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 30 subjects with left hemisphere lesion and aphasia. The short term objective, and purpose of this CAC presentation, is to present data from the large scale trial from 17 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 an interactive activation model (Dell, 1986) and 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 ability to translate concept representations into phonological word forms.

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 withmeaning, enabling both word comprehension and 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 semantic representations and the substrate for phonological representations 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 phonological treatment program focused on rebuilding phonemes was applied to 17 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: Seventeen 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 (n=30 over 3 years) and employs a pre- and post-treatment design (see Figure below). Pre- and post-treatment language results from 17 individuals 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, 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. Photographic pictures representing the real word stimuli were used. **Outcome measure description**: All outcome 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 3. Acquisition data for n=17, three-month post maintenance data for n=13 and 1 year post maintenance data for n=4 have been analyzed. Paired t-tests were performed on pre-treatment versus 1-week, 3 months and 1 year post-treatment scores for the outcome measures. The magnitude of treatment associated changes is shown in Tables 2 and 3 ***Treatment acquisition effects****:* A significant group effect was observed for repetition of trained nonwords (p=.001) and trained real word confrontation naming (p=.001) immediately following treatment. ***Generalization to phonological processing:*** A significant group effect was evident for the SAPA (p=.001) and untrained nonword repetition (p=.001) immediately following treatment. ***Generalization to lexical function***: No significant difference was present for confrontation naming of untrained real words (p=.127) immediately post treatment termination. ***Ecologic validity*** of this treatment program was measured by pre- and post treatment performance on the SAQOL and FOQ-A. A significant difference was present immediately following treatment (p=.048 and p=.024 respectively). ***Performance at 3 months post treatment****:* Pre-treatment and 3 months post treatment termination data were analyzed for n=13 individuals and were found significantly improved for SAPA (p=.000), trained real word confrontation naming (p=.001), untrained real word confrontation naming (p=.034), trained nonword repetition (p=.012), untrained nonword repetition (p=.003) and SALQOL (p=.009). No significant difference was noted for FOQ-A (p=.349). ***Performance at 1 year post treatment****:* Pre-treatment and 1 year post treatment termination data were analyzed for n=4 individuals and were found significantly improved for SAPA (p=.036), trained nonword repetition (p=.062), untrained nonword repetition (p=.023) and SALQOL (p=.001). No significant difference was noted for trained real word confrontation naming (p=.130), and untrained real word confrontation naming (p=.173).

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) and 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). These data also show that some effects of treatment are maintained 1 year following treatment termination.

Figure 1: Study Design

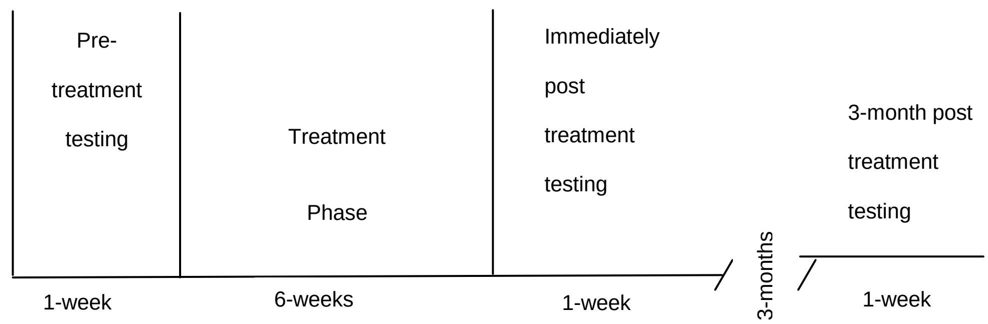

Table 1: Participant demographics

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
IT8	57	R	20	16
IT9	64	R	20	52
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
AVE (SD)	**54.5 (14.7)**	**15 Right 2 Left**	**16.5 (2.9)**	**52.8 (57.6)**

