Sound Production Treatment: Synthesis and Quantification of Outcomes

Treatment for acquired apraxia of speech (AOS) has taken numerous forms, with positive outcomes reported for most treatments. Following a critical evaluation and synthesis of the AOS treatment literature, AOS treatment guideline developers concluded that "taken as a whole, the AOS treatment literature indicates that individuals with AOS may be expected to make improvements in speech production as a result of treatment, even when AOS is chronic….and the strongest evidence for this conclusion exists for treatments designed to improve articulatory kinematic aspects of speech production" (Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006; p.lxii). This conclusion was based upon general criteria concerning the overall quantity and quality of the evidence-base. Strom (2008) subsequently confirmed the positive effects of articulatory-kinematic AOS treatment approaches using meta-analysis.

The AOS guidelines developers grouped treatment studies by general focus (e.g., articulatory-kinematic, rate/rhythm, intersystemic reorganization, and alternative/augmentative); at the time of the guidelines report, no one treatment had a sufficient database to warrant individual consideration (Wambaugh et al., 2006). Over the past decade, additional AOS treatment evidence has accumulated with investigations moving toward comparisons of treatment approaches (Wambaugh, Mauszycki, & Ballard, 2013).

Sound Production Treatment (SPT; Wambaugh, Kalinyak-Fliszar, West, & Doyle, 1998) is an articulatory-kinematic AOS treatment that has received relatively systematic study over the past 15 years. There are now sufficient reports of SPT to support its evaluation as a specific approach rather than as part of the general category of articulatory-kinematic approaches. A synthesis and quantification of the effects of SPT is needed to permit comparison to other treatments, to allow evaluation of different applications of SPT, and to facilitate examination of generalization effects of treatment. The purpose of the current investigation was to quantify the effects of SPT in terms of the magnitude of change (i.e., effect size) associated with treatment and follow-up phases of efficacy studies.

Method

Evidence Identification

SPT studies were identified through personal knowledge and literature searches. Extensive database searches were conducted as part of the AOS treatment guidelines and updated guidelines (Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006a; Ballard et al., in preparation), and these search results were available for the current project. Additional searches were completed for the time period following the guidelines searches. Ten published studies and one conference report were identified. One published investigation was excluded because it overlapped another report.

To assure that data were derived from studies with internal validity (Robey, Schultz, Crawford, & Sinner, 1999), the studies were evaluated for evidence of experimental control following criteria described by Kratochwill et al. (2010). Multiple baseline experimental designs with a minimum of three data points per phase (baseline and treatment) were employed in all studies, and changes in behavior were associated with application of treatment.

Participants

There were 24 participants across the 10 investigations. Descriptive variables were coded for all participants (Table 1). Across the studies, there were six females and 18 males and all presented with AOS and Broca's aphasia. AOS severity estimates ranged from mild to severe,

and Western Aphasia Battery Aphasia Quotients (WAB-AQs; Kertesz, 1982; 2007) ranged from 14.8 to 75.5. Twenty-three of the participants were more than one year post-stroke (min-max: 8 to 259 months-post-onset).

Data Extraction

Original graphing software files were available for 17 of the participants and were used for obtaining probe values for effect size calculations. For the remaining participants, probe values were determined using published graphs.

Effect Size Calculations

Effect sizes (d-index; Bloom, Fischer, & Orme, 2003) were calculated as indications of the magnitude of change associated with treatment. Effect sizes were calculated for each target (i.e., set of items) for each participant, with separate calculations made for treated items (acquisition effects) and untreated items (generalization effects). Separate effect sizes were obtained for changes associated with treatment phases and follow-up phases.

To calculate *treatment phase* effect sizes, all baseline probe values for the behavior (i.e., probes conducted prior to the application of treatment for that behavior) and the final three probe values in the treatment phase were utilized. To calculate *follow-up phase* effect sizes, the probe values from the initial baseline phase for each behavior (i.e., probes conducted in baseline prior to the application of *any* treatment) and all follow-up probe values were used. The follow-up phase effect sizes reflected the *cumulative* effects of all phases of treatment on the behavior. (i.e., any generalization effects would be included). In cases where only one follow-up probe value was available, delta values were calculated instead of d-index values.

Results

Effect sizes are shown in Table 2 for each participant and are displayed by treatment target and study phase, with treated and untreated targets shown separately. Treatment targets per participant ranged from two to nine sets of items. In all but one investigation, data for untrained exemplars were available for calculation of response generalization effect sizes. Across the participants, 272 effect size calculations were performed; d-index values could not be obtained for 14 calculations due to lack of variance.

