Quotient [WAB-AQ; Kertesz, 1982]). Plowman, Hentz, and Ellis (2012) conducted a literature review aimed at identifying evidenced based patient and stroke related variables predictive of long-term language recovery, and initial severity of aphasia emerged as the most predictive indicator of prognosis. Pedersen et al. (2004) found similar results. Language outcomes at onset of injury and one year post-stroke were evaluated in 103 stroke patients. Initial severity of language impairment and stroke severity (but not age or sex) were the only variables predictive of language function at one year. Interestingly, these authors reported 2-4 weeks post-stroke as the ideal time frame to assess language for prognostic purposes, which is consistent with previous findings (Lendram & Lincoln, 1985; Pedersen et al., 1995). Lazar et al. (2010) went a step further by statistically analyzing the relationship between initial language impairment and status at 90 days post onset in patients with

mild-moderate aphasia. Results indicated a significant and proportional relationship, with participants recovering 0.73 of their maximal potential recovery. This highly predictable, proportional relationship is consistent with the motor recovery literature. It is no surprise that initial severity is strongly related to degree of spontaneous recovery and long-term language prognosis, however, the relationship between initial severity and response to intervention is far less clear.

Response to intervention. Even when persons with aphasia are equated for degree of language impairment, their response to treatment can vary greatly depending on a number of other factors. Beyond identifying initial severity as an important factor, there is variability in the direction of this relationship. Some studies found an advantage for participants with more mild aphasia (Code et al., 2010, Eoute, 2010), some found an advantage for participants with more severe aphasia (Laska et al., 2001; Robey, 1998), and some found mixed results within their sample (Persad et al., 2013). A closer look at results from studies utilizing a variety of methodological designs sheds light on methodological and individual factors that may impact the relationship between initial severity of aphasia and response to treatment.

Case-series designs, although not as robust as randomized control trials or meta-analyses, are common in aphasia research due to the heterogeneity of the population and ethical concerns in denying the benefits of treatment to a control group. Importantly, case series have the power to detail response to treatment on a case-by-case basis, emphasizing the importance of covering treatment for individuals with poorer prognosis (e.g., very old age, co-morbid medical complications, etc.) who may not emerge as successful in group designs. Additionally, case series suggest factors that warrant exploration in higher-level designs. Overall, results of case series studies examining initial severity of aphasia are mixed. Code et al. (2010) tracked the progress of

8 participants with chronic aphasia during a one-month, intensive treatment program. The group, as a whole, experienced significant improvement. Individually, response to treatment varied with a general trend of more mild aphasics making greater progress. However, the oldest, most impaired individual made the most progress overall, highlighting the complexity of factors that contribute to success. Using a series of fMRI scans, Fridriksson, Morrow-Odom, Moser, Fridriksson, and Baylis (2006) examined neural recruitment associated with anomia treatment in three patients with chronic aphasic. The participant with the most severe aphasia co-morbid with severe apraxia of speech did not respond to treatment, but two patients who began treatment with language deficits classified as “moderate” and “severe” did make significant gains. Despite their differing abilities at baseline, however, the two responders made similar progress. Compared to the responders, the nonresponder’s fMRI results showed limited cortical activation on baseline scans, and reduced white matter connections to residual cortex.

Group designs and meta-analyses also provide mixed evidence, with a trend towards initial severity as an important predictor, especially when considered in conjunction with other variables. A meta-analysis conducted by Robey (1998) examined 55 reports on language treatment that had data available to calculate effect sizes. Results revealed a large effect size for individuals with severe aphasia and a medium effect size for individuals with moderate aphasia, but only when treatment was delivered in the acute stage of recovery (e.g., 1-3 months post-onset). Persad et al. (2013) examined two groups of aphasic patients who attended intensive, comprehensive treatment programs. Initial severity was significant in one group of participants, with more severe aphasics making the largest gains. Initial severity did not emerge as significant in the second group, despite participation in a very similar intensive treatment program. Unfortunately, only a limited number of predictors were examined, providing little information

on why this difference emerged. Demeurisse et al. (1980) followed 75 PWA who received treatment across a 6-month period, and overall, initial scores on measures of language related to outcomes at 6 months. They found an effect for initial severity of impairment, with patients classified as having more severe, global deficits progressing at a slower rate.

Van de Sandt-Koenderman et al. (2008) examined the predictive power of a multi-axial system in predicting response to treatment. Four of their five axes were useful in predicting treatment progress, including axis 1: linguistic information (e.g., type and severity of aphasia). However, only axis 3: neuropsychological information (e.g., attention, memory, concentration, executive functioning) independently contributed to the prediction of the post-therapy language scores, emphasizing the importance of considering non-verbal neuropsychological factors when selecting participants for treatment. Lambon Ralph, Snell, Fillingham, Conroy, and Sage (2010) found similar results. They examined predictors of response in 33 individuals with aphasia. Initial language impairment and cognitive status both emerged as significant predictors of improvement. Interestingly, these authors looked at individual components of language separately, rather than as a comprehensive whole. Within the language domains, naming ability and degree of phonological impairment emerged as predictive. Examining language impairment generally (vs. specifically by domain [e.g., lexical-retrieval, auditory comprehension, etc.]) is arguably less sensitive, and is one plausible for explanation for the mixed results related to initial severity of language impairment. Evidence suggests variable patterns of recovery for different components of language (Mazzoni et al., 1992). Therefore, semantics, syntax, lexical retrieval, and phonology should be investigated separately (El Hachioui, van de Sandt-Koenderman, Dippel, Koudstaal, & Visch-Brink, 2011). Many researchers have begun doing this, and both

impairment in naming (i.e., lexical retrieval), and severity of phonological impairment have emerged as potential predictors of success in treatment.

Severity of anomia. In aphasia, impairments in naming occur when a client is unable to retrieve the word form, and is due to some combination of decreased activation, equal activation of closely related neighbors, or graceful degradation within the bi-directionally activated semantic-lexical-phonological network. In contrast to a discrete, two-level model of lexical retrieval (Levelt et al., 1991), Dell's (1986) theory (discussed previously) is supported by the nature of errors produced by people with aphasia and experimentally generated speech error data (Laine & Martin, 1996). It is also supported by the observation that people with anomia often benefit from semantic or phonological cues that enhance activation (Saito & Takeda, 2001). Consistent with findings that initial (general) language impairment is related to treatment outcomes, severity of lexical retrieval impairment is also associated with functional language gains following treatment. At this time, lexical-retrieval ability alone has not been examined in relation to predicting spontaneous recovery, so only studies examining response to treatment will be discussed here. Conroy, Sage, and Lambon Ralph (2009) followed seven participants who participated in anomia treatment. Baseline confrontation naming abilities were significantly correlated with response to treatment. Similarly, Lambon Ralph et al. (2010) found that naming performance was highly correlated to therapy gain both immediately after therapy and at follow-up. Seniow et al. (2009) found that baseline language abilities predicted language outcomes following treatment, and specifically, baseline naming accuracy was the strongest predictor of improvement: individuals with less severe baseline impairment in naming experienced greater gains following treatment. These results suggest that residual lexical retrieval skills support success in anomia treatment programs.

Severity of phonological impairment.

Spontaneous recovery. In the spontaneous recovery literature, phonological impairment has recently gained support as a predictor of recovery. El Hachoui et al. (2013) followed 147 patients with aphasia over their first year of recovery. Initial phonology score emerged as the strongest linguistic predictor, and participants who recovered phonology within the first 6 weeks post onset fared better at the one-year mark. These authors proposed an explanation for this finding that relates to language lateralization. They reported on a meta-analysis by Vigneau et al. (2011), which found that semantic and syntactic processing activates both hemispheres, whereas phonology primarily activates the left hemisphere. Therefore, phonological deficits may play a role in indicating the degree of damage in the left, language-dominant hemisphere.

