**CAC 2012 Proposal**

# Using error type on confrontation naming as an indicator of improved linguistic processing following phonomotor treatment

BACKGROUND

This paper presents initial data on the influence of phonomotor treatment on *word retrieval accuracy* and *error type* from pre- and post-treatment confrontation naming probe responses produced by 10 individuals with aphasia. This study is part of a Phase II clinical rehabilitation research program which trains real- and non-words, comprised of low phonotactic probability and high neighborhood density phoneme sequences, to improve word retrieval in 30 subjects with left hemisphere lesion and aphasia. The treatment program is a logical advance on existing Phase I and Phase II clinical rehabilitation research (Kendall et al 2003, Kendall et al 2006a, Kendall et al 2006b, Kendall et al 2006c, Kendall et al 2008) and is motivated by a parallel distributed processing model of phonology (Nadeau, 2001).

This phonological treatment to improve word production is based on the ideas that a) word retrieval follows a two-step, bidirectional selection process using three basic levels of knowledge: semantic, word form/lemma, and phonologic (Dell, 1986; Dell, Schwartz, Martin, Saffran & Gagnon, 1997), and b) phonological representations are distributed across acoustic, semantic, orthographic and articulatory motor representations (Nadeau, 2001). This multi-modality (orthographic, acoustic, tactile, visual, articulatory motor) treatment program begins with training phonemes in isolation and builds to real and non-words, thus reinstantiating phonemes and phoneme sequences in the neural network, resulting in improved activation of lexical-semantic knowledge and word retrieval abilities.

We were interested to know if intensive treatment targeted at phonology would not only improve overall accuracy in confrontation naming (indicating correct semantic, lexical and phonological activation), but also influence a shift in processing across linguistic levels as measured by error type. Historically, errors have been used as a window into levels of linguistic processing (conceptual semantics, lexical, phonological) in normal controls (tip-of-tongue) and in aphasic word production (Martin, 2011; Nickels, 2002; Schwartz, Dell, Martin, Gahl & Sobel, 2006). Errors typically attributed to the level of the semantic feature network (conceptual semantics) include omissions and semantic substitutions. Errors attributed to the lexical network include mixed errors (both semantic and phonologic). Errors attributed to phonological processes include sound errors such as substitutions, omissions, additions, transpositions and anticipations.

If treatment targeted at the level of phonological substrates resulted in a bidirectional spread of activation to the lexical and semantic levels of processing, then we predict an increase in overall accuracy in word production. Additionally, we predict a change in error type as an indication of greater activation of semantic, lexical and/or phonological representations. If a significant decrease in the number of omission errors coupled with an increase in mixed and phonologic errors post-treatment was found, an improvement in lexical/phonological processing mechanisms would be evident.

To this end, the following research questions were asked: 1) Is there a significant difference between pre- and post-treatment confrontation naming accuracy on **trained** and **untrained** items? And 2) Is there a significant difference in error type when comparing pre- and post-treatment confrontation naming on **trained** and **untrained** items?

## METHODS

The data in this paper were extracted from a larger group study (n=30 over 3 years; VA RR&D Merit Review Grant, Kendall PI) that is examining the effects of intensive phonological treatment on lexical retrieval abilities in individuals with aphasia.

Participants: This study presents initial data from ten participants with the following characteristics: left-hemisphere lesion (at least six-months post), pre-morbidly right-handed, native speakers of English, and diagnosis of aphasia as determined by Western Aphasia Battery (WAB; Kertesz, 1982), word retrieval impairment (Boston Naming Test; Kaplan, 1983) and impaired phonologic processing (Standardized Assessment of Phonology in Aphasia; Kendall et al, 2010). Participants exhibiting severe apraxia of speech, as evaluated by clinical observation, were excluded. (Participant demographic information is available in *Table 1*; participant test scores are available in *Table 2*.)

Treatment program: All individuals received 60 hours of phonological treatment (1-hour treatment sessions, 2 sessions/day, 5 days/week for 6 weeks). For brevity, the treatment program is outlined in *Figure 1* and the *Appendix*.

