Behavioral Development Bulletin
2015, Vol. 20, No. 2, 186–206

1942-0722/15/$12.00 http://dx.doi.org/10.1037/h0101313

The Effects of an Auditory Match-to-Sample Procedure on Listener Literacy and Echoic Responses

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We tested the effects of an auditory match-to-sample (MTS) procedure in 2 experiments. In Experiment 1 the dependent variables were (a) following spoken instructions (listener literacy), and (b) clarity of echoic responses. Four elementary school students with autism participated. In Experiment 2, we added a dependent variable: (c) preference for listening to recordings of a variety of adult voices. Three elementary school students served as participants, 2 diagnosed with autism and 1 diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). During the intervention sessions, a computerized auditory MTS slide displayed 3 circles on a computer screen. Touching each circle produced a spoken word or phrase. The participants were taught to match words or phrases when correct and incorrect matches were available. Participants mastered the auditory MTS procedure for words or phrases. We used a delayed multiple probe design across participants in Experiment 1 and a multiple-probe design in Experiment 2. In both experiments, the training resulted in improvements in listener literacy and clarity of echoic responses. Moreover, in Experiment 2, the number of intervals for listening to recordings of adult voices increased for all participants, suggesting a relation between conditioned reinforcement for voices and listener and speaker responding.

Keywords: auditory match-to-sample procedure, conditioned reinforcement, echoic responding, listener literacy

The role of the listener has received increased attention in the analysis of verbal behavior and the development of complex language (Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000; Greer & Longano, 2010; Greer & Speckman, 2009; Horne & Lowe, 1996; Lodhi & Greer, 1989; Marion et al., 2003; Skinner, 1957). Evidence from linguistic and developmental psychology has consistently showed that the listener repertoire develops prior to the speaker (Bloom, 2002; Crystal, 2006; Decasper & Spence, 1986; Hoff & Shatz, 2009).

Behavior analysts who focused on development have identified critical developmental *cusps* (Rosales-Ruiz & Baer, 1997; Novak & Pelaez, 2004). Rosales-Ruiz and Baer (1997) defined a *cusp* as a behavioral change that has consequences for the organism beyond the change itself, some of which may be considered important" (p. 537). For example, when infants learn to crawl, they have increased access to environmental stimuli and the associated consequences of encounters with those stimuli. This line of research focuses on verbal behavior development and attempts to identify the instructional histories that contribute to the development of the verbal developmental *cusps* and the effects the *cusps* have on subsequent learning or emergent behavior (Greer & Speckman, 2009). Moreover, research over the last decade

This article was published Online First October 12, 2015.
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has identified developmental *cusps* for verbal behavior and ways to establish *cusps* when they are missing in children with language delays.

One potential verbal developmental *cusp* is the acquisition of auditory matching of words. When this cusp is in place the auditory discrimination of sameness of and differences in speech sound combinations is possible. In testing or training this cusp, words are presented and the listener must select whether the words they hear are the same or different. This capability appears basic to the discrimination of combinations of speech sounds that are foundational to phonemic awareness, responding by reproducing words as a speaker, either by parroting or echoing.

One example of *a listener cusp* that has been identified in verbal behavior developmental research is listener literacy. Listener literacy is the onset of, or increased facility in responding accurately to, combinations of the speech sounds of others (Greer, Chavez-Brown, Nirgudkar, Stolfi, & Rivera-Valdes, 2005; Greer & Ross, 2008; Greer & Speckman, 2009). The term incorporates what some developmental scholars refer to as phonemic awareness, but differs in that listener literacy refers to stimulus control of speech sound combinations (Crystal, 2006). Matching speech-sound combinations as a selection response (auditory match-to-sample responding) is a measure of phonemic awareness. This cusp would appear to be foundational to listener literacy. Moreover, a cusp that is thought to be prerequisite of the auditory matching *cusp*, according to current verbal behavior developmental theory, is conditioned reinforcement for listening to voices (Greer, Pistoljevic, Cahill, & Du, 2011).

In early research on the treatment of children with autism, Lovaas (1977) taught compliance as a first step. In that approach, compliance was not necessarily controlled solely by the phonemic properties of speech. Visual/gestural prompts or sequential variables might lead to compliance and the isolated control of speech sound combinations was not essential. Thus, although a child may be compliant, the child may be dependent on visual cues or prompts. His or her response may not be fully under auditory stimulus control, and as a consequence the child may emit incorrect responses when visual prompts are not present. If the responses are controlled by the teacher or therapists wittingly or unwittingly visual cues along with the presentation of vocal speech, those responses would not reflect true listener literacy. Skinner (1957) used the term "instructional control" to refer to speech sound control over the responses of a listener similar to the definition for listener literacy. True listeners are verbally governed by others as they respond to verbal topographies, and if the topography of the community is speech the controlling stimuli are speech sound combinations.

The developmental onset of auditory match-to-sample (MTS) responding for speech sound combinations, in turn, builds on a foundation of conditioned reinforcement for voices. Some evidence suggests that auditory stimulus control of mother's voices develops in utero for typically developing infants (Moon, Lagercrantz, & Kuhl, 2013). According to verbal behavior developmental theory this constitutes one of the early conditioned reinforcers for observing responses that lays the foundations for the onset of behavioral developmental verbal cusps. Thus, the infants' responses to their mothers' voices is theorized to be the outcome of in utero conditioning. Several experiments in verbal behavior development suggest this possibility (Greer et al., 2011; Greer & Han, in press; Tsai & Greer, 2006). Greer et al. (2011) found that the establishment of conditioned reinforcement for voices, and the establishment of a criterion for preference for listening to recorded voices as duration of free operant choice, contributed to (a) accelerated learning of curricula that incorporated vocal instructions, (b) choosing to listen to stories in free-play settings, as well as (c) increased awareness of others in the immediate environment in preschoolers with language delays. In related findings, conditioned reinforcement for looking at books and the choice of books in free-play settings contributed to accelerated rates of responding to textual stimuli (Tsai & Greer, 2006) consistent with Dinsmoor's (1985) findings on the relation of conditioned reinforcement for observing responses and the rate of discrimination learning. Moreover, Greer and Han (in press) found that establishing conditioned reinforcement for two-dimensional visual stimuli resulted in generalized visual MTS for over 70 stimuli. These relations between conditioned reinforcement for observing responses suggested the possibility that auditory MTS effects might be related to conditioned reinforcement for listening to speech-sound combinations. Thus, in the second experiment, reported herein, we included measures of conditioned reinforcement for speech sound combinations as a dependent variable.