Neuroimaging and lesion site studies have specifically associated left inferior parietal lobe cortical activity with phonological storage and encoding (Becker, McAndrew & Fiez, 1999), and it is likely that degree of phonological impairment in relation to recovery will be better understood as neuroimaging continues to become more commonplace in studies examining observable language behaviors and associated lesions.

Response to intervention. Because the phonomotor treatment program is a phonologically based approach, it is essential to understand the impact of pretreatment phonological knowledge on success in treatment. Degree of phonological impairment as a predictor of response to treatment has received support within the literature. Lambon Ralph et al. (2010) used a variety of background tests of language and cognition to predict treatment outcomes. Both a phonological factor and cognitive factor emerged as significant, independent predictors of a positive response to anomia treatment. In their study of cueing-based anomia treatment, Hickin, Best, Herbert, Howard and Osborne (2002) examined 8 participants with

chronic aphasia. In this sample, response to treatment was significantly related to baseline ability to access output phonology, as well as reading and repetition abilities. Interestingly, these authors also found a relationship between benefiting from phonological and orthographical cues prior to treatment and response to a phonologically based treatment program. This suggests that participants may reap greater benefits from treatment protocols where they can apply and strengthen phonological knowledge. Conroy et al. (2009) found that in addition to baseline language skills in naming, phonology was also significantly correlated with response to treatment. Phonological knowledge appears to be an important factor related success in many types of language treatment, motivating its evaluation in relation to an intensive, phonologically based treatment program such as phonomotor.

Current Aims

The purpose of this study is to investigate if 5 carefully selected patient factors predict response to intensive phonomotor treatment. Using data from 26 individuals who have completed phonomotor treatment (Kendall et al., 2015), we will retrospectively examine links between patient demographics (i.e. age, months post onset), tests of linguistic performance (Western Aphasia Battery-Aphasia Quotient [WAB-AQ; Kertesz, 1982], Boston Naming Test [BNT; Kaplan, Goodglass, Weintraub & Segal, 1983], Standardized Assessment of Phonology in Aphasia, [SAPA; Kendall et al., 2010]) and treatment outcome measures administered immediately following treatment and 3 months following treatment (i.e., confrontation naming of trained words, confrontation naming of untrained words, and non-word repetition). Please see Table 1 for a summary of patient factors and outcome measures.

Table 1.
Summary of Patient Factors and Outcome Measures

Patient Factors (evaluated prior to treatment)	Outcome Measures (evaluated immediately and 3 months following treatment)
Age	Confrontation Naming of Trained Words
Month Post Onset (MPO)	Confrontation Naming of Untrained Words
Severity of Aphasia: Western Aphasia Battery-Revised (WAB-R) Score	Repetition of Non-words
Severity of Anomia: Boston Naming Test (BNT)	
Severity of Phonological Impairment: Standardized Assessment of Phonology in Aphasia-Total Score (SAPA T)	
Severity of Phonological Impairment (Auditory Phonological Processing): Standardized Assessment of Phonology in Aphasia-Subtest 2 (SAPA 2)	
Severity of Phonological Impairment (Repetition, Parsing, Blending): Standardized Assessment of Phonology in Aphasia-Total Score-Subtest 3 (SAPA 3)	

Methods

Phonomotor Treatment Trial

Participants. The phonomotor treatment trial investigated in this study was a single group design with repeated testing (Kendall et al., 2015). Persons with aphasia (PWA) were recruited through the Veterans Affairs Medical Center Puget Sound and the University of Washington Aphasia Registry and Repository. PWA were six or more months post onset of acquired left hemisphere damage due to a single stroke (documented by CT or MRI scan and/or report). To be included in the study, participants had to have demonstrated aphasia with anomia and impairment of phonology. Presence of aphasia was defined using the criteria of McNeil and Pratt (2001): impaired language reception or expression caused by left hemispheric damage that results in impaired processing and loss of access to language representation (rather than a loss of language knowledge) that affects some or all levels of language: phonology, morphology and or lexical-semantics. Additionally, aphasia often varies over time and fluctuates based on external

cueing or stimulation. Phonologic function was measured via the Standardized Assessment of Phonology in Aphasia (SAPA; Kendall et al., 2010).

Individuals were excluded if they exhibited severe apraxia of speech (AOS). Apraxia of speech was defined by a slowed speaking rate (prolonged sounds and/or intersegment durations); distortions and/or distorted substitutions; and prosodic abnormalities during discourse production, repetition of words and nonwords and naming tasks. Additional exclusion criteria included major depressive disorder or other psychiatric illness, degenerative neurological disease, chronic medical illness, or severe and/or uncorrected impairment in vision or hearing. 26 PWA fit inclusion criteria. They were, on average, 56 years of age ($SD=15$), had 16 years of education ($SD=3$) and were, on average, 48 months since stroke onset ($SD=53$). There were 15 males and 11 females.

Assessment procedures. The WAB, BNT, and SAPA were administered at three time points: immediately prior to the beginning of treatment, immediately following treatment completion, and at three months following treatment completion. Outcome measures (i.e., confrontation naming of trained words, confrontation naming of untrained words, non-word repetition) were administered at each time points. The three data points (representing a three-day test sequence) were averaged to reduce the effects of test-retest variability on statistical analysis of outcomes. For the current study, the mean performance for two testing days, rather than three, was used in the statistical analysis due to the frequency of missing data.

Treatment procedures. The phonomotor treatment protocol (please see appendix A for a detailed outline) and primary outcomes from a phonomotor treatment trial using this sample ($n=26$) have been reported (Kendall et al., 2015). All participants received 60 hours of phonomotor treatment (one-hour treatment sessions, two consecutive sessions/day, five

days/week for six weeks) provided by three certified research speech-language pathologists (SLPs). Treatment was associated with a statistically significant gain in the primary outcome measure, which captured generalization and maintenance (untrained real word naming at three months posttreatment).

Current Study

Patient factors. Five intra-individual factors receiving either strong or mixed evidence in the current literature were analyzed. Age and MPO data were collected prior to treatment. Baseline language performance was evaluated prior to treatment and measured in the following ways: severity of aphasia was measured using the WAB-AQ, severity of anomia was measured using the BNT, and severity of phonological impairment was assessed using the SAPA. The SAPA contains three sub-tests, and two were analyzed independently of the total score to isolate specific phonologically-based skills: auditory phonological processing (SAPA subtest 2) and repetition, parsing and blending (SAPA subtest 3).

Outcome measures. Accuracy of confrontation naming was assessed using 42 trained and 41 untrained real words. Accuracy of repetition of non-words was assessed using 72 items. All stimuli were comprised of low phonotactic probability and high neighborhood density items. Phonotactic probability was calculated using methods similar to those of Vitevitch and Luce (1999). All nonwords were phonotactically legal in English. A web-based interface was used to calculate phonotactic probabilities for the real words and nonwords (Vitevitch & Luce, 2004). Neighborhood density was computed by counting the number of words in the dictionary that differed from the target by a one phoneme addition, deletion, or substitution. Phonotactic probability and neighborhood density were computed for stimuli and were categorized as high or low based on a median split (using procedures similar to those of Storkel, Armbruster & Hogan,

2006). Real word stimuli were created using the MRC Psycholinguistic Database (Coltheart, 1981) to determine written frequency, imageability, age of acquisition, syllable number, syllable complexity and semantic category. Photographic color pictures representing the real word stimuli were used.

