BACKGROUND

The purpose of this line of 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 30 subjects with left hemisphere lesion and aphasia. The short term objective, and purpose of this CAC presentation, is to present initial data from the large scale trial from 4 individuals who have completed the intensive treatment program. 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 a parallel distributed processing model of phonology (Nadeau, 2001).

The treatment 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 activation of lexical-semantic knowledge and word retrieval abilities.

Support for this hypothesis comes from studies of language acquisition in young children. They first learn many of the various phonological sequence regularities of their language (Gathercole, 1995; Gathercole & Martin, 1996). Subsequently they learn to assemble these various sequences into combinations and associate these combinations with concepts (meaning), enabling both word comprehension and word production. If this principle of language development also applies to language redevelopment after brain injury, it suggests two possibilities: (1) that effective retraining in phonological sequence knowledge may generalize to all words containing the trained sequences; and (2) that once given an adequate repertoire of phonological sequence knowledge during treatment, individuals with aphasia should be able to continue after therapy to enhance existing but inadequate connections between the substrate for conceptual semantic representations and the substrate for phonological sequence knowledge and steadily rebuild their working vocabularies. It is also possible that training some phonological sequences will generalize to other phonological sequences (e.g., through shared distinctive feature and motor programming sequences).

To this end, an intensive, multi-modal, phonological treatment program focused on rebuilding phonemes first in isolation, then in combinations of 1-, 2- and 3-syllable chains, was applied to 4 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: Four participants with chronic (duration of six or more months) aphasia following left hemisphere damage due to stroke were recruited through the speech pathology/audiology service at the VA Puget Sound Healthcare System and the University of Washington Speech and Hearing Clinic. Three were right-handed, one was left-handed. All were mono-lingual English, exhibited aphasia (Western Aphasia Battery, AQ)(Kertesz, 1982), word retrieval deficits (Boston Naming Test) (Kaplan et al, 1983), demonstrated evidence of impaired phonologic processing (Standardized Assessment of Phonology in Aphasia)(Kendall et al, 2010). Subjects were excluded if they exhibited severe apraxia of speech as determined by perceptual assessment of rate (segment durations), distorted substitutions, prosodic abnormalities and effortful groping. See Table 1 for details.

Study Design: The study was designed as a group study (n=30 over 3 years) and employs a pre- and post-treatment design (see Figure below). Pre- and post-treatment language results from four subjects are described in this conference proposal.

Treatment program: All subjects received 60 hours of phonological treatment of (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, and nonwords real words consisting of low phonotactic probability and high neighborhood density. Vowel (V), consonant-vowel

(CV), CVC, CCV, VCC, CCVC, CVCC, CCVCC combinations were constructed in 1- and 2-syllable real and nonword combinations. Phonotactic probability was calculated using methods similar to Vitevitch and Luce (1999). Two measures were used to determine phonotactic probability: 1) positional segment frequency (how often a segment occurs in a position in a word) and 2) sum biphone frequency (segment-to-segment probability). 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. Photographic pictures representing the real word stimuli were used.

Outcome measure description: All outcome measures were collected pre-treatment, 1-week post treatment and 3 months later. In order to determine treatment *acquisition* effects, data were collected on *trained* stimuli of nonword repetition 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).

RESULTS

Results are outlined in Table 3. *Treatment acquisition effects:* All four participants demonstrated significant improvement on repetition of trained nonwords immediately following treatment. Three of four participants showed significant improvement on confrontation naming of trained real words ($p \leq .05$). *Generalization to phonological processing abilities:* Three of four subjects showed significant improvement on the SAPA ($p \leq .05$). Two of the four participants showed significant improvement on repetition of untrained nonwords. *Generalization to lexical function*: One participant showed improved ability on confrontation naming of untrained nouns. All four participants demonstrated improvement on the Standardized Assessment of Phonology in Aphasia that exceeded 1 SD of group norms (3.68). *Ecologic validity* of this treatment program was measured by pre- and post treatment performance on the SAQOL. Minimal improvement was noted for three of four participants.