Prior research (Greer & Keohane, 2005) identified the listener literacy *cusp* through an intervention designed to induce listener literacy by ensuring that reinforcement was obtained only when participants responded to spoken instruction. In Experiment 2 of the current study, we enhanced the isolation of the control of speech stimuli in the intervention used in Greer and Keohane (2005) by testing participants' responses to the spoken instructions in the presence of conflicting visual models. This procedure ensured that correct responses were solely the result of the spoken word by having the experimenter emit synchronous movements that were different from the vocal instructions. Also, the requirement of having the experimenter present a visual distracter as he spoke instructions decreased the likelihood that the experimenter would provide unwitting visual cues.

An earlier study by Marion et al. (2003) suggested the possibility of a listener literacy *cusp*. They found positive correlations between measures of auditory MTS selection responses for words spoken by others and speaker responses of severely delayed adults. Greater accuracy in auditory MTS correlated with a larger speaker repertoire. Building on these findings, Chavez-Brown (2005) found a functional relation between the mastery of an auditory MTS procedure, in which children were required to match spoken words when nontarget words were also options, and improvements in participants' point-to-point correspondence between hearing and saying. This auditory MTS procedure led to increases in full echoics in children who showed incorrect or partial echoics during the preintervention probes. In her first experiment, participants with no echoic responses acquired some improvements in echoic responding. In a second study, participants who had had partial echoic responses but after a few weeks of the intervention they gained several months of language development in clarity of speech as assessed by independent evaluators using a standardized test, *Goldman Fristoe* (Goldman & Fristoe, 2000). The intervention tested by Chavez-Brown (2005) included a sequence requiring that participants' progress from matching nonword sounds to like nonword sounds, when no sound or a different sound was the comparison, and then to matching sets of five simple two- and three-syllable words. The training continued until participants matched a novel set of five words without error on first exposure. Chavez-Brown (2005), Speckman-Collins, Lee Park, and Greer (2007), and Longano and Greer (2014) argued that the auditory match-to-sample procedure may also act to condition adult voices as reinforcers for listening to speech-sound combinations by incidentally providing stimulus-stimulus pairings.

Taken together, these studies and current theory suggest that auditory MTS repertoires for speech sound combinations may be instrumental in the development of discriminative responding to classes of combined speech sounds (i.e., listener literacy) and enhancement of echoic responding. In the studies we present herein, we tested the effects of the auditory MTS procedure on the improvement or emergence of echoic clarity and listener literacy. In Experiment 1, we tested the effect of a multistage auditory MTS procedure on the clarity of echoics and listener literacy. In Experiment 2, we replicated the experimental procedure of Experiment 1 and additionally tested the effects of the same procedure on conditioned reinforcement for listening to voices.

Experiment 1

Method

Participants. Four elementary students were selected from district based self-contained special education 3rd-grade classes that implemented the Comprehensive Application of Behavior Analysis to Schooling, a research and development school model (Selinske, Greer, & Lodhi, 1991; www.cabasschools.org). Participants were chosen for this study because of their inexact echoic repertoires (i.e., lack of enunciation clarity or point-to-point correspondence between hearing and saying) and low numbers of correct responses to instruction requiring that they respond to spoken instructions. They were diagnosed with Autism Spectrum Disorders (ASD). All participants functioned below grade levels in reading and writing. See Table 1 for a full description of the participants' test scores.

Table 1
Description of Participants A–D For Experiment 1 and E–G For Experiment 2

Participant	Standard scores
A. 7-year-old male diagnosed with ASD (Experiment 1)	Stanford-Binet Intelligence Scale: Fifth Edition - IQ 58 Goldman Fristoe Test of Articulation Sounds In Words - AE:5.2 Test for Auditory Comprehension of Language-3 Vocabulary - AE:5.9; Grammatical Morphemes - AE:5.3
B. 8-year-old female diagnosed with ASD (Experiment 1)	Goldman Fristoe 2 Speech Articulation SS:88; AE: 4.11 Test for Auditory Comprehension of Language-3 Grammatical Morphemes - AE:5.3; Vocabulary AE: 4.3
C. 7-year-old male diagnosed with ASD (Experiment 1)	Stanford-Binet Intelligence Scale: Fifth Edition - Full Scale IQ 66 Goldman Fristoe Test of Articulation Sounds In Words - AE:5.6 Test for Auditory Comprehension of Language-3 Vocabulary - AE:5.9; Grammatical Morphemes - AE:5.0
D. 7-year-old male diagnosed with ASD (Experiment 1)	Stanford-Binet Intelligence Scale: Fifth Edition - IQ 43 Goldman Fristoe 2 Speech Articulation - AE: 5.0 Test for Auditory Comprehension of Language-3 Vocabulary - AE: 4.3; Grammatical Morphemes - AE:3.6
E. 8-year-old Female with ASD (Experiment 2)	Expressive One-Word Picture Vocabulary Test - SS:58; <1% Receptive One-Word Picture Vocabulary Test - Total SS;63; 1% Test for Auditory Comprehension of Language-3 - AE:5.9
F. 7-year-old Male with ADHD (Experiment 2)	Wechsler Intelligence Scale for Children -IV - IQ 88 Beery-Buktenica Developmental Test of Visual-Motor Integration - Total SS:77 Naglieri Nonverbal Ability Test - SS:91
G. 8-year-old Male with ASD (Experiment 2)	Beery-Buktenica Developmental Test of Visual-Motor Integration - SS:89 Core Language Score SS 94, 34%ile; Expressive Vocabulary SS 11, 63%ile; Grammatical Structures SS: 9, 37%ile; Recalling Sentences SS 6, 9%ile; Sentence Structure SS 8, 25%ile; Expressive Word Classes SS 6, 9%ile; Receptive Word Classes SS 5, 5%ile Test of Pragmatic Language Total Test - SS: 80, 9%ile

Note. The Stanford-Binet Intelligence Scale measures are from Roid (2003); Goldman Fristoe Test measures are from Goldman and Fristoe (2000); Wechsler Intelligence Scale for Children measures are from Wechsler (2003). Expressive One-Word Picture Vocabulary Test measures are from Brownell (2000a); Receptive One-Word Picture Vocabulary Test measures are from Brownell (2000b); Beery-Buktenica Developmental Test of Visual-Motor Integration measures are from Beery, Norman, Buktenica, and Beery (2010).