Data conversion. Outcome measures were administered immediately following treatment and 3 months posttreatment. Raw scores on outcome measures, including confrontation naming tasks (42 trained items and 41 untrained items) and non-word repetition tasks (72 items) were adjusted using the following formula:

$$\frac{\textit{posttreatment performance} - \textit{baseline performance}}{\# \textit{ of test items} - \textit{baseline performance}}$$

This conversion, which is referred to as “percentage of maximum possible improvement” (Seniow et al., 2009) or “proportion of potential maximum gain” (Lambon Ralph et al., 2010) is considered a more representative change score compared to raw change scores (e.g., *posttreatment performance – baseline performance*) because it takes into account the variation in baseline naming as well as the number of items that a participant could have potentially gained in treatment. For example, if participant A scores 40/100 at baseline, the denominator of the equation would be 60, representing the number of items that this participant could potentially gain in treatment. Following treatment, if participant A scores 65/100, then a raw change score of 25 would be obtained and used in the numerator of the equation. Then, the raw change score is divided by the number of items participant A could have gained (e.g., 25/60) to get 0.42, which is easily converted to 42%. In other words, following treatment, participant A gained 42% of the items that they could have gained in treatment. Although this conversion only partially controls for floor and ceiling effects, it is considered superior to raw change scores given that it accounts

for individual variation in baseline performance and the number of test items on a measure.

Please see appendix B for a series of detailed examples comparing hypothetical converted and unconverted (raw) change scores.

Correlation. Relationships between patient demographics (i.e., age, months post onset), language tests (i.e., WAB-AQ, BNT, SAPA), and phonomotor treatment outcome measures (i.e. confrontation naming and non-word repetition performance) were initially explored using Pearson's correlation coefficient (r) to quantify the strength of associations between variables.

Simple linear regression. After correlations of interest were identified, they were used to guide simple linear regression analyses. This type of analysis determined how well patient demographic factors or language factors predicted scores on outcome measures. Although many relationships may be identified through calculation of correlations, this type of analysis revealed which variables add independent information about language performance on outcome measures. Although multiple regression would have been an ideal tool to determine the overall fit of the model and the relative contribution of each of the predictors to the total variance explained in outcome measures, sample size for this study was not adequate to complete this type of analysis.

Results

Descriptive Statistics

Patient factors. Pretreatment patient factors exhibited significant variability. Across the 26 participants, age ranged from 26-78 years ($m=56$, $SD=14.5$). Participants were selected based on being classified in the chronic phase of recovery, but this range was especially variable. Participants ranged from 8-211 months post injury, with an average of 47.5 months since onset ($SD=53.3$). Initial severity of aphasia, measured by the WAB-AQ (out of 100 points), ranged

from 26-78 points ($m=78.68$, $SD=16.53$). Initial severity of anomia, measured by the BNT (out of 60 points), ranged from 1-57 points ($m=34.35$, $SD=18.11$). Initial severity of phonological impairment was also variable. Participants ranged from 50-131 points on the SAPA total score (out of 151 points [range: 50-131, $m=98.73$, $SD=25.67$]), from 31-62 points on SAPA subtest 2 (out of 65 points [$m=50.38$, $SD=9.29$]), and from 3-25 points on SAPA subtest 3 (out of 34 points [$m=14.77$, $SD=6.21$]). Please see Table 2 for full report of descriptive statistics.

Table 2.
Descriptive Statistics for Patient Factors

Patient Factor	N	Range	Mean \pm SD
Age	26	26 - 78	56.12 \pm 14.50
Months-Post Onset	26	8 - 211	47.50 \pm 53.25
WAB-AQ (out of 100)	26	37 - 96	78.68 \pm 16.53
BNT (out of 60)	26	1-57	34.35 \pm 18.11
SAPA Total Score (out of 151)	26	50-131	98.73 \pm 25.67
SAPA subtest 2 (out of 65)	26	31-62	50.38 \pm 9.29
SAPA Subtest 3 (out of 34)	26	3-25	14.77 \pm 6.21

Outcome measures. Across the 26 participants, there was a great degree of variability on the 3 outcome measures immediately following treatment and at 3 months. All outcome measures are expressed as adjusted change scores (discussed previously) that represent the percentage of items a participant actually gained following treatment, which is calculated using the number of items they could have gained in treatment (established using participant's baseline naming accuracy).

Immediate posttreatment. Immediately following treatment, trained-real word naming adjusted change scores ranged from 0% - 100% ($m=58\%$, $SD=26\%$). Untrained-real word

naming adjusted change scores ranged from -85% - 70% ($m=16\%$, $SD=32\%$). Trained-nonword repetition adjusted change scores ranged from 13% - 94% ($m=57\%$, $SD=22\%$).

3 months posttreatment. Trained-real word naming adjusted change scores ranged from 3% - 100% ($m=48\%$, $SD=31\%$). Untrained-real word naming adjusted change scores ranged from -19% - 83% ($m=18\%$, $SD=24\%$). Trained-nonword repetition adjusted change scores ranged from -60% - 100% ($m=46\%$, $SD=32\%$). Please see Table 3 for full report of descriptive statistics.

Correlation

Although several variables were significantly correlated, only correlations between pretreatment individual factors and phonomotor treatment outcome measures were of interest.

Immediately posttreatment. Age was significantly correlated with immediate posttreatment naming of trained real word items ($r = -.48$, $p<.05$). Months post onset was significantly correlated with immediate posttreatment naming of untrained real word items ($r = -.49$, $p<.05$).

3 months posttreatment. Baseline confrontation naming measured using the BNT was significantly correlated with trained- real word naming at 3 months ($r = .50$, $p<.05$). Additionally, the BNT was the only factor significantly correlated with the outcome measure that best captures generalization and maintenance, untrained real word naming at 3 months ($r = .43$, $p<.05$). See Table 4 for complete correlation results. Scatter-plots illustrating the relationship between significantly related patient factors and outcome measures are shown in Figure 2.

Table 3.

Descriptive Statistics for Outcome Measures: Adjusted Change Scores Pre to Immediate Posttreatment and Pre to 3 Months Posttreatment.

	Outcome Measure	N	Range	Mean \pm SD
Immediate	Confrontation Naming of Trained Words	26	0% - 100%	58% \pm 26%
	Confrontation Naming of Untrained Words	26	-85% - 70%	16% \pm 32%
	Non-word repetition	26	13% - 94%	57% \pm 22%
3 months	Confrontation Naming of Trained Words	26	3% - 100%	48% \pm 31%
	Confrontation Naming of Untrained Words	26	-19% - 83%	18% \pm 24%
	Non-word repetition	26	-60% - 100%	46% \pm 32%