DISCUSSION

The data presented in this abstract are only from 4 participants and should be interpreted cautiously. With that said, there is evidence to show that 60 hours of intensive, multi-modal 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) and, in one individual, improvement in activation of conceptual representations (improved confrontation naming). Maintenance data will be collected within a month of this abstract submission. Future research is ongoing and focused on the continuation of n=30 group data collection.

Figure 1: Study Design

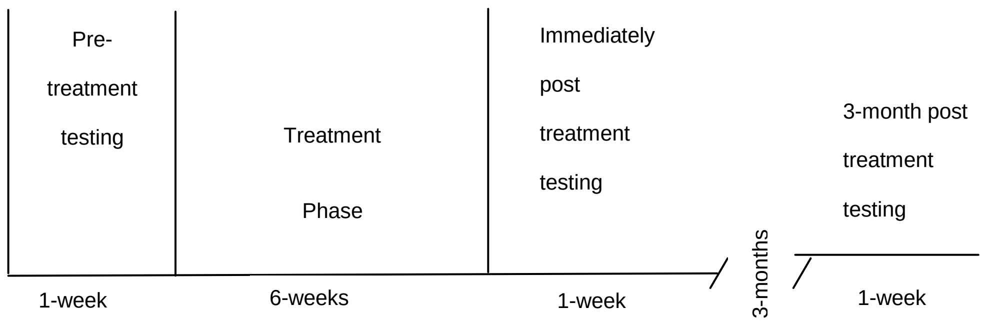

Table 1: Patient demographics participants' #1-4

Participant Number	Age (years)	Handedness	Education	Months post stroke onset
1	50	Right	16	21
2	26	Left	16	45
3	60	Right	18	65
4	57	Right	16	24

Table 2: Pre-treatment, immediately post-treatment and 3-month maintenance test results for Participants #1-4. 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 Number	WAB Aphasia Quotient (out of100)			BNT (spontaneous correct out of 60)			SAQOL (average score out of 5.0)			SAPA (raw score out of 151)		
	Pre-	Post 1-wk	Post 3-mos	Pre-	Post 1-wk	Post 3-mos	Pre-	Post 1-wk	Post 3-mos	Pre-	Post 1-wk	Post 3-mos
1	87.5	88.6	*	37	42	*	4.18	4.88	*	96	106	*
2	94.2	95.8	*	57	55	*	4.23	4.59	*	128	139	*
3	59.5	67.4	***	19	17	***	4.21	4.60	***	81	89	***
4	82	87.2	***	34	37	***	4.33	4.15	***	102	116	***

* Subjects completed treatment November 2010 and 3 month follow-up data will be collected in February 2011

*** Subjects completed treatment January 2011 and 3 month follow-up data will be collected in April 2011

Table 3: Participants #1-4. Average (SD) pre-treatment and immediately post-treatment data for treatment and generalization probes with results from paired t-tests. All probes were administered three times pre-treatment and three times post-treatment.

Pt	TREATMENT EFFECTS Trained nonword repetition number of items = 72			TREATMENT EFFECTS Trained confrontation naming number of items = 42			GENERALIZATION EFFECTS UN-Trained nonword repetition number of items = 73			GENERALIZATION EFFECTS UN-Trained confrontation naming number of items = 42		
	Pre-	Post 1-wk	T-test p value	Pre-	Post 1-wk	T-test p value	Pre-	Post 1-wk	T-test p value	Pre-	Post 1-wk	T-test p value
1	60 (4)	86 (4.8)	.0020	85 (9.9)	97 (1.37)	.1061	64 (4.4)	77 (4.9)	.0268	78 (1.4)	83 (8.6)	.3765
2	94 (.80)	100 (0)	.0002	90 (1.4)	98 (0)	.0006	92 (2.85)	99 (.79)	.0149	91 (2.7)	94 (2.75)	.2489
3	53 (9.76)	92 (.80)	.0023	40 (5)	78 (3.64)	.0004	56 (8.67)	68 (4.11)	.0962	40 (4.1)	37 (1.4)	.2830
4	83 (.79)	91 (1.6)	.0015	58 (5)	79 (8.6)	.0216	85 (6.28)	89 (4.8)	.4302	60 (4.1)	77 (3.73)	.0060

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<u>APPENDIX:</u> 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, <u>th/</u>, /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.