Setting and materials. All pre- and postintervention sessions took place at child-size desks in the classroom, while other members of the class received individual or small group instruction. During the intervention sessions, we used a computer with an auditory match-to-sample (MTS) Flash® software program developed by the first author. The software program was designed to display three solid red circles (15 cm diameter) on a computer screen (50 cm diagonal), one at the top center of the screen and two below it, side by side on the bottom half of the screen. A solid black horizontal line divided the top and bottom solid red circles. When touched, in instances when a touch screen was used, or clicked when a mouse was used, the top circle produced the spoken sample word or phrase, and the two circles located below either produced an identical target or nontarget sound. The order of the location of the identical and nonidentical matches was rotated to avoid position control. Each participant was taught to match the top button sound or sample with one of the two comparison buttons, one of which produced a match and the other a nonmatch. The participant sat directly in front of the computer screen. The experimenter sat to the right of the participant. Intervention sessions took place at one of two computers in the classroom. One of the two used a touch screen. Depending on the participant's motor skills, the participant either responded by using a mouse or a touch screen. Participants A and C used the mouse and Participants B and D used a touch screen. Two or three intervention sessions were conducted per day. Each intervention session ranged from 10 min to 15 min with a mean of 13 min. The number of school days involved range from 25 to 30 with a mean of 22.5. A sample picture of the auditory MTS Flash® program is shown in Figure 1.

The experimenter presented vocal directions along with visual distracters during the advanced listener literacy probes shown in Table 2. We defined this capability as "advanced" listener literacy because the participant was presented with conflicting visual distracters, ensuring that the participant was responding only to the spoken instructions (e.g., responding to vocal instructions to point to your nose while the experimenter pointed to his head). The Chavez-Brown (2005) procedure was extended to include more complex response assessments of echoic responding. The advanced procedure required the participants to echo 100 two- and three-syllable English words that were common and 40 Korean words (see Table 3). The Korean words were chosen because they were unfamiliar speech sound combinations that would serve as stringent tests of hear-and-say responding. Although the Korean words were unfamiliar to the participants, the Korean Language is entirely transparent and individuals with awareness of phonemic speech sounds should be capable of echoing these novel combinations. Hence, the inclusion of Korean words provided a rigorous test of hear and say responding.

Dependent variables. The two dependent variables in Experiment 1 were (a) correct responses to advanced listener literacy probe trials and (b) echoic clarity. Clarity of echoic responses was recorded as full echoic responses, partial echoic responses, or incorrect vocalizations. In the advanced listener literacy probes, the experimenter presented a vocal direction while simultaneously presenting a visual distracter (e.g., saying "touch your nose," while the experimenter touched his head). The purpose of these probe trials was to test participants' ability to follow vocal antecedents under visually distracting conditions. Correct response during these sessions consisted of accurate listener responses to the vocal direction only within 3 s after the experimenter-presented antecedent.

Full echoics were defined as responses that had direct phonemic point-to-point correspondence with the experimenter-presented vocal antecedent ("because" in response to "because"). A partial echoic response was recorded when the participant emitted a response that had partial correspondence with the target echoic (i.e., "bau-ce" in response to "because"). Incorrect vocalizations consisted of responses without any points of correspondence to the original antecedent ("sopo" in response to "because").

Independent variable: The auditory match-to-sample procedure. The independent variable was implemented at the point when the participants mastered all of the stages of the auditory match-to-sample (MTS) procedure. The auditory MTS procedure consisted of two sets involving multiple phases: (Set 1) six phases (Phase 1through 6) of matching combined speech sounds of words or morphemes, (Set 2) three phases (Phase 7 through 9) of matching short spoken phrases where the nontarget words differed by one word. As phases progressed, the speech-sound combinations were more complex. During the first six phases, the participants were required to match speech sounds of single words when exact match and similar but nonmatching words were the choices. During the next four phases, they were required to match phrases with progressively more fine-grained distinctions. See Table 4 for the list of words and matching responses required for each phase.

The participants watched the computer screen as the experimenter touched or clicked the target solid red circle at the top of the screen or the sample combined speech sounds of a word or phrase, and then touched the bottom left and bottom right circle consecutively. The target sample circle was touched or clicked

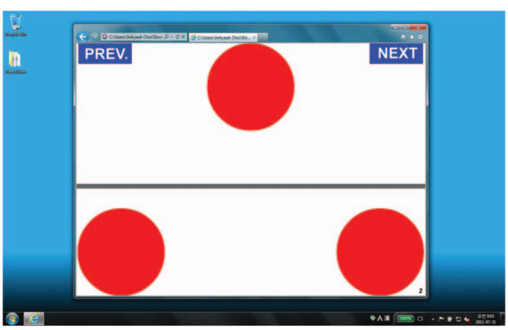

Figure 1. Picture of the Auditory MTS Flash® Computer Program. The top button produced the sample word or phrase, and the two buttons located below either produced an identical target or nontarget sound. For those interested in replicating the auditory MTS procedure or using it for research, an iPad application is now available. Please contact the first author for more information.

Table 2
Vocal Directions and Visual Distracters Used During the Listener Literacy Probe Sessions

Vocal directions vs. Visual distracters	Vocal directions vs. Visual distracters
Touch nose vs. Touch mouth	Touch arm vs. Touch feet
Touch ear vs. Touch eyes	Tap table vs. Touch knees
Clap hands vs. Stand up	Touch head vs. Tap table
Blow kiss vs. Roll arms	Touch belly vs. Touch arm
Roll arms vs. Touch nose	Touch feet vs. Tap lap
Touch eyes vs. Touch ear	Touch knee vs. Stomp feet
Touch mouth vs. Clap hands	Wave hands vs. Touch elbow
Stand up vs. Blow kiss	Raise arms vs. Touch shoulder
Stomp feet vs. Touch head	Touch elbow vs. Raise arms
Tap lap vs. Touch belly	Touch shoulder vs. Wave hands

again and the vocal instruction "Match" was given as an instruction for the participant's matching response. A correct response consisted of the participant touching or clicking the circle that produced the same target words or phrase within 5 s of the vocal verbal antecedent. An incorrect response consisted of the participant responding after 5 s or touching the solid red circle that emitted the nontarget sounds. If an incorrect response was emitted, a correction (experimenter's model response) was given. Corrected responses were not reinforced. Correct responses were immediately followed by reinforcement in the form of praise and other reinforcers, such as edibles and tokens that could later be exchanged for other reinforcers. The particular reinforcers used for each child were based on an extensive history of using