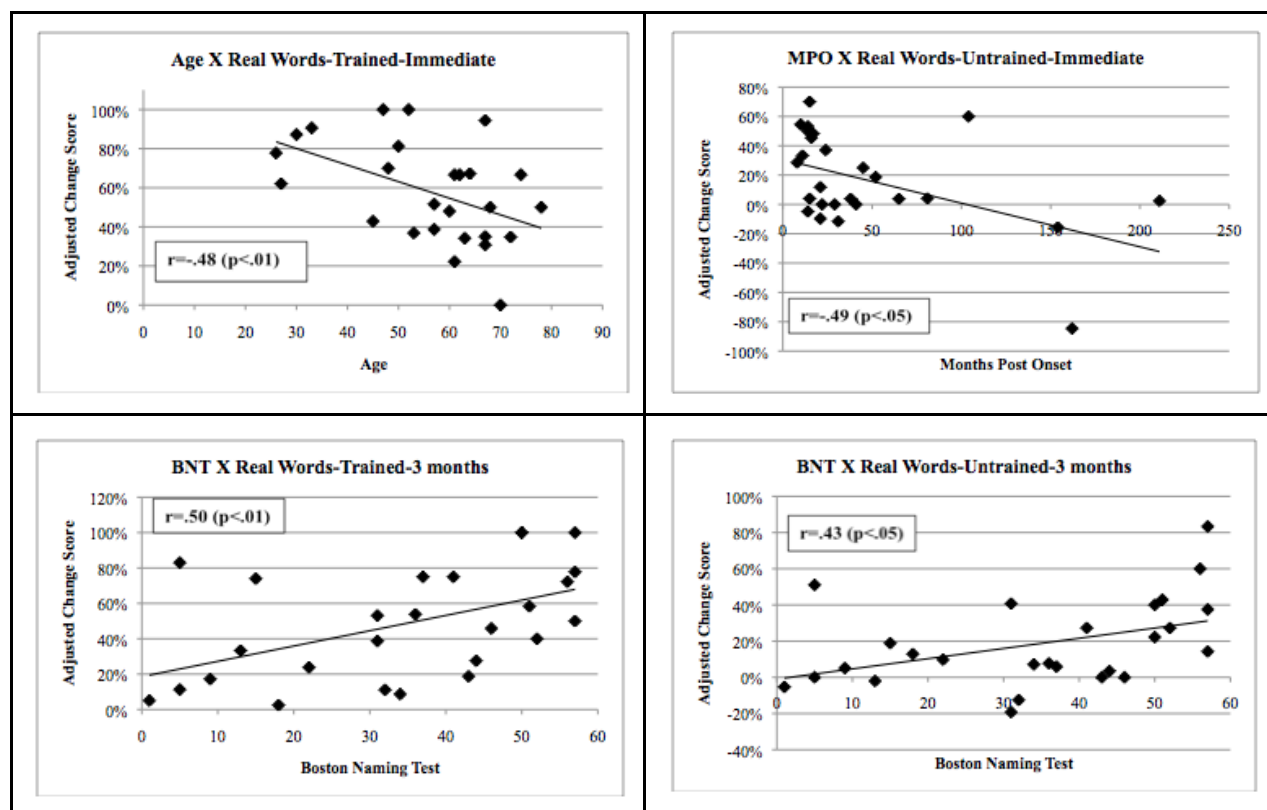


Figure 2. Significant relationships between patient factors and outcome measures

Table 4.

Correlation matrix for demographics, standardized tests and outcome measures

	<i>M</i>	<i>SD</i>	Age	MPO	WAB	BNT	S Total	S 2	S 3	RW T Im	RW T 3m	RW U Im	RW U 3m	NW T Im	NW T 3m
Age (Years)	56.12	14.50	--	.30	.26	.07	.20	.07	-.11	-.48 **	-.25	-.17	.03	-.30	-.28
MPO	47.50	53.25	.30	--	-.03	-.05	-.09	.04	-.31	-.32	-.25	-.49 *	-.23	.08	-.16
WAB	78.68	16.53	.26	-.03	--	.72 **	.89 **	.72 **	.65 **	.04	.29	.05	.23	-.14	-.02
BNT	34.35	18.11	.07	-.05	.72 **	--	.70 **	.70 **	.52 **	.31	.50 **	.30	.43 *	.18	.27
S Total	98.73	25.67	.20	-.09	.89 **	.70 **	--	.82 **	.80 **	.02	.18	.10	.25	-.13	-.03
S 2	50.38	9.29	.07	.04	.72 **	.70 **	.82 **	--	.59 **	.01	.22	.00	.33	-.11	.03
S 3	14.77	6.21	-.11	-.31	.65 **	.52 **	.80 **	.59 **	--	.18	.13	.26	.20	.18	.10
RW T Im	57.91	25.70	-.48 **	-.32	.04	.31	.02	.01	.18	--	.71 **	.31	.39	.37	.34
RW T 3m	48.31	31.27	-.25	-.25	.29	.50 **	.18	.22	.13	.71 **	--	.25	.48 *	.28	.37
RW U Imm	1.64	3.24	-.17	-.49 *	.05	.30	.10	.00	.26	.31	.25	--	.57 **	.04	.24
RW U 3m	1.84	2.40	.03	-.23	.23	.43 *	.25	.33	.20	.39	.48 *	.57 **	--	.11	.12
NW T Im	5.67	2.19	-.30	.08	-.14	.18	-.13	-.11	.18	.37	.28	.04	.11	--	.36
NW T 3m	4.56	3.23	-.28	-.16	-.02	.27	-.03	.03	.10	.34	.37	.24	.12	.36	--

Note. MPO = months post onset; WAB = Western Aphasia Battery; BNT = Boston Naming Test; S = Standardized Assessment of Phonology; RW = % change on real words; NW = % change on nonwords; T = trained; U = Untrained; Im = Immediate post-treatment; 3m = 3 months

* $p < .05$, ** $p < .01$

Simple Linear Regression

Immediately posttreatment. There was an estimated mean decrease of 0.85% in naming improvement of trained real words immediately posttreatment for each year of age. There was an estimated mean decrease of 0.3% in naming of untrained real words immediately posttreatment for each month post onset.

3 months posttreatment. There was an estimated mean increase of 0.87 percent in naming of trained real words 3 months following treatment for each point on the BNT. There was an estimated mean increase of .56 percent in untrained real word naming 3 months following treatment for each point on the BNT. See Tables 5a-5d for complete regression results. See Table 6 for a summary of correlation and regression results.

Table 5a.

Simple Linear Regression (Real Words - Trained - Immediate Change Score)

	<i>Standard Regression</i>						
	R^2_{Total}	R^2_{Adj}	F_{total}	b	(SE)	t	β
Real Words Trained Immediate	.23	.20	7.16 (1,24)*				
Intercept				105.59	(18.38)	5.74 **	
Age (Years)				-.85	(0.32)	-2.68*	-.48

* $p < .05$, ** $p < .01$

Table 5b.

Simple Linear Regression (Real Words - Untrained - Immediate Change Score)

	<i>Standard Regression</i>						
	R^2_{Total}	R^2_{Adj}	F_{total}	b	(SE)	t	β
Real Words Untrained Immediate	.24	.21	7.54 (1,24)*				
Intercept				30.59	(7.66)	4.0 **	
Months Post Onset				-.30	(.11)	-2.75*	-.49

* $p < .05$, ** $p < .01$

Table 5c.
Simple Linear Regression (Real Words - Trained - 3 Months Change Score)

	<i>Standard Regression</i>						
	R^2_{Total}	R^2_{Adj}	F_{total}	b	(SE)	t	β
Real Words Trained 3 Months	.25	.22	8.05 (1,24)*				
Intercept				18.60	(11.80)	1.58	
Boston Naming Test				.87	(.31)	2.84**	.50

* $P < .05$, ** $p < .01$

Table 5d.
Simple Linear Regression (Real Words - Untrained - 3 Months Change Score)

	<i>Standard Regression</i>						
	R^2_{Total}	R^2_{Adj}	F_{total}	b	(SE)	t	β
Real Words Untrained 3 months	.18	.15	5.31 (1,24)*				
Intercept				-.98	(9.47)	-.10	
Boston Naming Test				.56	(.25)	2.30*	.43