Stimuli: Treatment stimuli involved all individual English phonemes, phoneme sequences, and one- and two-syllable phonotactically legal non-words and real words. Real and nonwords were selected based on low phonotactic probability and high neighborhood density.

Outcome measure: All outcome measures were collected 1-week pre-treatment, 1-week post-treatment, and 3 months later. Only data from pre- and 1-week post-treatment were analyzed for this study. The primary outcome measure for this investigation was confrontation naming of trained (n=42) and untrained (n=41) nouns, presented as photographs, comprised of low phonotactic probability and high neighborhood density.

Data processing: Each data collection session was digitally recorded for later analysis. Responses were coded as correct or incorrect based on first response. Correct responses following vocal hesitation were scored as correct. One visual and one specificity cue were allowed, and the first response after either such cue was scored as correct or incorrect. Incorrect responses were coded as one of the following error types (and subtypes): phonological (additions, substitutions, distortions, distorted substitution, transpositions, omissions), semantic (related, unrelated), mixed (phonologic+semantic), omissions (no response, with semantic description), correct plural, neologisms, and self-cue (phonologic/correct or incorrect, semantic/correct or incorrect).

Data analysis: Paired t-tests were used to compare pre- and post-treatment confrontation naming accuracy and proportion of each error subtype on trained and untrained items.

## RESULTS

To address research question 1: results of paired t-tests showed a significant difference between pre- and post-treatment confrontation naming accuracy on trained ($p=.001$) but not untrained ($p=.211$) items. To address research question 2: results of paired t-tests showed a significant decrease in omissions ($p=.032$) and near significant decrease in omissions with semantic description ($p=.072$) in post-treatment confrontation naming on trained items. Additionally, results showed a near significant increase in phonemic substitution ($p=.068$) on trained items. For untrained items, results showed a near significant increase in semantically related errors ($p=.067$) on post-treatment naming. (See detailed results in *Table 3*.)

## DISCUSSION

Omitted responses, as well as omissions with semantic description (i.e. circumlocutions), may occur when candidate items for selection at the level of semantics do not reach an activation

threshold (Dell, Lawler, Harris & Gordon, 2004). A decline in these types of omissions, as seen here for trained items, is considered an indicator of recovery (Schwartz and Brecher, 2000). Furthermore, trained items have a near significant proportional increase in phonologic substitution errors. Taken together, these findings suggest a change in linguistic processing; specifically, greater activation is evident in the phonological level, resulting in greater activation across levels of processing and improved lexical selection. As for untrained items, a near significant increase in semantically related errors during post-treatment naming may point to the upward spread of activation from the phonological level to the conceptual semantic level. This study does not show generalization to untrained items during immediate post-treatment confrontation naming. However, the larger clinical rehabilitation program shows significant improvement in untrained confrontation naming at three-month post-treatment, suggesting experience in everyday communication may continue to strengthen the interactive processing pathways reestablished during treatment. An additional analysis of error type, comparing pre-treatment to three-month post-treatment and beyond, is warranted.