Table 3
Words Used During the Echoic Probe Sessions for Experiments 1 and 2

Sets	Words
100 English words used in Experiment 1	about, again, almost, also, always, another, anyone, are, ask, beautiful, because, before, buy, can't, city, community, confusion, could, countries, didn't, discover, doesn't, don't, enough, especially, everybody, everything, except, exciting, favorite, friendly, general, getting, hopeless, impossible, independent, into, its, journal, laugh, let's, lovable, made, member, mine, myself, neighbor, new, news, no, off, one, our, owl, people, prettier, prettiest, pretty, probably, question, really, recycle, right, said, school, sister, something, sometimes, teacher, terrible, that's, their, then, through, trouble, unhappiness, until, usually, vacation, very, want, was, wave, we're, wear, weather, went, were, who, whole, winner, with, won, won't, wouldn't, write, writing, yell, young, you're
40 Korean words used in Experiments 1 and 2	Kuksu (noodles), Adeul (son), A-nae (wife), Annyong (hello), A-re-ro (down), Bop (rice), Chal-buen (short), Chihach'ol (subway), Chin-gu (friend), Chog-ee (there), Ddok-ba-ro (straight), Ga-ka-un (near), Geomjeong (black), Gin (long), Hayang (white),, Huchu (black pepper), Hwajangshil (toilet), Jido (map), Kicha (train), Konghang (airport), Nampyeon (husband), Norang (yellow), Omma (mom), O-reun-chok (right), Parang (blue), Ppalgang (red), Pudu (ferry pier), Pyongwon (hospital), Saengson (Fish), Sogogi (beef), Sogum (salt), Sugon (Towel), Ttal (daughter),, Unhaeng (Bank), Upyo (stamp), Uyu (milk), Wenchok (left), Wiro (up), Yyogee (here), Kong (beans)
50 four-syllable and uncommon words used in Experiment 2	aspiration, auditory, biology, behavioral, capacity, conditioning, diabetes, depreciate, echolalia, economics, formalities, felicity, gastropathy, generation, homogeneous, hypotheses, inflectional, invertebrate, journalist, justifying, kinesthetic, kyanite, locomotion, laboratory, molecular, methodology, nationalism, neuroscience, organization, oscillator, phenomenon, phonology, quantitative, qualitative, radiation, retroactive, salivation, sensitivity, tonality, transformation, university, unconditional, vestibular, velocity, westernization, welfare, xerinae, yerbamate, zincography, zeppelin

Table 4
Single Words and Phrases Used During the Auditory MTS Procedure in Experiment 1 (Phase 1–9) and Experiment 2 (Phase 1–13)

Sets	Phases	Stimuli
Single words (Exp. 1 & 2)	Phase 1	Plate vs. eight, night vs. fight, rain vs. pain, pay vs. say, fun vs. sun
	Phase 2	tumor vs. harbor, explain vs. plain, humanity vs. zesty, threw vs. breakthrough, pleat vs. complete
	Phase 3	adoring vs. exploring, walking vs. talking, humming vs. coming, refrigerator vs. alligator, friction vs. addiction
	Phase 4	frightening vs. brightening, combination vs. explanation, antelope vs. cantaloupe, greenery vs. scenery, mightily vs. vitally
	Phase 5	table vs. tailor, car vs. carpet, soccer vs. sauce, sole vs. soil, game vs. gain
	Phase 6	Carrot vs. caring, tulip vs. twosome, extra exhale, triple vs. trim, five vs. fire
Phrases (Exp. 1 & 2)	Phase 7	blue hat vs. red hat, two cats vs. three cats, first floor vs. second floor, music class vs. art class, cold water vs. hot water, blue hat vs. blue cat, two cats vs. two bears, first floor vs. first time, Music class vs. music teacher
	Phase 8	My best friend vs. your best friend, A fast dog vs. the fast dog, A big triangle vs. blue big triangle, My best friend vs. my little friend, The fast dog vs. the slow dog /A big triangle vs. a small triangle, My best friend vs. my best book /the fast bird vs. the fast dog, a big triangle vs. a big circle
	Phase 9	The book is on the table. vs. The pen is on the table., Can you draw an ant? vs. Can I draw an ant?, Bear sits on the ground. vs. Turkey sits on the ground., The book is on the table. vs. The book is over the table., Can you draw an ant? vs. Can you get an ant?, Bear sits on the ground. vs. Bear walks on the ground., The book is on the table. vs. The book is on the cabinet. /Can you draw an ant? vs. Can you draw an elephant?, Bear sits on the ground. vs. Bear sits on the tree.
4-syllable and uncommon words (Exp. 2)	Phase 10	biological, aboriginal, balletomania, calamine, defibrate, emollient, facultative, fasciculation, galactose, headquarters
	Phase 11	immunization, impulsivity, juvenile, kilogram, labyrinth, malleability, management, occupational, occurrence, tendentious
	Phase 12	lamella, laparoscope, maxillofacial, olfaction, palatine, palpability, population, randomize, receptor, regenerate
	Phase 13	measurement, obstruction, octosyllabic, pandiculation, paramountcy, quicksilver, questionnaire, radiation, thermoplastic, transaction

reinforcement operations to teach the participants. Criterion for each session was at 90% accuracy of 20 intervention trials across two consecutive sessions for each of the 9 intervention phases. The intervention continued until the participants achieved the mastery criteria for all phases that required 25 to 35 school days with a mean of 30 days. One or 2 intervention sessions were conducted.

Experimental design and procedure. We used a delayed multiple probe design across participants in Experiment 1. Sessions were delayed across participants to control for instructional history (Cooper, Heron, & Heward, 2007; Johnston & Pennypacker, 2008; Murphy & Bryan, 1980). Participants received probe trials before intervention, as well as after the mastery criterion for each set of phases: (a) matching combined speech sounds of words or morphemes, and (b) matching short spoken phrases where the nontarget words differed by one word. See Figure 2 for the experimental sequence. Before the implementation of the auditory MTS procedure, the experimenter conducted Participant A's probes for clarity of echoic responding and advanced listener literacy. Participant B's probes were conducted as Participant A completed the first intervention phase. The other participants' preintervention probes were time lagged in the same manner. The experimental sequence of the auditory MTS procedure phases was counterbalanced. Participants A and C began the intervention by matching single words. Participants B and D began the intervention by matching phrases. The experimenter did not deliver reinforcement or corrective feedback during the probe sessions. After the probe sessions were completed, the participants began the next set of the intervention, which consisted of the intervention