* $p < .05$, ** $p < .01$

Summary of Results

		Acquisition (immediately post-treatment)				Maintenance (3-months post-treatment)					
		Task	Mean/SD	Correlation (*p<.05; **p<.01)	Percent Variance Explained	Simple Linear Regression Interpretation	Task	Mean/SD	Correlation (*p<.05; **p<.01)	Percent Variance Explained	Simple Linear Regression Interpretation
Trained	Trained Real Words X Age	Adjusted Change Score M=58% SD=26%	r=-.48**	23%	There was an estimated mean decrease of 0.85% in naming of trained real words immediately post treatment for each year of age						
	Generalization	Untrained Real Words X MPO	Adjusted Change Score M=16% SD=32%	r=-.49*	24%	There was an estimated mean decrease of 0.30% in naming of untrained real words immediately post treatment for each month post onset	Trained Real Words X BNT	Adjusted Change Score M=48% SD=31%	r=.50**	25%	There was an estimated mean increase of 0.87% in naming of trained real words 3 months following treatment for each point on the BNT
						Untrained Real Words X BNT	Adjusted Change Score M=8% SD=24%	r=.43*	18%	There was an estimated mean increase of .56% in untrained real word naming 3 months following treatment for each point on the BNT	

Discussion

The intensive, neurally distributed, phonologically based phonomotor treatment protocol has demonstrated efficacy and generalization in an open trial that included 26 persons with aphasia (Kendall et al., 2015). The purpose of this study was to investigate individual factors that predict posttreatment performance following participation in phonomotor treatment, with the aim of better understanding factors that favor positive treatment outcomes. Individual patient factors evaluated at baseline (i.e., age, MPO, severity of aphasia, severity of anomia, severity of phonological impairment) were evaluated to determine their ability to predict performance on outcome measures representing naming performance on trained items and untrained items. Outcome measures were administered at two time points posttreatment (i.e., immediately and 3 months posttreatment) in order to best capture acquisition, generalization and maintenance. Overall, three out of five of the individual factors were related to treatment success either immediately posttreatment or at a 3 month follow-up. Each of these factors will be discussed in detail below.

Predictive Factors

Immediately posttreatment.

Age. Age was related to trained-real word naming immediately posttreatment. Specifically, for each year of age, there was an estimated mean decrease of 0.85% in trained-real word naming improvement following completion of treatment. This illustrates a slight advantage for younger participants in acquisition of real words that were trained in treatment. As people age, cognitive functioning and capacity for new learning decreases to some extent as cortical thickness, white-matter integrity, and functional engagement of posterior structures (e.g., hippocampus) is reduced (Goh & Park, 2009; Raz et al., 2005). However, this degradation is

variable in terms of degree and rate, and is related to a number of confounding factors (e.g., general health status). Additionally, functional imaging studies provide evidence that older brains naturally compensate, to some degree, for neural decline via recruitment. This is referred to as the scaffolding theory of cognitive aging (SCAT), which was proposed by Park & Reuter-Lorenz (2009). Although there is a general association between age and cognitive-linguistic decline, this relationship is a complicated one based on a multitude of factors that are not well understood. At this point in time there is not a clear picture of how age may impact success in a cognitively demanding language treatment context.

Variability in methodological design between studies examining predictors of success has been discussed in relation to mixed support for age. Sampling in aphasia research is complicated by a population that is heterogeneous in some respects (e.g., lesion characteristics), yet homogenous in others (e.g., educational background). In regards to age, some studies exclude older individuals in order to reduce confounds (Seniow et al., 2009), yet others may unintentionally recruit a group of participants that lacks variability because stroke is more prevalent in older adults. Although this lack of variability was not at issue in the current study, it ultimately affects the power of statistical analyses in studies where this is an issue.

Overall, the results obtained in the current study in no way suggest that older participants should be excluded from receiving treatment that may have a marked impact on their daily functional communication. This is true in regards to phonomotor treatment given that age was only associated with one outcome measure at one time point, but failed to reach significance elsewhere. There are numerous complexities related to age as a predictor of treatment, and although at this point in time it may not aid in participant selection, it is nonetheless motivates

important discussions surrounding age as it relates to aphasia research, neuroplasticity and methodology.

Months post onset. Individuals who had a more recent stroke fared better on a measure of untrained real word naming. Specifically, for each month post onset, there was a mean decrease of 0.30% in naming untrained real words immediately posttreatment. At face value, this appears as an important finding given that gains in naming items that were not trained in treatment represents generalization. With the current dataset, however, this finding must be interpreted with caution: MPO was related only to untrained naming immediately posttreatment (i.e., not maintenance at 3 months), and the MPO in the sample of 26 participants ranged from 8-211 months. With a range this wide in a sample of $n=26$, the data were prone to outlier effects that may have altered the odds of making a type I error (i.e., “false positive,” or incorrectly concluding significance); a type II error (i.e., “false negative,” or incorrectly concluding insignificance) (Osborne & Overbay, 2004). Additionally, because participants were up to 17 years post onset, MPO may be conflating age effects. Given these limitations, the results of the current study are limited and MPO cannot be verified as a potent predictor of success in phonomotor treatment. Interestingly, many researchers have discussed the limitations of using MPO as a participant selection factor, even if it emerges as a significant or near-significant predictor of success. Patients in a chronic phase of recovery, even if their potential may be less, often make gains in treatment (Meinzer et al., 2004) and these gains often have an impact on their daily functional communication, which is the ultimate goal of treatment (Persad et al., 2013).

3 months posttreatment.

Severity of anomia. Better lexical retrieval ability prior to treatment (as measured by BNT) predicted a greater response for both trained and untrained real word confrontation naming 3 months following treatment termination. This relationship was significant at a time point representing maintenance (i.e., 3 months posttreatment) and on stimuli that reflect generalization (untrained real words). These findings indicate that residual lexical retrieval skills relate to success in phonomotor treatment. Although individual language domains (e.g., lexical-retrieval, phonology, syntax) are commonly looked at using comprehensive measures of language vs. analyzed separately, these findings are consistent with many studies that examined lexical-retrieval in relation to success in anomia treatment (Conroy et al., 2009; Eoute, 2010; Lambon Ralph et al., 2010; Seniow et al., 2009). As a whole, results from this growing handful of studies not only suggest that residual lexical retrieval skills support success in anomia treatment programs, but importantly the direction of this relationship is consistent across studies: those with residual lexical-retrieval skills who appear to get a boost from intact skill in this area (Conroy et al., 2009; Eoute, 2010; Lambon Ralph et al., 2010; Seniow et al., 2009). Interestingly, baseline naming skill has proven an important predictor of success in a study that provided repetitive transcranial magnetic stimulation (rTMS) aimed at improving naming among persons with aphasia. Martin et al. (2009) provided rTMS to a group of patients and found that individuals who correctly named fewer than three items on average across three BNT administrations did not show treatment related naming improvement. Thus, participants without a certain degree of residual lexical-retrieval were excluded from receiving treatment. Although the effect outlined in the current study does not suggest exclusion of participants with a lower degree of residual naming skill from participating in phonomotor treatment, the support for this

factor in relation to treatment outcomes is promising. These findings lend support for having a substrate of neural processing of lexical-semantic activation upon which to build. These lexical-semantic representations can then be activated more easily following treatment designed to enhance phonemes and phonologic sequencing knowledge.

