BACKGROUND

The purpose of this Phase II clinical rehabilitation research is to investigate whether a phonological treatment, which uses real- and non-words comprised of low phonotactic probability and high neighborhood density phoneme sequences, will improve word retrieval in 26 subjects with left hemisphere lesion and aphasia. The treatment program is a logical advance on existing Phase I and Phase II clinical rehabilitation work (Kendall et al 2003, Kendall et al 2006a, Kendall et al 2006b, Kendall et al 2006c, Kendall et al 2008) and is motivated by an interactive activation model (Dell, 1986) and parallel distributed processing model of phonology (Nadeau, 2001).

The treatment, called phonomotor, is based on the notion that phonological representations are distributed across acoustic, semantic, orthographic and articulatory motor representations. So, through the application of a multi-modality (orthographic, acoustic, tactile, visual, articulatory motor) treatment, starting with phonemes in isolation and building to longer syllables, phonemes and phoneme sequences will be reinstantiated in the neural network resulting in improved ability to translate concept representations into phonological word forms.

The over arching goal of anomia therapy is to improve words trained, generalize to untrained words and psycholinguistic levels, as well as to maintain those effects over time. The potential for generalization using current therapy techniques is doomed to be modest unless the scope of intrinsic generalization can be expanded and thereby impact a significant portion of the semantic domain used in daily life. Broad intrinsic generalization is difficult to achieve for most semantic therapies because their principal aim is to enlarge knowledge of the semantic attributes of single items, one item at a time. Studies that have provided evidence of generalization have suggested that, to the extent that it occurs, it is limited to words that are semantically closely related to those in the training corpus (Kiran and Thompson (2003); McNeil et al (1997); Nickels (2002); Edmonds et al (2011)). Knowledge of particular semantic domains (e.g. animals) might usefully be fleshed out in this way, especially through presentation of atypical exemplars (Plaut (1996); Kiran (2003)), but semantic knowledge that spans the breadth of daily life is difficult to achieve with this approach.

An alternative approach to remediating anomia that focuses on phonemes and phoneme sequences has shown promise. Because the verbal production of all words involves the translation of a semantic representation into a phonological representation, full training of the repertoire of phonological sequences should enable individuals with anomia to regain the ability to learn trained words and sequences, generalize to untrained items, and continue growth following treatment termination.

To this end, an intensive phonological treatment program focused on rebuilding phonemes was applied to 26 individuals with aphasia and word retrieval impairment. The following research specific aims were addressed: 1) to assess acquisition and generalization effects, 2) asses improvement in phonological and lexical function, and 3) to assess changes in caregiver rating of language function.

METHODS

Participants: Twenty-six participants with chronic aphasia following left hemisphere damage due to stroke completed the treatment program. All participants were mono-lingual English, exhibited aphasia (Western Aphasia Battery, AQ)(Kertesz, 1982) (average AQ 79.3/100), word retrieval deficits (Boston Naming Test) (Kaplan et al, 1983)(average 37.1/60), demonstrated evidence of impaired phonologic processing (Standardized Assessment of Phonology in Aphasia)(Kendall et al, 2010)(average 100.7/151). Subjects were excluded if they exhibited severe apraxia of speech as determined by perceptual assessment of rate, distorted substitutions, prosodic abnormalities and effortful groping (see Table 1). **Study Design**: The study was designed as a group study and employs a pre- and post-treatment design. **Treatment program:** All subjects received 60 hours of phonological treatment (1-hour treatment sessions, 2 sessions/day, and 5 days/week for 6 weeks). For brevity, the treatment program is outlined in the Appendix. **Treatment stimuli:** Stimuli were comprised of phonemes in isolation, nonwords, and real words consisting of phonological sequences of low phonotactic probability and high neighborhood density. Phonotactic probability was calculated using methods similar to Vitevitch and Luce (1999). All nonwords were phonotactially legal in English. A web-based interface was used to calculate phonotactic probabilities for the real 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 (Storkel, 2006). Real word stimuli were also controlled for frequency, imagibility, age of acquisition, syllable number, syllable complexity and semantic category. **Outcome measure description**: All outcome measures were administered 3 times at each data collection point. Measures were collected pre-treatment, 1-week post treatment, 3-months and 1-year later. In order to determine treatment ***acquisition*** effects, data were collected from repetition of trained nonword stimuli and confrontation naming of *trained* real words. In order to determine any effects of treatment ***generalization*** to phonological processing abilities, the Standardized Assessment of Phonology in Aphasia (SAPA)(Kendall et al 2010) was administered, and data were collected on repetition of *untrained* nonwords. In order to assess effects of treatment *generalization* to lexical function, confrontation naming of *untrained* real words was probed. In order to determine ***ecologic validity*** *of* this treatment, data were collected on the Stroke and Aphasia Quality of Life scale (SAQOL)(Hilari & Byng, 2001) and the Functional Outcomes Questionnaire (Glueckauf et al, 2003).