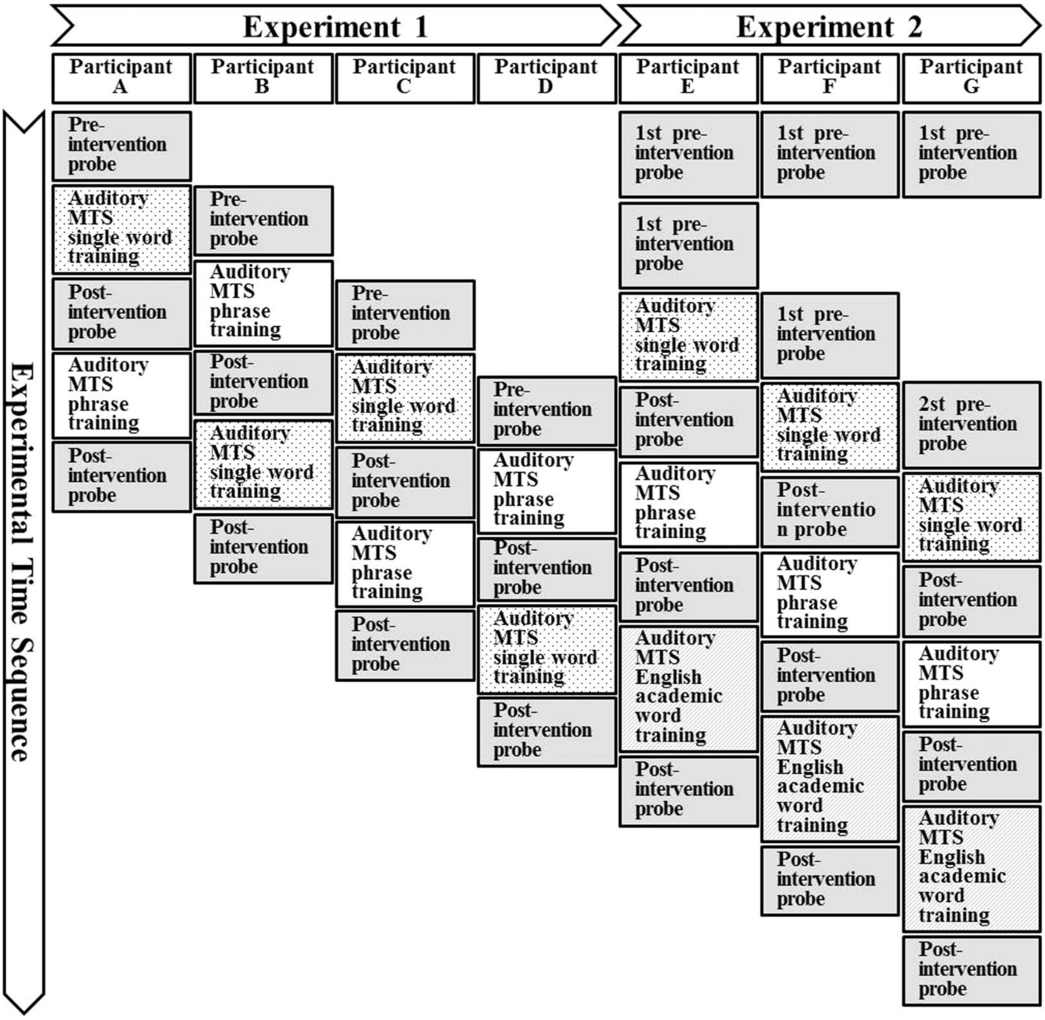

Figure 2. Sequence of conditions in Experiments 1 and 2.

phases they had not completed before (single words or phrases).

Interobserver agreement for participants responses and procedural fidelity. Interobserver agreement (IOA) was conducted using the Teacher Performance Rate and Accuracy (TPRA) procedure directly or from video recording to test fidelity of treatment and accuracy of measurement of the participants' responses (Ingham & Greer, 1992; Ross, Singer-Dudek, & Greer, 2005). Independent observers completed a calibration protocol for IOA by observing students who were not participants in the experiment, and after demonstrating mastery of the protocol were able to provide IOA for responses. The TPRA procedure implemented simultaneously allowed for the observation of student responses as well as the experimenters' fidelity in presenting probes for the dependent variables and implementation of the independent variable.

The TPRA observation procedure requires observers to observe and record the behaviors of both the experimenter and the participant. First, the observer, or observers, record whether or not the experimenter presents unambiguous instruction or antecedents, that the participant is attending to the experimenter, and no unwitting cues are presented. Next, the child's accurate or inaccurate response to the presentation is recorded followed by recording the experimenter's consequation responses to the participant's response. Accurate or inaccurate reinforcement or corrections by the experimenter are recorded. If any of the experimenter's behaviors in the presentation shows an error, the instructional trial does not meet the criterion for an accurate instructional trial; hence, the presentation was not accurate and that would constitute lack of procedural integrity for that interventional trial. In the case of probe presentations that are unconsequated, the experimenter must not reinforce or correct, or provide unwitting cues. Accurate presentations of probe trials also show step by step procedural fidelity of the experimenter. Thus, the TPRA provides both procedural measures of the experimenter responses and measures of the participants' responses. IOA was calculated by dividing the number of point-to-point agreements and disagreements by the total number of agreements plus disagreements and multiplied by 100% for the participants (Johnston & Pennypacker, 2008). IOA was calculated for 55% of intervention sessions for Participants A and B. IOA was 100%. IOA was calculated for 50% of intervention sessions for Participant C at 100% agreement. IOA was calculated for 25% of intervention sessions for Participant D and was also 100%. Procedural fidelity for these same intervention and probe sessions was 100%.

Results

Figure 3 shows the number of correct responses to the listener literacy probe trials in pre- and postintervention probes. Participant A's correct responses increased from 11 to 16 after the mastery of 6 phases of matching two- or three-syllable single words and increased again to 18 after the mastery of matching spoken phrases. Participant B's correct responses also increased from 9 to 15 after the mastery of matching single words and then increased to 17 after the mastery of matching spoken phrases. Participant C emitted 4 correct responses in the preintervention probe and 17 following the MTS for single words. After the completion of the auditory MTS procedure, he emitted 19 correct responses. Participant D increased from 8 to 15 after the mastery of matching single words and then increased to 17 after the mastery of matching phrases. Participant D showed the smallest gain and also had the fewest correct responses to the preintervention probes.

Figure 4 shows the participants' speaker responses to 40 Korean words (left half of Figure 4) and 100 English words (right half of Figure 4) for full and partial echoic responses. For Korean words, Participant A's full echoic responses increased from 13 in the preintervention probe to 34 following the completion of the auditory MTS procedure. Participant B's full echoic responses were 14 in the preintervention probe and increased to 24 following the intervention. Participant C's full echoic responses increased from 16 in the preintervention probe to 29, and Participant D's full echoic responses increased from 16 to 33. For English words, Participant A's full echoic responses increased from 80 to 97 following the completion of the auditory MTS procedure. Participant B's full echoic responses increased from 51 in the preintervention probe to 72 in the postintervention probe. Participant C's full echoic responses increased from 73 to 98. Participant D's full echoic responses increased from 66 to 89.