Acquisition Effects of SPT (effects on trained items)

In all but one instance (Wambaugh & Nessler, 2004, one of nine trained sounds), positive effect sizes were obtained for changes associated with the *treatment phase.* A wide range of effect sizes was found across participants, with a minimum of d = -.18 and a maximum of d = 47.13. Wide variation was also found within participant in some cases (e.g., d = -.18 to +23.09; d = 1.8 to 23.3). However, little variation in effect sizes was found in other cases (e.g., d = 3.11 to 3.55).

Effect sizes for changes associated with the follow-up phase for trained items ranged from d= .94 to 16.84. Although follow-up effect sizes were generally smaller than treatment phase effect sizes, some participants demonstrated larger effect sizes for follow-up.

Response Generalization Effects of SPT (effect on untrained exemplars of trained items).

As with trained items, positive effect sizes were found in all but one instance for untrained items (Wambaugh et al., in press, Participant 1). Effect sizes for untrained exemplars

of trained items ranged from d = -.26 to d = 22.14 for changes associated with the *treatment phase*. Although effect sizes for untrained items were generally smaller than effect sizes for corresponding trained items, in some cases the magnitude of change was comparable.

Effect sizes for untrained items associated with the follow-up phase ranged from d = -.82 to 20.79. For some participants, follow-up effect sizes tended to be smaller for untrained items than for trained items.

Planned Meta-Analysis

Two participants are currently completing a second and final phase of SPT (Wambaugh et al., in preparation, P3 & P4). Effect sizes for their second treatment targets and follow-up data will also be calculated. Then, a meta-analysis of all the studies will be completed to obtain benchmarks for small, medium, and large effect sizes (e.g., first, second and third quartiles for the d-statistic; Beeson & Robey, 2006).

Discussion

Group findings concerning the overall magnitude of change for treated items relative to untreated items will be considered relative to theories of speech production and implications for treatment application/modification. Individual participant findings will be discussed with regard to participant characteristics and treatment targets. Findings will also be discussed with respect to ramifications for AOS treatment design.

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Table 1

Participant Characteristics from All SPT Studies

Study	P#	Sex	MPO	Etiology	AOS Severity	WAB AQ	Aphasia Type
Wambaugh et al. 1998	P1	M	20	CVA	moderate	30	Broca's
	P2	M	33	CVA	severe	29.3	Broca's
	P3	M	67	CVA	moderate	31.2	Broca's
Wambaugh, West, Doyle, 1998	P1	F	61	CVA	mild-moderate	75.5	Broca's
Wambaugh & Cort, 1998	P1	M	26	CVA	moderate-severe	34	Broca's
Wambaugh et al., 1999	P1	M	8	CVA	moderate	51	Broca's
Wambaugh, 2004	P1	M	70	CVA	moderate-severe	37.1	Broca's
	P2	F	50	CVA	mild-moderate	63.4	Broca's
Wambaugh & Nessler, 2004	P1	M	48	CVA	moderate-severe	70	Broca's
Wambaugh & Mauszycki, 2010	P1	M	24	CVA	severe	14.8	Broca's
Wambaugh et al., 2013	P1	M	231	CVA	mild-moderate	65.1	Broca's
	P2	F	61	CVA	moderate	51.8	Broca's
	P3	M	26	CVA	moderate-severe	26.7	Broca's
	P4	M	232	CVA	moderate	61	Broca's
Wambaugh et al., in press	P1	M	64	CVA	moderate	68.9	Broca's
	P2	M	87	CVA	moderate-severe	53.4	Broca's
	P3	M	86	CVA	moderate-severe	34.5	Broca's
	P4	M	58	CVA	severe	28.7	Broca's
	P5	F	83	CVA	moderate	56.4	Broca's
	P6	M	28	CVA	moderate-severe	48.2	Broca's
Wambaugh et al., in preparation	P1	F	48	CVA	mild-moderate	60.0	Broca's
	P2	F	17	CVA	mild	64.6	Broca's
	P3	M	34	CVA	mild-moderate	65.4	Broca's
	P4	M	259	CVA	mild-moderate	59.9	Broca's