RESULTS

Results are outlined in Table 2. Intra- and inter-rater reliability performed on 25% of the data for the primary outcome measure (untrained real word naming) showed .992 (intra) and .989 (inter-). Acquisition data for n=26 and three-month post maintenance data for n=25 have been collected and analyzed. Paired t-tests were performed on pre-treatment versus 1-week and 3 months post-treatment scores for the outcome measures. The magnitude of treatment associated changes is shown in Table 2. Significance was determined as p<.01. ***Treatment acquisition effects****:* A significant group effect was observed for repetition of trained nonwords (p=.000) and trained real word confrontation naming (p=.000) immediately following treatment. ***Generalization to phonological processing:*** A significant group effect was evident for the SAPA (p=.000) and untrained nonword repetition (p=.001) immediately following treatment. ***Generalization to lexical function***: A significant effect was present for confrontation naming of untrained real words (p=.003) immediately post treatment termination. ***Ecologic validity*** of this treatment program was measured by pre- and post treatment performance on the SAQOL (n=26) and FOQ-A (n=24). There was no significant difference immediately following treatment (p=.022 and p=.024 respectively). ***Performance at 3 months post treatment***: Pre-treatment and 3 months post treatment termination data were analyzed for n=25 individuals and were found significantly improved for SAPA (p=.000), trained real word confrontation naming (p=.000), untrained real word confrontation naming (p=.002), trained nonword repetition (p=.000) and untrained nonword repetition (p=.000). No significant difference was noted for SALQOL (p=.030).

DISCUSSION

The data presented in this abstract indicate there is evidence to show that 60 hours of intensive phoneme based treatment using stimuli comprised of real- and non-words comprised of low phonotactic probability and high neighborhood density generalizes to phonological abilities (SAPA and untrained nonword repetition), leads to improvement in ability to translate conceptual representations into phonological word forms 3 months post treatment termination (improved confrontation naming of untrained real words); however does not appear to generalize to a self report measure of overall communicative ability (SAQOL; communication items). Data analysis on discourse production is forthcoming.

Table 1: Participant demographics

Participant Number	Age (years)	Handedness	Education	Months post stroke onset
IT1	49	R	16	21
IT2	26	L	16	45
IT3	48	R	13	16
IT4	27	R	13	17
IT5	67	R	14	162
IT6	53	L	19	81
IT7	63	R	16	15
IT9	64	R	20	52
IT10	57	R	14	38
IT11	47	R	16	11
IT12	62	R	15	29
IT13	74	R	18	8
IT14	30	R	14	14
DT1	60	R	18	65
DT2	57	R	16	24
DT3	72	R	18	211
DT4	67	R	16	104
DT5	68	R	23	14
DT6	33	R	15	31
DT7	70	R	16	10
DT8	45	R	12	14
DT9	78	R	13	41
DT10	61	R	16	15
DT11	67	R	15	20
DT13	61	R	18	155
DT14	51	R	13	22
AVE (SD)	**56.0 (14.5)**	**24 Right 2 Left**	**15.8 (2.5)**	**47.5 (53.3)**

Table 2: Group average (SD) and t-test results for primary and secondary outcome measures. Significance p < .017 due to Bonferroni adjustment.

Research aim	Outcome measure	**Acquisition** *(pre-treatment versus immediately post-treatment)* **N=26**	**3-month maintenance** *(pre- treatment versus 3 month post-treatment termination)* **N=25**
Acquisition	*Trained nonword repetition	P=.000 Pre 72% (SD 21) Post 88% (SD 10)	P=.000 Pre 71% (SD 21) Post 85% (SD 12)
	*Trained real word confrontation naming	P=.000 Pre 65% (SD 24) Post 83% (SD 17)	P=.000 Pre 65% (SD 24) Post 78% (SD23)
Generalization to phonological processes	**Standardized Assessment of Phonology in Aphasia (SAPA)(raw score/151)	P= .000 Pre 99 (26) Post 108 (22)	P=.000 Pre 99 (26) Post 107 (24)
	*Untrained nonword repetition	P=.000 Pre 73% (SD 23) Post 84% (SD 16)	P=.000 Pre 72% (SD 23) Post 82% (SD 17)
Generalization to lexical semantics	*Untrained real word confrontation naming	P=.003 Pre 66% (SD 24) Post 71% (SD 23)	P=.002 Pre 65% (SD 24) Post 70% (SD 24)
Ecologic validity	**FOQ-A	P=.024 Pre 4.08 (SD .61) Post 4.32 (SD .48)	***
	**SALQOL	P=.022 Pre 3.35 (SD .71) Post 3.68 (SD .87)	P=.030 Pre 3.34 (SD .73) Post 3.70 (SD .72)

* Administered 3 times at each time point and averaged
** Administered 1 time at each time point
*** Missing data – unable to calculate paired t-tests

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APPENDIX: Treatment protocol

Stage1 – 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 in the following order: /p,b/, /f,v/, /t,d/, /k,g/, /th, th/, /s,z/. One vowel will be introduced following each minimal pair in the following order /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 high 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.