*Figure 1:* Treatment study design

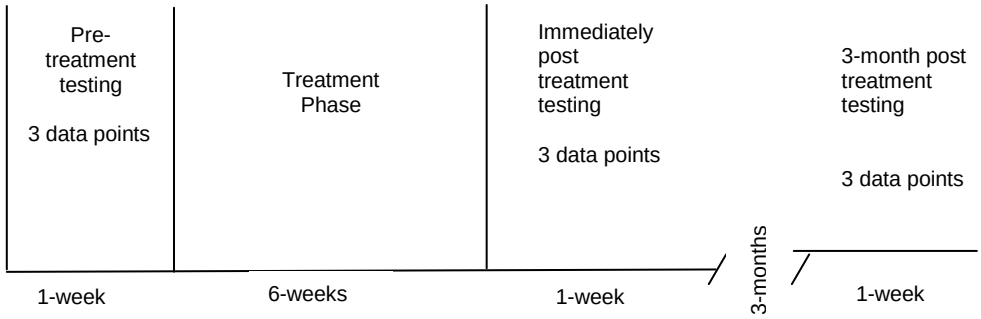

*Table 1*: Participant demographics

| Participant Number | Age (years) | Education | Months post stroke onset |
|---|---|---|---|
| 1 | 49 | 16 | 21 |
| 2 | 48 | 13 | 16 |
| 3 | 27 | 13 | 17 |
| 4 | 67 | 14 | 162 |
| 5 | 60 | 18 | 65 |
| 6 | 57 | 16 | 24 |
| 7 | 72 | 18 | 211 |
| 8 | 67 | 16 | 104 |
| 9 | 68 | 23 | 14 |
| 10 | 33 | 15 | 31 |
| **MEAN** | **54.8** | **16.2** | **66.5** |
| **SD** | **15.38** | **2.97** | **70.16** |

*Table 2:* Pre-treatment, 1-week post-treatment and 3-month maintenance test results: Western Aphasia Battery-AQ (WAB), Boston Naming Test (BNT), Stroke and Aphasia Quality of Life Scale (SAQOL), and Standardized Assessment of Phonology in Aphasia (SAPA).

| **Participant** | **WAB Aphasia Quotient (out of 100)** | | | **BNT (spontaneous correct out of 60)** | | | **SAQOL (mean score of 5.0* communication only)** | | | **SAPA (raw score out of 151)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre | Post 1-wk | Post 3-mo | Pre | Post 1-wk | Post 3-mo | Pre | Post 1-wk | Post 3-mo | Pre | Post 1-wk | Post 3-mo |
| 1 | 87.5 | 88.6 | 87.1 | 37 | 42 | 47 | 3.86 | 4.57 | 4.14 | 96 | 106 | 119 |
| 2 | 94.6 | 93 | 94.4 | 52 | 49 | 52 | 3.14 | 3.57 | 3.71 | 131 | 137 | 135 |
| 3 | 51.1 | 70.1 | 70.3 | 44 | 50 | 45 | 2.57 | 4.29 | 4.43 | 74 | 91 | 80 |
| 4 | 84.5 | 86.9 | 89.8 | 36 | 38 | 42 | 3.57 | 5 | 4.29 | 94 | 106 | 105 |
| 5 | 59.5 | 67.4 | 64.7 | 19 | 17 | 24 | 3 | 3.43 | 4.14 | 74 | 89 | 73 |
| 6 | 82 | 87.2 | 84.1 | 34 | 37 | 41 | 3.57 | 3.14 | 3.29 | 106 | 116 | 112 |
| 7 | 69.8 | 80.6 | 65.4 | 34 | 27 | 26 | 4.57 | 3.71 | 4.66 | 81 | 76 | 92 |
| 8 | 81.1 | 85.7 | 80.5 | 56 | 57 | 47 | 2.86 | 2.43 | 4.41 | 109 | 119 | 115 |
| 9 | 92 | 94.4 | 93.2 | 57 | 56 | 56 | 4.14 | 4.29 | 4.43 | 114 | 118 | 117 |
| 10 | 78.2 | 83.5 | 80.4 | 31 | 41 | 40 | 3.86 | 3.71 | 4.29 | 72 | 85 | 85 |
| **MEAN** | 78.03 | 83.74 | 80.99 | 40 | 41.4 | 42 | 3.51 | 3.814 | 4.18 | 95.1 | 104.3 | 103 |
| **SD** | 14.0 | 8.9 | 10.9 | 12.1 | 12.6 | 10.2 | 0.6 | 0.7 | 0.4 | 20.0 | 18.9 | 19.9 |