Table 2

Treatment Targets and Effect Sizes for Treatment and Follow-up Phases

Study/Comments	P#	Treatment Targets	Treated Items d-Index Tx. Phase	Treated Items d-Index Follow-Up Phase	Untreated Items d-Index Tx. Phase	Untreated Items d-Index Follow-Up Phase
Wambaugh et al. 1998	P1	/z/ initial, 1- and 2-syl. words	2.94	11.26^	11.41	*
		/ʃ/ final, 1- and 2-syl. words	6.18	*	7.21	1.50^
		/ʤ/ initial, 1- and 2-syl. words	6.14	9.80^	4.57	6.01^
	P2	/ʃ/ final, 1- and 2-syl. words	5.84	6.49^	5.47	5.66^
		/r/ initial, 1- and 2-syl. words	10.07	7.00^	9.97	19.68^
		/sw/ initial, 1- and 2-syl. words	5.97	4.75^	6.01	8.61^
	P3	/ʧ/ initial, 1- and 2-syl. words	6.61	3.91^	4.00	2.21^
		/ʃ/ final, 1- and 2-syl. words	1.99	0.94^	3.53	0.16^
		/z/ initial, 1- and 2-syl. words	3.45	26.08^	4.11	20.79^
Wambaugh, West, & Doyle, 1998	P1	Stops, all positions, 3-5 word sentences	5.92	7.11^	12.36	12.19^
		Fricatives, all positions, 3-5 word sentences	8.63	7.51^	4.00	5.48^
		Glides/liquids, all positions, 3-5 word sentences	4.93	2.50^	2.83	2.23^
		Mixed consonants, all positions, 3-5 word sentences	n/a	na	na	.94^
Wambaugh & Cort,1998	P1	/b/ initial, 1-syl. words	8.43	n/a	3.75	n/a
		/ʤ/ initial, 1-syl. words	5.15	n/a	5.69	n/a
		/d/ initial, 1-syl. words	2.05	n/a	2.05	n/a
		/g/ initial, 1-syl. words	2.24	n/a	2.50	n/a
		/θ/ final, 1-syl. words (control set)	n/a	n/a	n/a	n/a
Wambaugh et al., 1999	P1	/p/ initial, 1-syl. words	9.17	16.50^	11.12	16.50^
		/k/ initial, 1-syl. words	19.19	*	4.72	17.50^
		/ʃ/ initial, 1-syl. words	5.35	*	7.71	*
Wambaugh, 2004	P1	/v/ initial, 1- and 2-syl. words	21.3	13.86	7.59	11.31
		/r/-blends initial, 1- and 2-syl. words	2.93	4.31	1.74	4.90
	P2	/ʃ/ syl.-final, 1-syl. words in 2-word phrases	7.50	5.81^	5.39	7.57^

		/z/ syl.-initial, 1- and 2-syl. words in 2-word phrases /θ/ syl.-final, 1-syl. words in 3-word phrases (control set)	3.71 na	4.74^ na	2.27 na	-0.71^ 8.57^
Wambaugh & Nessler, 2004	P1	/s/ initial, 1-syl. CV(C) words	17.16	n/a	n/a	n/a
		/p/ initial, 1-syl. CV(C) words	*	n/a	n/a	n/a
		/v/ initial, 1-syl. CV(C) words	8.86	n/a	n/a	n/a
		/k/ initial, 1-syl. CV(C) words	23.09	n/a	n/a	n/a
		/ʃ/ initial, 1-syl. CV(C) words	9.10	n/a	n/a	n/a
		/ʤ/ initial, 1-syl. CV(C) words	-0.18	n/a	n/a	n/a
		/l/ initial, 1-syl. CV(C) words	2.26	n/a	n/a	n/a
		/m/ initial, 1-syl. CV(C) words	1.53	n/a	n/a	n/a
		/n/ initial, 1-syl. CV(C) words	5.13	n/a	n/a	n/a
Wambaugh & Mauszycki, 2010	P1	/b/ initial, 1-syl. CV(C) words	5.43	3.20	3.00	2.37
		/s/ initial, 1-syl. CV(C) words	1.40	2.24	1.84	1.58
		/l/ initial, 1-syl. CV(C) words	7.01	6.47	2.60	*
		/m/ initial, 1-syl. CV(C) words	5.45	0.88	3.03	-0.82
		/d/ initial, 1-syl. CV(C) words	3.97	7.66	7.07	1.58
		/f/ initial, 1-syl. CV(C) words	*	*	19.80	6.32
Wambaugh et al., 2013 *Words elicited in target phrase "I say…"* *Accuracy of entire word scored +/-*	P1	/s/ initial, 4-syl. words – IB	11.09	3.98	3.67	1.95
		/ɪ/ and /ɛ/ initial, 3-syl. words - IR	4.37	2.51	1.33	3.29
		/r/ initial, 4-syl. words - TR	6.90	2.63	2.85	2.25
		/ɑ/ /æ/ /i/ or /o/ initial, 3-syl. words - TB	2.43	5.59	0.31	3.89
	P2	/θ/ initial or final, 2-syl. words - IR	8.99	4.37	1.73	3.58
		/ʃ/ initial or final, 2-syl. words - IB	8.62	7.49	3.24	3.54
		/z/ initial, or /k/ final, 2-syl. words - TB	9.10	3.56	1.43	-0.33
		/ʤ/ initial or final, 2-syl. words - TR	3.71	6.28	1.55	1.44
	P3	/sw/ initial, 1-syl., or /θ/ final, 2-syl. words - TR	1.80	3.50	1.00	2.00
		/sm/ initial, 1-syl., or /ʃ/ final, 2-syl. words –TB	23.33	2.40	4.90	1.73
		/bl/ initial, 1-syl., or /z/ final, 2-syl. words- IB	17.14	2.58	2.98	5.00
		/fl/ initial, 1-syl., or /ʤ/ final, 2-syl. words- IR	15.20	3.78	9.48	2.00
	P4	/θ/ or /br/ initial, 3-syl. words – TB	9.97	3.66	1.69	2.38
		/z/ or /gl/ initial, 3-syl. words – TR	3.32	5.40	2.21	0.39
		/st/ or /t/ initial, 3-syl. words – IR	6.92	0.31	4.16	3.49