One hypothesis that sheds light on the benefits of having a greater degree of baseline lexical-retrieval skill is that participants are able to achieve a higher complexity of treatment steps, increasing their overall exposure to learning opportunities and stimuli. Eoute (2010) discusses this in relation to average paradigm completions (APC), or in other words, the average number of times participants complete a set of treatment items during each session. Their study explicitly looked at this in relation to treatment outcomes, and APC was significantly related to improvement in naming trained items. On average, every time participants completed a set of treatment items twice, they gained approximately one additional correct response posttreatment. This is in contrast to participants who progressed more slowly through treatment items and did not gain as much exposure. In the phonomotor treatment open trial (Kendall et al., 2015), participants all received 60 hours of intensive treatment, yet some spent a larger majority of this time in stage 1: sounds in isolation versus some who moved more quickly through the protocol to stage 2: sounds in syllables. It certainly is plausible that participants with more intact lexical-retrieval skill were able to master treatment materials at a faster rate, providing greater opportunity to strengthen connections between their phonological and lexical-semantic knowledge. However, this cannot be determined without additional analyses that explicitly examine this factor, such as the one by Eoute (2010). In addition, the impact of cognitive functioning (e.g., attention, executive function, etc.) as it relates to one's ability to master treatment material cannot be overlooked. Specifically, there is emerging evidence that patients

with a higher level of residual cognitive capacity are better able to benefit from demanding treatment activities. This is discussed in greater detail under the heading *Future Directions*.

Non-predictive Factors

Severity of phonological impairment. Surprisingly, baseline severity of phonological impairment, measured comprehensively using the SAPA total score and with two individual SAPA subtests (i.e., SAPA 2: auditory phonological processing, SAPA 3: repetition, parsing, and blending), was not related to treatment gains at any time point. Theoretically, it was expected that residual skill in this area would benefit participants completing a phonologically based treatment program that places high demands on this realm of knowledge. The results of the current study are in contrast to findings of some authors, who found that baseline phonology is associated with outcomes related to both spontaneous recovery (El Hachoui et al., 2013) and response to treatment (Conroy et al., 2009; Hickin et al., 2002; Lambon Ralph et al., 2010). In line with the results of the current study, others have also found no relationship between baseline phonology and treatment outcomes. Fillingham, Sage and Lambon Ralph (2006) found that none of the baseline language measures used in their study were related to treatment outcomes, which is an unusual finding that surprised the authors and is contrasted by many other studies of a similar nature. These authors discussed small sample size (i.e., 11 participants) and the fact phonological skill was measured using only single word reading and repetition as potential factors that influenced their findings.

In the current study, a larger sample size (n=26) and both a comprehensive and specific measure of phonological functioning were utilized, yet results were to the same effect. In this case, it is not entirely clear if or how methodology or analysis contributed to this insignificance. Specifically, it was expected that SAPA 2 (auditory phonological processing) scores would

positively correlate with gains in trained and untrained confrontation naming, given that clinically, participants with poor auditory discrimination pretreatment often performed poorer in the treatment protocol (e.g., did not progress to stage 2: sounds in syllables by the end of treatment). However, the results of this study indicate that having more phonological capacity, relative to less phonological capacity (as measured by the SAPA) did not make a difference in regards to gains in treatment. Instead, individuals benefitted from having some lexical-semantic substrates upon which to build their phonological skills, rather than being able to operate on phonology alone.

Initial severity of aphasia. Initial severity of aphasia (measured using a comprehensive measure of language functioning [WAB-AQ]) was also not related to treatment gains at any time point. This result is consistent with the generally mixed findings outlined in single-subject, group designs and meta-analyses that examined this factor as a predictor of response to treatment. In many studies where language was associated with gains following treatment, this effect was only significant when considered within the framework of other variables. For example in a meta-analysis, Robey (1998) found that initial severity of language impairment was associated with outcomes for participants only if they were in the acute stage of recovery. Additionally, methodological differences, such as sample size, selected outcome measures, statistical techniques employed, etc. also contributes to mixed results related to general language functioning. This is especially the case when considering that some research designs have the power to look at factors in combination with one another, yet some do not have adequate data for this type of analysis. Overall, using a comprehensive measure of language to predict success in phonomotor treatment does not appear to be beneficial, and appears inferior to completing a more detailed examination of how the status of specific language domains (e.g., phonology,

lexical-semantics, auditory comprehension) relates to success. Future studies will benefit from both measuring separate domains of language using tools that validly and reliably capture each construct and considering baseline language status in combination with other variables such as cognitive status.

Limitations

Methodology. Sampling is a habitual issue in aphasia research for many reasons. First, sample sizes are frequently limited due to the large investment of time and monetary resources required to provide treatment to a large number of individuals. Second, recruiting persons with aphasia that are similar enough to maintain experimental control poses a challenge: participants that are available and willing to attend an intensive treatment program may have variable lesion characteristics, time since injury, medical co-morbidities, etc. that would ideally be controlled for in participant selection. On the other hand, when examining predictors of success in treatment, there must be a large enough degree of variability in selected factors (e.g., age, severity of aphasia, etc.) to reach statistical power. These obstacles make aphasia research design an art, and ultimately limit the selection of study design and appropriate statistical techniques. A limitation of the current study is that the data were extracted from an open trial, rather than a randomized control trial that includes a control group. Ideally, future studies examining predictors of success in phonomotor treatment would compare results across a group of participants receiving phonomotor treatment and a group receiving a control anomia treatment in order to better understand how patient factors relate to the unique demands of a specified treatment program.

Additionally, despite the fact that data were available for 26 participants (a considerably large sample size in this realm of research), it was nowhere near large enough to allow for the use of multiple linear regression. Multiple linear regression allows for several explanatory

variables to predict the outcome of a response variable. This would have been an ideal tool to examine how the five factors explored in this study independently and in combination predicted posttreatment performance. Instead, this study was limited to use of simple linear regression that only had the predictive power to examine one isolated factor in relation to one isolated outcome measure. Watila & Balarabe (2015), in their review of predictors of response to treatment, discussed statistical considerations for these types of studies. They highlighted the statistical complexities that may arise from interplay between many factors. They also discussed the issue of increased difficulty in making statistical inferences as the number of observations and predictors increases. They referred to this as the “curse of dimensionality.” This emphasizes the need for researchers to carefully select and limit the number of examined variables by choosing predictors that are (a) supported in the literature and (b) relevant to the selected treatment program.

Defining and measuring change. There is much debate over the best way to measure change between pretreatment and posttreatment time points. Some authors utilize arbitrary cut-offs to define “responders” and “nonresponders” to treatment. For example, Persad et al. (2013) divided participants into two groups based on what they described as clinically significant improvement on the WAB-AQ, which was defined as a gain of ≥ 5 points. Other authors utilize raw change scores on measures between pretreatment and posttreatment measures (i.e., *posttreatment performance – baseline performance*). This is arguably a more transparent representation of change given that it is readily interpretable and more intuitive than scores adjusted with more complex equations. However, this type of change score is susceptible to effects created by participants who score very low or very high at baseline (please see *Methods* section and appendix B for a more detailed comparison of unconverted [raw] and converted

change scores). For this reason, many authors have adopted the use of a converted change score that aims to remove variability in baseline naming:

$$\frac{\text{posttreatment performance} - \text{baseline performance}}{\# \text{ of test items} - \text{baseline performance}}$$

This equation results in a converted change score, which is referred to as “percentage of maximum possible improvement” (Seniow et al., 2009) or “proportion of potential maximum gain” (Lambon Ralph et al., 2010). It is considered a more representative figure because it takes into account variation in baseline naming as well as the number of items that a participant could have potentially gained in treatment. However, a limitation of defining change in this way is that it is also susceptible to participants who score at extreme ends of the spectrum. For example, if participant A scores 95/100 on a baseline measure of naming (e.g., mild anomia) and person B scores 10/100 (e.g., severe anomia), then a gain of 5 items by each participant will appear as a 100% gain for participant A, and only a 6% gain for participant B despite the fact that they both gained 5 items. In the current study, the use of converted change scores was deemed the most accurate way to capture change between pre- and posttreatment time points, yet this is a limitation in this study, as well as in this realm of research in general given that all available measures of change are flawed to some degree.