*Table 3:* Group mean (SD) and t-test results for each research aim (****p<.05, *p<.10**)

| Research aim | Outcome measure | Word retrieval (N=10) *pre-treatment versus immediate post-treatment* | | |
|---|---|---|---|---|
| **Word retrieval accuracy** | **Trained** real word confrontation naming (percent correct) | **P=.001****<br>Pre 56% (SD 15)<br>Post 77% (SD 13) | | |
| | **Untrained** real word confrontation naming (percent correct) | P=.211<br>Pre 57% (SD 15)<br>Post 62% (SD 17) | | |
| **Word retrieval error type** | **Trained** real word confrontation naming (percentage error type) | | **Mean error type % (SD)** | |
| | | Phonologic | p= | Pre | Post |
| | | Substitution | **.068*** | 6.6 (7.9) | 10.6 (10.6) |
| | | Distortion | .170 | 0 | 3.7 (7.8) |
| | | Distorted Subs | .343 | 0.5 (1.4) | 0 |
| | | Addition | .722 | 2.7 (4.3) | 2.1(4.8) |
| | | Transposition | *none* | 0 | 0 |
| | | Omission | .168 | 1.0 (2.0) | 0 |
| | | Semantic | | | |
| | | Related | .845 | 46.9 (23.2) | 48.4 (25.1) |
| | | Unrelated | .986 | 1.2 (2.0) | 1.3 (4.0) |
| | | Mixed | .962 | 12.2 (12.4) | 12.0 (11.6) |
| | | Omission | | | |
| | | No response | **.032**** | 9.9 (8.6) | 3.8 (6.4) |
| | | Sem description | **.072*** | 9.4 (9.0) | 3.7 (6.8) |
| | | Correct Plural | .343 | 0 | 0.6 (2.0) |
| | | Neologism | .546 | 1.0 (2.0) | 2.1 (4.7) |
| | | Self-cue | | | |
| | | Phonologic/correct | .845 | 3.6 (7.6) | 4.6 (8.3) |
| | | Phonologic/incorr | .289 | 1.4 (3.4) | 6.5 (13.3) |
| | | Semantic/correct | .430 | 2.0 (4.1) | 0.7 (2.1) |
| | | Semantic/incorrect | .343 | 0.4 (1.2) | 0 |
| | **Untrained** real word confrontation naming (percentage error type) | | **Mean error type % (SD)** | |
| | | Phonologic | p= | Pre | Post |
| | | Substitution | .585 | 6.5 (7.4) | 5.1 (6.0) |
| | | Distortion | .479 | 0.5 (1.6) | 2.2 (7.0) |
| | | Distorted Subs | *none* | 0 | 0 |
| | | Addition | .431 | 2.9 (4.4) | 3.8 (4.7) |
| | | Transposition | *none* | 0 | 0 |
| | | Omission | .488 | 1.7 (2.7) | 2.9 (4.6) |
| | | Semantic | | | |
| | | Related | **. 067*** | 42.1 (10.5) | 51.3 (11.4) |
| | | Unrelated | .194 | 0.7 (2.3) | 1.7 (3.8) |
| | | Mixed | .422 | 7.3 (9.8) | 9.2 (8.6) |
| | | Omission | | | |
| | | No response | .109 | 11.4 (12.0) | 5.6 (4.5) |
| | | Sem description | .230 | 16.6 (11.2) | 12.4 (13.2) |
| | | Correct Plural | .845 | 0.9 (1.9) | 1.1 (2.4) |
| | | Neologism | .546 | 2.0 (4.2) | 0.9 (2.9) |
| | | Self-cue | | | |
| | | Phonologic/correct | .366 | 4.2 (4.4) | 2.3 (4.9) |
| | | Phonologic/incorr | .343 | 1.5 (4.7) | 1.4 (4.5) |
| | | Semantic/correct | .343 | 1.4 (3.0) | 0.7 (2.1) |
| | | Semantic/incorrect | .343 | 0.4 (1.2) | 0 |

REFERENCES


Dell, GS (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93*(3), 293-321.

Dell, GS, Lawler, EN, Harris, HD, Gordon, JK (2004). Models of errors of omission in aphasic naming. *Cognitive Neuropsychology, 21*(2/3/4), 125-145.

Dell, GS, Schwartz, MF, Martin, N, Saffran, EM, Gagnon, DA (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review, 104*(4), 801-838.