Figure 5 shows the data collected in the intervention sessions during the auditory MTS procedure for all participants. Participant A required 25 sessions to complete the auditory MTS procedure. Participant B completed the intervention after 39 sessions. Participants C and D mastered the training after 36 and 43 sessions, respectively.

Discussion

The first experiment demonstrated that the auditory MTS procedure resulted in improvements in listener literacy and full echoic responses. Speckman-Collins et al. (2007) suggested a relation between the auditory MTS procedure and conditioned reinforcement. They argued that the auditory MTS procedure might incidentally provide the reinforcement conditioning history leading to conditioned reinforcement for listening to vocal speech sounds. Verbal behavior developmental theory proposes that conditioned reinforcement for voices may be a necessary prerequisite for several listener and speaker *cusps* (Greer & Keohane, 2005; Greer & Longano, 2010; Greer & Speckman, 2009; Greer & Ross, 2008) and the findings of Greer et al. (2011) were consistent with this. In Experiment 2, therefore, we added another dependent variable that measured conditioned re-

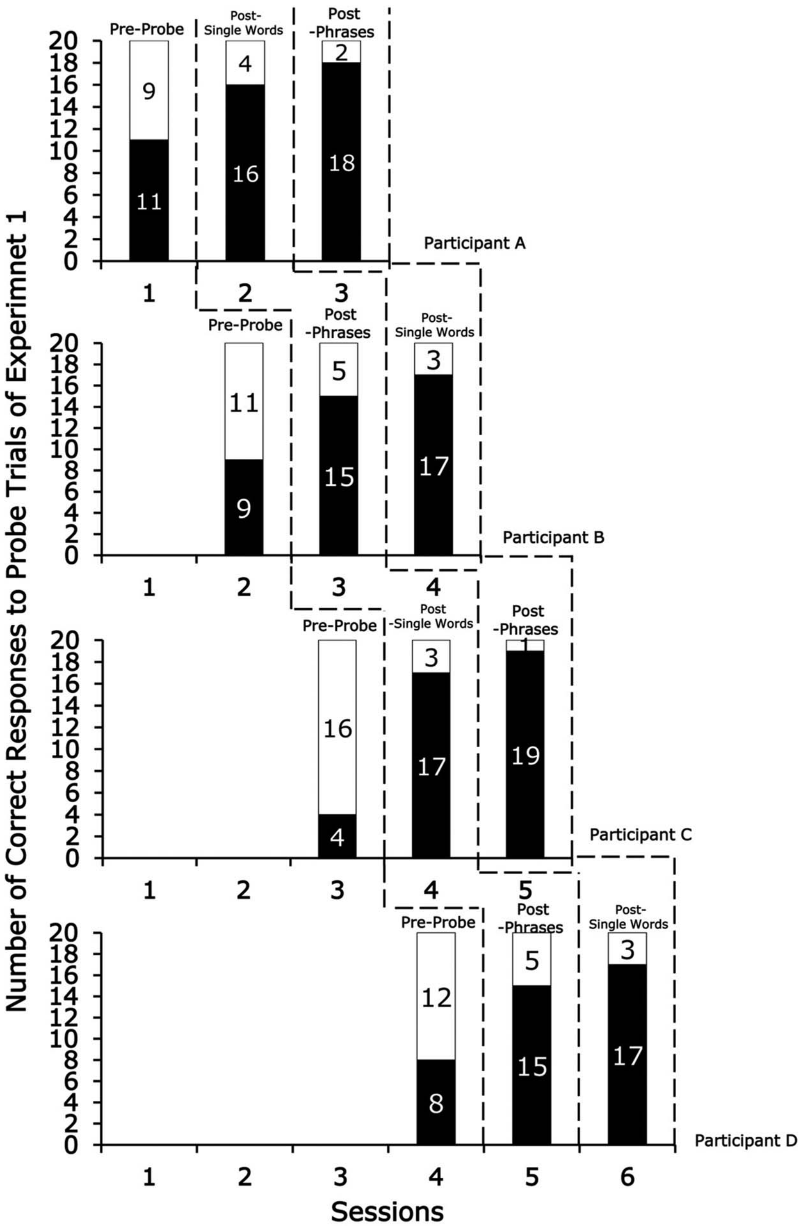

Figure 3. Number of correct responses to probe trials for 20 vocal directions that were simultaneously presented with a visual distracter prompt in Experiment 1 where the dark portion of the bar graph shows correct and the white incorrect.

inforcement for listening to recordings of adult's reading. We considered whether conditioned reinforcement for listening to voices might have occurred as a function of the intervention. This potential occurrence suggests areas for future research.

One of the limitations in Experiment 1 was that there was only one preintervention probe. Although the preintervention probes were done immediately before the intervention, and in a delayed fashion to control for instructional history, the addition of additional preintervention