Another limitation related to the current study is the ecological validity of the selected outcome measures. The current study included outcome measures that capture only naming of trained and untrained items. Ideally, a wider variety of outcome measures designed to capture functional communication in daily contexts should be used to better capture treatment-related language gains. Measures of discourse such as the Correct Information Unit (CIU; Nicholas & Brookshire, 1988), measures of functional communication such as the The American

Speech-Language-Hearing Association Functional Assessment of Communication Skills (ASHA FACS; Thompson, Frattali, & Holland, 1995), or a measure of functional communication from the perspective of a communication partner such as the Communicative Effectiveness Index (CETI; Lomas et al., 1989) might contribute to a better understanding of how patient factors predict functional communication gains.

Group versus case-series analyses. When examining the predictive power of patient factors, there is added value in completing both group and case-series analyses in order to best examine the complex dynamics at play. Group analyses are useful in capturing trends within a select sample of a specified population, but this type of analysis may also “wash out” important individual differences. For example, Code et al. (2010) tracked the progress of 8 participants with chronic aphasia who completed a month of intensive treatment. Group trends showed an advantage for patients with more mild impairments, yet in individual analyses, the oldest and most impaired individual experienced the most gains overall. Fillingham et al. (2006) examined the effects of errorless learning in anomia treatment. They presented detailed individual profiles of results, as well as results of group analyses, the latter of which allowed for examination of predictors of success in therapy. Nickels (2002) in her review of therapy for naming disorders, argued that future treatment studies need to dissect tasks, impairments and their interactions across a series of single cases in order to best understand the dynamics at play. A limitation of the current study is that only group analyses were completed. Future studies would benefit from including both types of analyses in order to paint a clearer, more detailed picture of relationships between individual factors and outcome measures.

Future Directions

A detailed literature search that informed the selection of relevant patient factors for this study outlined important factors that warrant inclusion in future studies of this nature. A brief summary of each factor is discussed below.

Cognition. Although the presence of aphasia does not necessarily imply an impairment in other cognitive functions, cognitive impairment associated with aphasia almost certainly impacts aspects of language processing and learning potential in the context of a demanding treatment setting. Murray (2012) examined the presence of cognitive deficits in a sample of persons with aphasia (PWA). Compared to normal controls, PWA performed significantly more poorly on measures of cognition, yet displayed within-group variability in terms of severity of deficits in different domains (e.g., attention). This study also emphasized the interplay between language processing, attention, and other cognitive processes. Baddeley (2003) has developed a comprehensive model of working memory, a domain that is commonly affected in PWA. They postulate that this domain likely plays a role in one's ability to acquire semantic knowledge related to the appearance of objects, use of objects, understanding of complex systems such as machinery, and spatial orientation. Studies that have examined baseline cognition in relation to treatment provide strong support for this factor as a potent predictor of success.

Cognition appears to be important in relation to both spontaneous recovery and treatment outcomes. Wagle et al. (2011) found that cognition, as measured the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, Tierney, Mohr & Chase, 1998) administered 2-3 weeks post-stroke predicted long-term functional outcomes at follow-up. Van de Sandt-Koenderman et al. (2008) determined the predictive power of a multi-axial aphasia system (MAAS) in predicting the outcome of cognitive-linguistic treatment. Of the five axes,

only axis III: neuropsychological information (i.e., attention, concentration, verbal and non-verbal memory, semantic reasoning, and executive functioning) contributed independently to posttreatment scores. Seniow et al. (2009) found a relationship between patients' baseline visuo-spatial working memory and improvement in naming and comprehension following treatment. Fillingham et al. (2006) also found that cognitive domains predicted success in anomia treatment. Patients who responded well to therapy had better recognition memory, executive function and monitoring skills. Interestingly, semantic tasks that required problem-solving and decision making for accurate performance (e.g., Pyramids and Palm Trees [Howard & Patterson, 1992]) also related to immediate therapy effects.

Pre- and post-morbid depression. Although pre- or post-morbid depression have not received as much attention, the few studies that have considered this factor find a strong relationship between depression and treatment outcomes. Depressive symptoms following stroke are common, often have a chronic course, and are associated with greater stroke severity and functional impairment (Berg, Palomäki, Lehtihalmes, Lönnqvist & Kaste, 2003). Williams, Rittman, Boylstein, Faircloth and Haijing (2005) found that pre-stroke depression is often overlooked in the literature, yet it is a significant predictor of recovery in aphasia. A critical review by Provinciali and Coccia (2002) found that depression relates to level of disability, caregiver burden, and the social-economic impact of cerebrovascular disease. Stroke-related depression has emerged as an important consideration in stroke rehabilitation, and should be explored as a relevant factor in predicting success in aphasia treatment.

Presence of supportive caregiver. Like depression, this area is also often overlooked in studies that identify predictors of spontaneous recovery and response to treatment. Yet, the presence of a supportive caregiver has a proven impact on recovery and quality of life following

stroke (McClung et al. 2010). The presence of a supportive caregiver has been associated with the maintenance of communicative competence, even in the context of reduced language abilities: persons with aphasia may retain the ability to spontaneously participate in a socially interactive context utilizing discourse and pragmatic strategies even if their use of language is restricted (Blonder, 2000). Importantly, the “supportive” distinction is crucial because evidence has shown that not just the presence of a caregiver, but the quality of communicative interactions and support from this caregiver is what matters; without these qualities a caregiver may actually hinder the recovery process (Manzo, Blonder & Burns, 1995). In the current study, data on simply the presence of a caregiver was available and considered for inclusion as a predictor, but it is suggested that just a presence isn’t enough, but rather the quality of care and interactions is what impacts outcomes (Thompson, Sobolew-Shubin, Graham & Janigian, 1989). Future studies will benefit from examining (a) the presence of a caregiver and (b) the quality of communicative support and social interactions that this caregiver facilitates. Although the latter is hard to measure and quantify, work is being done in this area. In a comprehensive review of communication partner training in aphasia, Simmons-Mackie, Raymer, Armstrong, Holland, and Cherney (2010) provide a detailed review of outcome measures used in partner training. It is clear that there is no “gold standard” in measuring the quality of communicative interactions between dyads, but many authors use a combination of quality of life questionnaires (e.g., Communication Activities of Daily Living [CADL; Holland, Frattali & Fromm, 1999]), informal scoring of dyadic interactions, and psychosocial measures to capture the quality of interactions. Carlsson, Hartelius and Saldert (2014) outlined codable themes for scoring dyadic interactions that demonstrated a basic level of reliability. After analyzing conversations between couples that included one partner with a neurogenic communication disorder, participation in the repair of

conversational breakdowns, requests for clarification and modification, and providing candidate solutions (i.e., guessing, elaborating, specifying part of the message) all emerged as important indicators of communicative support. The presence of a supportive caregiver in the life of a PWA has a number of benefits, and future studies should consider measuring and including this variable as a predictor of treatment outcomes.