Kendall, D, Conway, T, Rosenbek, J, Gonzalez Rothi. L (2003). Phonological rehabilitation of acquired phonologic alexia. *Aphasiology, 17*(11), 1073-1095.

Kendall, DL, Rosenbek, J, Heilman, K, Conway, T, Klenberg, K, Gonzalez Rothi, LJ, Nadeau, S (2008) Phoneme-based rehabilitation of anomia in aphasia. *Brain and Language, 105*, 1-17.

Kendall, D, Nadeau, S, Conway, T, Fuller, R, Riestra, A, Gonzalez Rothi, LJ (2006a). Treatability of different components of aphasia – insights from a case study. *Journal of Rehabilitation Research & Development, 43*(3), 323-336.

Kendall, D, Rodriguez, A, Rosenbek, J, Conway, T, Gonzalez Rothi, L (2006b). The influence of intensive phono-motor rehabilitation of apraxia of speech. *Journal of Rehabilitation Research and Development. 43*(3), 323-336.

Kendall, D, Rosenbek, J, Nadeau, S, Heilman, K, Conway, T, Klenberg, K, Gonzalez Rothi, LJ (2006c). Phonologic rehabilitation of anomia in aphasia. Clinical Aphasiology Conference, Belgium.

Martin, N (2011). Disorders of word production. In I. Papathanasiou, P. Coppens, and C. Potagas (Eds), *Aphasia And Related Neurogenic Communication Disorders* (pp. 131-155). Burlington, MA: Jones & Barlett Learning.

Nadeau, SE (2001). Phonology: A review and proposals from a connectionist perspective. *Brain and Language, 79*, 511–579.

Nickels, L (2002). Therapy for naming disorders: revisiting, revising and reviewing. *Aphasiology, 16*(10/11), 935-979.

Schwartz, MF, Brecher, A (2000). A model-driven analysis of severity, response characteristics, and partial recovery in aphasics' picture naming. *Brain and Language, 73*, 62-91.

Scwartz, MF, Dell, GS, Martin, N, Gahl, S, and Sobel, P (2006). A case-series test of the interactive two-step model of lexical access: evidence from picture naming. *Journal of Memory and Language, 54*, 228-264.

APPENDIX

## Treatment protocol

Treatment Stage 1 – Consonants in Isolation:

1. Overview of Stage 1: The purpose of Stage One is to explore individual sounds by teaching a) motor descriptions (e.g., the tip of your tongue is behind your front teeth and taps to make the sound /t/); b) perceptual discrimination (e.g., does /t/ and /d/ sound the same or different?); c) production (e.g., repeat after me…say /t/); and d) grapheme to phoneme correspondences (e.g., letter for each sound is displayed). The length of Stage 1 is 15 hours. The subject will be seated at a treatment table directly across from the therapist. A mirror will be placed on the table for the participant to use for visual feedback for recognition and correction of errors. Each sound will be represented by a picture of a mouth in the corresponding posture. Sounds will be introduced, including: /p,b/, /f,v/, /t,d/, /k,g/, /th, <u>th</u>/, /s,z/. One vowel will be introduced following each minimal pair, including: /ee, i, e, a, ae/.
2. Stage 1-Task 1: Exploration of sounds: The participant is shown a mouth picture of a sound and asked to look in the mirror and repeat after the therapist to make the sound. Knowledge of results (KR) will initially be given at 100% frequency following each production then faded to 30% across trials. Following production, the therapist will ask the participant what they saw and felt when the sound was made. Socratic questioning will be used to enable the participant to "discover" the auditory, visual, articulatory and tactile/kinesthetic attributes of the sounds (e.g., "What do you feel when you make that sound? What's moving? What do you see? Is it a quiet (unvoiced), or noisy (voiced) sound?"). Through practice and repetition the participant will become adept at recognizing what they actually need to feel, see, hear and do to make the sound. The voiced or voiceless cognate of that sound will then be introduced using the above steps.
3. Stage 1-Task 2: Motor description: A description of each sound will be provided. The therapist will describe what articulators are moving and how they move (e.g., for /p/ the lips come together and blow apart, the voice box is turned off, the tongue is not moving). The subject will be asked to repeat the sound and then asked to describe how the sound was made. Knowledge of results (KR) will initially be given at 100% frequency following each production then faded to 30% across trials. Socratic questioning will be used to probe the participant about motor description. For example, "Do your lips or tongue move to make that sound?", "Did your lips blow apart or stay together?"
4. Stage 1-Task 3: Perception Task: The therapist will make a sound (e.g., /p/) and asks the participant to choose that sound from an array of pictures (e.g., /f/, /g/, /p/). Knowledge of results (KR) will initially be given at 100% frequency following each production then faded to 30% across trials. Socratic questioning will be used for correct and incorrect responses.
5. Stage 1-Task 4: Production Tasks: Production of sounds will be elicited auditorily (repetition), visually (mouth picture), and via motor description (e.g., "make the sound where your lips come together and blow apart"). Knowledge of results (KR) will initially be given at 100% frequency following each production, then faded to 30% across trials. Socratic questioning will be used for correct and incorrect responses. For example, "you said /b/ is that the sound where your tongue taps the roof of your mouth?"
6. Stage 1-Task 5: Graphemes: Graphemic tiles representing sounds will be placed on the table with the mouth pictures. The participant will be asked to select a single grapheme and place it on a picture that represents that sound. When they are finished the therapist will use Socratic questioning (e.g., "this letter says "/f/", does this picture represent /f/?"). If the