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	WAB Aphasia Quotient (out of100)			BNT (spontaneous correct out of 60)			SAQOL (average score out of 5.0 * communication only)			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**
IT1	87.5	88.6	87.1	37	42	47	3.86	4.57	4.14	96	106	119
IT2	94.2	95.8	95.4	57	55	59	3.86	4.71	4.29	128	139	141
IT3	94.6	93	94.4	52	49	52	3.14	3.57	3.71	131	137	135
IT4	51.1	70.1	70.3	44	50	45	2.57	4.29	4.43	74	91	80
IT5	84.5	86.9	89.8	36	38	42	3.57	5	4.29	94	106	105
IT6	63.9	68.7	70.8	20	29	21	2.29	2.86	2.14	64	74	68
IT7	37.6	47.1	48.8	2	3	2	2.43	3.14	3.29	53	59	61
IT8	93.5	95.8	*	51	56	*	2.00	2.29	*	117	134	*
IT9	76.3	76.5	*	9	11	*	2.29	3.29	*	80	89	*
DT1	59.5	67.4	64.7	19	17	24	3	3.43	4.14	74	89	73
DT2	82	87.2	84.1	34	37	41	3.57	3.14	3.29	106	116	112
DT3	69.8	80.6	65.4	34	27	26	4.57	3.71	4.66	81	76	92
DT4	81.1	85.7	80.5	56	57	47	2.86	2.43	4.41	109	119	115
DT5	92	94.4	93.2	57	56	56	4.14	4.29	4.43	114	118	117
DT6	78.2	83.5	80.4	31	41	40	3.86	3.71	4.29	72	85	85
DT7	94.7	93.7	*	34	45	*	4.29	4.86	*	113	112	*
DT8	85.2	87.2	*	31	32	*	4.00	4.14	*	126	140	*
AVE (SD)	**79.3 (16.7)**	**82.5 (13.0)**	**78.8 (14.0)**	**37.1 (17.6)**	**37.9 (16.3)**	**38.6 (16.1)**	**3.31 (0.80)**	**3.7 (0.82)**	**4.0 (0.69)**	**100.7 (20.6)**	**112 (20.0)**	**100.2 (25.7)**

Table 3: Group average (SD) and t-test results for primary and secondary outcome measures.

Research aim	Outcome measure	Acquisition *(pre-treatment versus immediately post- treatment)* N=17	3-month maintenance *(pre- treatment versus 3 month post-treatment termination)* N=13	1-year maintenance *(pre-treatment versus 1 year post-treatment termination)* N=4
Acquisition	Trained nonword repetition	P=.000 Pre 68% (SD 20) Post 88% (SD 9)	P=.012 Pre 66% (SD 21) Post 82% (SD 15)	P=.062 Pre 73% (SD 19) Post 83% (SD 15)
	Trained real word confrontation naming	P=.001 Pre 64% (SD 26) Post 81% (SD 17)	P=.001 Pre 65% (SD 26) Post 78% (SD24)	P=.130 Pre 70% (SD 22) Post 85% (SD 10)
Generalization to phonological processes	Standardized Assessment of Phonology in Aphasia (SAPA)(151)	P= .000 Pre 96% (24) Post 105% (25)	P=.000 Pre 92% (25) Post 100% (26)	P=.036 Pre 101% (22) Post 111% (17)
	Untrained nonword repetition	P=.001 Pre 70% (SD 20) Post 81% (SD 15)	P=.003 Pre 68% (SD 20) Post 81% (SD 17)	P=.023 Pre 75% (SD 15) Post 80% (SD 15)
Generalization to lexical semantics	Untrained real word confrontation naming	P=.127 Pre 63% (SD 25) Post 67% (SD 24)	P=.034 Pre 63% (SD 26) Post 70% (SD 26)	P=.173 Pre 66% (SD 26) Post 85% (SD 10)
Ecologic validity	FOQ-A	P=.048 Pre 3.94 (SD .60) Post 4.25 (SD .53)	P=.349 Pre 3.90 (SD .19) Post 4.06 (SD .19)	No data
	SALQOL	P=.024 Pre 3.33 (SD .77) Post 3.73 (SD .82)	P=.009 Pre 3.39 (SD .41) Post 3.96 (SD .69)	P=.001 Pre 3.57 (SD .41) Post 4.42 (SD .48)

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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.