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Appendix A

Phonomotor Treatment Protocol

Phonomotor treatment protocol		
Treatment materials	Small mirror Line drawings of mouth postures, icons for voiced/voiceless consonants Letter tiles Wipe-off board with markers Small colored blocks	
	Stage 1: Sounds in Isolation	Stage 2: Sounds in syllables
Overview	<p>The purpose of Stage 1 is to train sounds in <i>isolation</i> through multi-modal instruction using tasks designed to engage distributed articulatory-motor, acoustic, tactile-kinesthetic, and orthographic representations.</p> <p>Consonant sounds are introduced using mouth pictures and SLP model as cognate pairs by place/manner of articulation and grouped according to tactile-kinesthetic description (lip, tongue, air, nasal, wind). They are introduced in the following order: lip (<i>p/b, f/v</i>), tongue (<i>t/d, k/g, th/th</i>), air (<i>s/z, sh/zh, ch/j</i>), tongue (<i>l/r</i>), nasal (<i>m/n/ng</i>) and wind (<i>h/w/wh</i>). When mastery of a consonant pair is achieved (e.g. <i>p/b</i>) in perception and production (approximately 85% accuracy), the next sound pair is introduced (e.g. <i>t/d</i>). Once a sound pair is introduced, training continues on this pair in all subsequent sessions. Once a participant can perceive and produce all consonants in isolation, corresponding graphemes are introduced using the corresponding mouth picture.</p> <p>Vowel sounds are trained according to lip and jaw placement via mouth pictures and letter tiles. Vowel sounds (<i>ee, o, oo</i>) are introduced with consonants to allow for minimal pair discrimination (e.g., <i>eep, op, oop</i>). The remaining vowels are trained after consonants.</p>	<p>The purpose of Stage 2 is to extend skills acquired in Stage 1 to <i>phoneme sequences</i>. Treatment tasks remain similar to Stage 1 tasks, with the exception that sounds will be produced in combinations rather than isolation. Training progresses from shorter, monosyllabic sequences to longer, multisyllabic (more complex) sequences (e.g., VC, CV, CVC, CCV, VCC, CCVC, CVCC, CCVCC, CVCV). Both real and nonwords are trained using phonologic tasks (in other words, only phonological features, <i>not</i> semantic features, are trained for real words). Nonword training is introduced before real word training to allow for emphasis on phonology; however, as treatment progresses nonwords and real words are trained simultaneously.</p>
Introduction of sounds and sound sequences	<p>Participant observes SLP producing a single sound (e.g. <i>/p/</i>). SLP asks participant what they observed (heard, saw) and if needed, describes what articulators are moving and how they move. For the sound <i>/p/</i>, for example, "the lips come together and blow apart, the sound is 'quiet' so the voice is turned off, the tongue is not moving." The participant is then shown the line drawing of the mouth posture corresponding to the sound.</p> <p>After looking at the mouth picture and hearing the SLP's production, the participant is then asked to repeat the sound while looking in the mirror. The participant is also asked to place their hand on their throat in order to feel for vocal fold vibration ("quiet" versus "noisy"). Following production, the SLP asks the participant what s/he saw and felt when the sound was made. Socratic questioning is used to enable the participant to "discover" the auditory, visual, articulatory, and tactile/kinesthetic attributes of the sound (e.g., "What do you feel when you make that sound? What moved? What did you see when you made that sound?"). Within therapy, progression for all levels is based on 85% accurate performance on task.</p>	<p>The process of "discovering" sounds primarily occurs in Stage 1; however, knowledge of the auditory, visual, articulatory and tactile/kinesthetic attributes of sounds can also be used later in the program as a cueing technique to identify individual phonemes within a phoneme sequence. For example, if a participant had trouble parsing the initial sound in <i>peef</i>, the SLP would use Socratic questioning (e.g., "What do you feel when you make that first sound? What moved? Did your lips or tongue move when you made that sound?" etc.) to help identify the initial sound <i>/p/</i>. Put differently, rather than give the participant a model and tell them what the initial</p>

		sound is, the SLP assists the participant in self-awareness of errors and how to repair them.
<i>Perception tasks</i>	<p>Perception of sounds in isolation can be trained through various multi-modal tasks. Examples:</p> <p>Mouth pictures: SLP produces a sound (e.g., <i>p</i>) and asks the participant to choose that sound from an array of mouth pictures (e.g., <i>p, b, t, d</i>)</p> <p>Colored blocks: SLP produces a string of individual sounds (e.g., <i>p, t, t, b</i>) and asks the participant to lay out blocks to demonstrate ability to discriminate sounds (e.g., blocks: red, blue, blue, green).</p> <p>Verbal: SLP produces two sounds (e.g., <i>p, p</i> or <i>p, b</i>) and asks the participant “same or different.”</p> <p>Letters: SLP produces a sound and asks participant to point to the corresponding letter from an array of letters.</p>	<p>The SLP produces a real or nonword sound combination and asks the participant to depict the target through various tasks:</p> <p>Mouth pictures: If the participant heard the CVC <i>peef</i>, they would select the pictures corresponding to <i>p, ee</i>, and <i>f</i>.</p> <p>Colored blocks: If the participant heard the CVCV <i>peefee</i>, they would select three differently colored blocks arranged in the following order: white, black, red, black.</p> <p>Verbal: If the participant heard the CCVCs <i>groom</i> and <i>glook</i>, the SLP would ask “same or different.”</p> <p>Letters: If the participant heard <i>chootee</i>, s/he would select the corresponding letter tiles.</p>
<i>Production tasks</i>	<p>Production of sounds in isolation can be trained through various tasks. Here are some examples:</p> <p>Mouth pictures: The SLP shows participant a mouth picture and asks the participant to produce that sound (e.g., <i>d</i>).</p> <p>Motor description: The SLP describes a sound (e.g., “make the sound where your voice is noisy and your tongue quickly taps the roof of your mouth”) and asks the participant to say the sound.</p> <p>Verbal: The SLP asks the participant to repeat a sound <i>p</i> or a string of individual sounds <i>p, p, s, d</i>.</p> <p>Letters: The SLP shows the participant a letter to elicit production of the sound.</p>	<p>The SLP elicits a real or nonword sound combination by asking the participant to produce the target through various tasks:</p> <p>Mouth pictures: The SLP lays out a series of mouth pictures and asks the participant to “touch and say” each sound (<i>f-ee-p</i>) and then blend the sounds to produce the target (<i>feep</i>).</p> <p>Verbal: The SLP asks the participant to repeat a nonword <i>groom</i> and parse the word apart (<i>g-r-oo-k</i>).</p> <p>Letters: The SLP lays out letter tiles (or writes letters on dry erase board). The participant parses out the sounds by underlining and verbalizing each grapheme and then blends the sounds to produce the target.</p>

Note: This appendix is meant to provide an overview and quick reference for those already familiar with the phonomotor treatment program. Readers interested in implementing this program are strongly encouraged to contact Diane Kendall, PhD, CCC-SLP for further information: dkendall@u.washington.edu

Appendix B

Raw and Converted Change Score Comparison

Conversion equation: $\frac{\text{posttreatment performance} - \text{baseline performance}}{\# \text{ of test items} - \text{baseline performance}}$

Mild Patient: 85/100 on a measure of baseline naming; 95/100 on the same naming measure posttreatment

Raw change score: Gain of 10 items

Converted change score: Participant gained 67% of the items they could have gained in treatment ($10/15=.66$)

Moderate Patient: 55/100 on a measure of baseline naming; 70/100 on the same naming measure posttreatment

Raw change score: Gain of 15 items

Converted change score: Participant gained 33% of the items they could have gained in treatment ($15/45=.33$)

Severe patient: 15/100 on a measure of baseline naming; 35/100 on the same measure posttreatment

Raw change score: gain of 20 items

Converted change score: Participant gained 24% of items they could have gained in treatment ($10/85=.24$)