production is correct, the therapist will move onto the next letter tile, if the production is incorrect the therapist will set aside the letter tile and move onto the next tile. After the subject is able to correctly match graphemes to mouth pictures, graphemes will then be used in production and perception tasks described above. For example, in a production graphemic task, the therapist will place the tile /p/ in front of the subject and ask them to produce that sound. Both correct and incorrect responses are reviewed using Socratic questioning (e.g., "What moved to make that sound?" "Is that sound noisy/quiet")

7. Progression to Stage II will occur after 15 hours of treatment.

Treatment Stage 2 – Syllables:

1. Overview of Stage 2. The purpose of this stage is to extend skills acquired in Stage 1 to various phonemic combinations. Production, perception and graphemic tasks remain the same with the one difference that sounds will be produced in combinations rather than isolation. Training progresses hierarchically (e.g., VC, CV, CVC, CCV, VCC, CCVC, CVCC, CCVCC). Upon mastery of 1-syllable stimuli, 2-syllable stimuli will be composed using various combinations of 1-syllable stimuli. Sound combinations (both real- and non-words) consist of phonemes and phonological sequences with low phonotactic probabilities. Both real- and non-words will be trained using the same procedures detailed below. Stage II is time-based and will last 45 hours.
2. Stage 2-Task 1: Perception Task: The therapist will produce a real word or nonword sound combination (e.g., VC or VCC-VC). The therapist will ask the participant to arrange pictures or graphemes to depict the target. For example, if the subject heard the VC "ip", they would select the graphemes /i/ and /p/. Knowledge of results (KR) will initially be given at 100% frequency following each production then faded to 30% across trials.
3. Stage 2-Task 2: Production and Graphemic Task: The therapist will show a mouth picture or grapheme tiles and ask the participant to produce the sounds within the real- or non-word individually - then blended together. For example, the participant would say "/p/ /ee/ /f/" that says /peef/. For both correct and incorrect responses, Socratic questioning will be used. In this example, the therapist would say "You said /peef/, does that match these letters?" Next, the therapist will change one sound in the word (e.g., /peef/ changed to /feef/). The participant will be cued to say the old word by touching each sound individually, then identifying the new sound and blending the new word (e.g., the old word says /p/ /ee/ /f/, /p/ will be removed and /f/ will be added, the new word says /feef/). Making one sound change will be done for a series of 5-10 nonwords.
4. Stage II treatment is discontinued after 45 hours.