		/ʃ/ or /sk/ initial, 3-syl. words – IB	5.42	5.43	2.00	4.00
Wambaugh et al., in press	P1	*(Words elicited in target phrase "I say…") -P1 only*				
		/pr/ initial, 3-syl. words	3.11	2.81	1.93	0.27
		/ks/ medial, 3-syl. words	3.55	4.65	2.29	2.63
		/gl/ initial, 3-syl. words	3.15	3.31	-0.26	0.27
		/nd/ medial, 3-syl. words	3.15	3.69	0.36	2.00
	P2	/z/ final, 1-syl. words	12.34	9.33	2.64	3.30
		/st/ initial, 1-syl. words	7.58	1.57	4.21	1.18
		/f/ final, 1-syl. words	7.22	8.05	6.48	7.91
		/gl/ initial, 1-syl. words	41.99	2.64	5.06	2.27
	P3	/θ/ initial, 1-syl. words	8.83	8.16	3.87	4.93
		/gl/ initial, 1-syl. words	*	14.00	*	6.50
		/ʤ/ initial, 1-syl. words	42.69	2.51	5.89	1.39
		/sm/ initial, 1-syl. words	29.44	6.00	2.10	2.68
	P4	/f/ final, 1-syl. words	14.04	4.63	9.72	9.72
		/sm/ initial, 1-syl. words	12.35	1.86	*	2.16
		/bl/ initial, 1-syl. words	*	14.97	22.14	2.86
		/p/ final, 1-syl. words	19.35	16.84	6.35	6.89
	P5	/gl/ initial, 2-syl. words	28.87	10.39	3.20	*
		/kw/ medial, 2-syl. words	14.05	10.14	2.62	4.06
		/θr/ initial, 2-syl. words	47.13	10.91	12.05	10.37
		/st/ medial, 2-syl. words	7.08	11.77	8.25	3.02
	P6	/θr/ initial, 2-syl. words	18.51	14.44	9.00	5.02
		/gl/ initial, 2-syl. words	8.83	1.71	6.28	2.81
		/sn/ initial, 3-syl. words	34.69	12.73	12.72	4.24
		/kw/ initial, 3-syl. words	4.32	3.00	10.28	4.51
Wambaugh, et al., in prep *accuracy of entire word scored +/-* .	P1	/θ/ medial, or /s/-blends, 3- and 4-syl. words (B) /br/ initial or medial, or /l/ medial, 3- and 4-syl. words (R)	7.39 5.42	7.14 8.76	1.07 1.24	0.88 3.36
	P2	/st/ initial or /tr/ medial, 4-syl. words (R)	11.34	9.86	1.57	1.18
		/θ/ medial or /fl/ initial, 4-syl. words (B)	3.74	6.21	3.85	3.71
	P3	/st/ initial or /dz/ medial, 3- and 4-syl. words (B) /gl/ initial or /θ/ medial, 3- and 4-syl words (R)	7.75		2.85	

	P4	/kw/ or /br/ medial, 4-syl. words (R) /fl/ or /sp/ medial, 4-syl. words (B)	5.32		1.15	

syl. = syllable; B = Blocked; R = Random; TB = traditional blocked; TR = traditional random; IB = intense blocked; IR = intense random
* indicates no variance – could not calculate effect size
^ indicates delta value