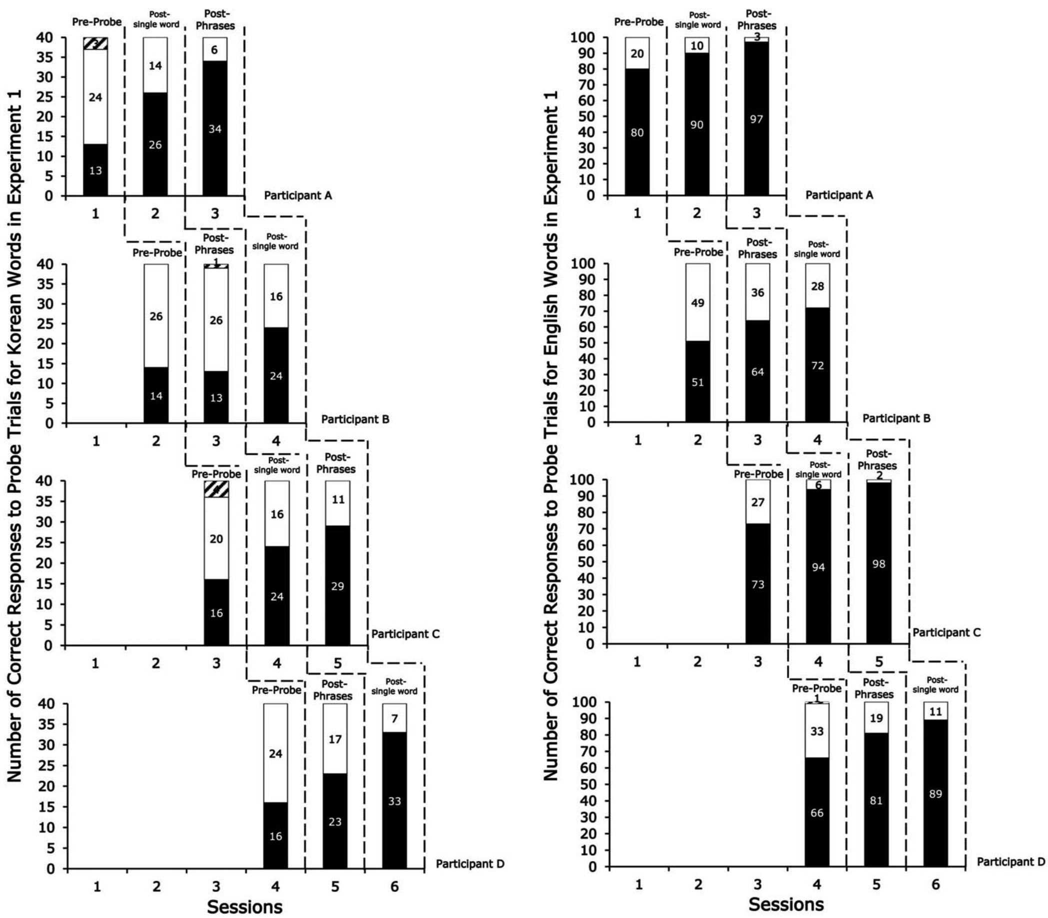

Figure 4. Number of full, partial, and incorrect echoic responses to 40 Korean words (left column) and 100 English words (right column) for Experiment 1.

probes would have provided better evidence of the stability of the repertoires. However, although preintervention repeated measures can show the reliability of a repertoire under constant conditions, it is also possible that, when learning is being tested the responses improve simply as a result of repeating probes even without consequent reinforcement or testing as a result of exclusion for example. Thus, repeated preinterventions can also be a limitation. Repeated measures are often not completed when testing for emergent behavior or new learning for the latter reason. Nevertheless, when repeated measures are done under conditions that minimize the possibility of learning by exclusion, they are desirable (i.e., counterbalancing stimuli and avoiding other exclusion conditions). Thus, in Experiment 2 we used a multiple probe design that included a delayed feature controlling for instructional history, a feature present in the first experiment, as well as the addition of repeated measures including simultaneous initial probes controlling for maturation.

Experiment 2

The procedures were the same as described in Experiment 1 with the few differences and additions indicated above. These differences included changes in the design, the addition of two measures, the selection of three new participants, and some changes in the materials and stimuli. These are described below.

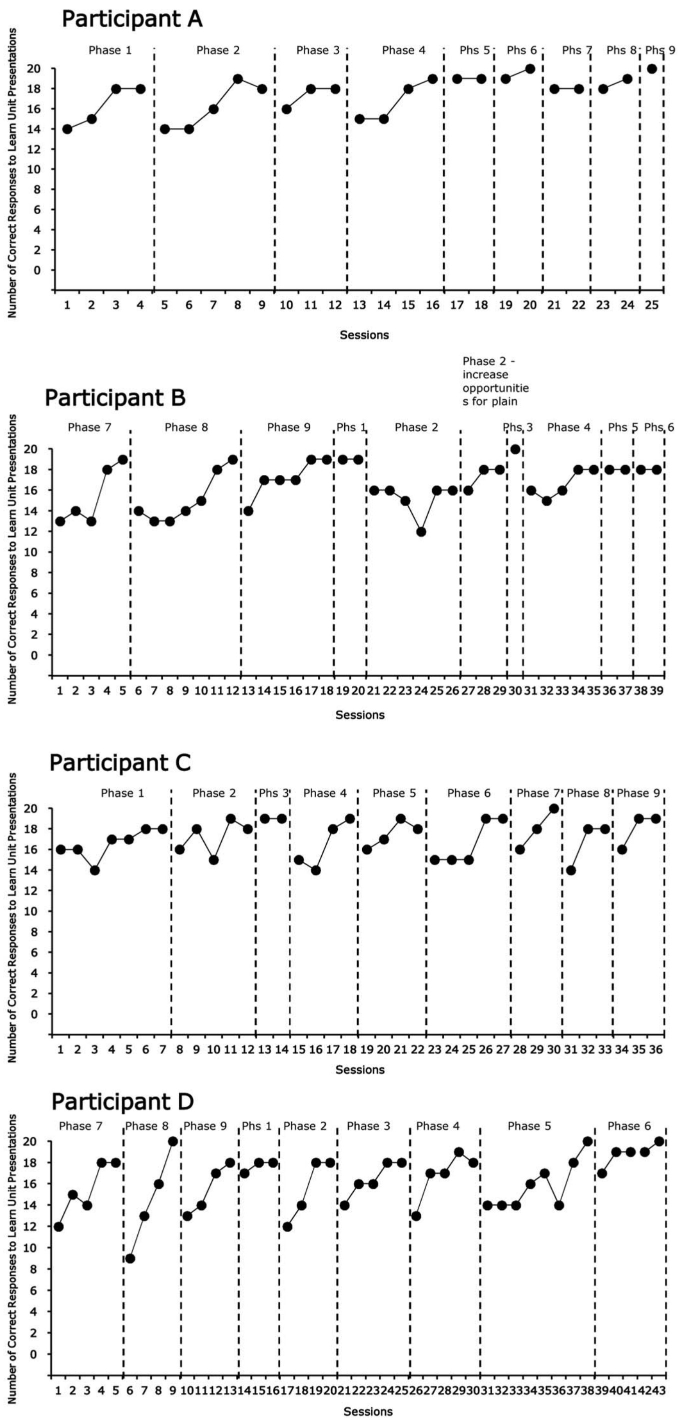

Figure 5. Number of correct responses emitted by the participants during the auditory MTS sessions in Experiment 1.

Method

Participants. Three elementary school students with Autism Spectrum Disorders (ASD) or Attention Deficit Hyperactivity Disorder (ADHD) participated in Experiment 2. See Table 1 for a complete description of all participants. All participants functioned at or below grade levels in reading and writing. But, they all had reading and writing repertoires.

Setting and materials. Experiment 2 was conducted in the same setting as Experiment 1 with the following *differences*. For the measurement of conditioned reinforcement (i.e., conditioned reinforcement for adult voices), the participants used a computer mouse or a touch screen using an iPad® to emit responses during the auditory MTS intervention sessions; whereas, in Experiment 1 computers only were used. All participants were fluent in the use of a computer mouse or touch screen with an iPad®. We used a different list of English words, because all participants in Experiment 1 showed a possible ceiling effect that suggested that the 100 two- and three-syllable words in English used in Experiment 1 were not difficult enough, or that the participants had some instructional history with the words. In Experiment 2, we presented 50 four-syllable words. These were words with which the participants were highly unlikely to have an instructional history (see Table 3).

We used an experimenter designed Flash® program that displayed a screen containing one red two-dimensional circle at the center of the screen to test conditioned reinforcement for adult's reading.

We added four additional phases (Phase 10 through 13) to the auditory MTS procedure thinking that the increase in phases might improve the outcomes for the dependent measures (Speckman-Collins et al., 2007). The participants were taught to match multisyllabic and uncommon words that were highly unlikely to have been in the participant's instructional history (See Table 4).

Dependent variables. We measured three dependent variables in Experiment 2: (a) the degree of conditioned reinforcement for choosing to listen to adult voices, (b) advanced listener literacy, and (c) echoic clarity.

Conditioned reinforcement for adult voices. The duration of free operant choice for listening to prerecorded voices was used as a measure of conditioned reinforcement for adult voices before, and after the completion of, each set of the auditory MTS procedure. The use of duration of free operant choice is well documented in laboratory research as a valid measure of reinforcement value (Greer, Dorow, & Hanser, 1973; Greer, Dorow, & Randall, 1974; Greer, Dorow, Wachhaus & White, 1973; Lovitt, 1965, 1968; Morgan & Lindsley, 1966).We measured how long the participant listened to the prerecorded story by using continuous whole-interval recording for five-min sessions. We used an experimenter designed Flash® program. When the participant maintained touch contact with and followed a moving arrow in the red circle, prerecorded stories were played. If the participant stopped touching and following the pointing arrow in the red button area with his or her finger, the computer program immediately stopped the prerecorded stories. If the participant touched the arrow again the voice recording resumed. Following the arrow was a measure of the participants' listening because hearing the voices (touch conjugate reinforcement assessment) was contingent on moving the finger with the arrow. During these probe sessions, the experimenter used a timer that made a beeping sound every 5 s so that he or she recorded participants' responses for each interval. That is, we measured how long the participant chose to press a button that produced a voice telling a story and listened to prerecorded stories without stereotypy. Probe sessions consisted of 60 continuous 5 s-intervals or five min. During the probe sessions, the participants had the option to access to other choices rather than listening to adult's voice. That is, it was a free operant choice for either listening to adult's voice or other activities.

Independent variable: Mastery of auditory MTS procedure. The independent variable in Experiment 2 was the same as Experiment 1 with the following changes. In Experiment 2, the auditory MTS procedure involved four additional phases (Phase 10 through 13) that included matching of multisyllabic and uncommon words with which the participants were highly unlikely to have a history. See Table 4 for the word list of the additional phases words phase.

We used a multiple probe design across participants design without a counterbalanced experimental sequence for the phases that required matching words versus those requiring the matching of phrase because no differences were observed between the different sequences in Experiment 1. Initially, participants were all probed simultaneously for the dependent variables. Next Participant E received the second set of probes showing reliability of responding after which he began the intervention. After Participant E mastered the first phase, Participant F was probed again and entered the intervention and the same sequence occurred for Participant F. The second half of Figure 2 shows the design sequence. This design controlled for both history and maturation whereas, the design used in Experiment 1 controlled only for instructional history.

Interobserver agreement for participants responses and procedural fidelity. Interobserver agreement (IOA) and the experimenter's fidelity to procedures were conducted in the same way as Experiment 1. For the Korean and English word echoic probes, Participant E and G's IOA was conducted for 80% of probes with 94% and 98% agreement, respectively. Participant F's IOA was conducted for 100% of probes with 97% agreement. For the advanced listener literacy probes for Participants E and G, IOA was conducted for 80% of the probes with 100% agreement. For Participant F, IOA was conducted for 100% of the probes with 100% agreement. Procedural fidelity for these same probe sessions was 100%. For the voice conditioning probes for Participant E, IOA was conducted for 80% of probes with 100% agreement. For Participants F and G, IOA was conducted for 100% of probes with 100% agreement. IOA was also conducted for the auditory MTS sessions. For Participants E, F, and G, IOA was conducted for 61%, 40%, and 42% of intervention sessions, respectively. Across all participants, IOA was calculated at 100% agreement. Procedural fidelity for these same intervention sessions was 100%.

Results

Figure 6 shows the number of 5-s intervals in which the participant emitted listening to the prerecorded adult voices out of sixty 5-s opportunities. In Preprobes 1 and 2, Participant E listened to the prerecorded adult voice for 5 and 7 intervals, respectively. After the mastery of the auditory MTS procedure, she listened to the prerecorded adult voices for 50 intervals. Participant F appropriately listened to the prerecorded adult voice for 13 and 5 intervals in Preprobe 1 and 2, respectively. After the mastery of the auditory MTS procedure, he listened to the prerecorded adult voice for 30 intervals. Participant G listened to the prerecorded adult voices for 20 and 15 intervals in Preprobes 1 and 2, respectively, and increased to 60 after he mastered all the phases of the auditory MTS procedure.

Figure 7 shows the number of correct response to the listener literacy probe trials in which a vocal direction was presented with a visual distracter. Participant E emitted 13 correct responses of 20 probe trials in both preintervention probes and increased to 19 after the intervention. Participant F's correct responses increased from 13 and 13 to 20 correct responses afterward. Participant G emitted 3 and 2 correct responses and 17 after the completion of the auditory MTS procedure.

Figure 8 shows the number of full and partial echoics to 40 Korean words (left half) and 50 English words (right half). For Korean words, Participant F's full echoic responses increased from 16 and 17 before the intervention to 33 afterward. Participant F's full echoic responses increased from 15 and 15 before the intervention and 32 afterward. Participant G emitted 17 and 15 before the intervention and increased to 37 afterward. For English words, Participant E's full echoic responses increased from 18 and 18 in the preintervention probes to 42 afterward. Participant F emitted 20 and 22 full echoic responses before the intervention and 44 afterward. Participant G's full echoic responses also increased from 33 and 32 before the intervention to 49 afterward. All incorrect responses were partial echoics and there were no echoics that were not at least partial.

Figure 9 shows the data collected in intervention session for Participants E, F, and G. Participant E required 38 sessions to complete the auditory MTS procedure. Participant F completed the intervention after 28 sessions. Participants G mastered the training after 30 sessions. Each intervention session ranged from 10 min to 15 min with a mean of 13 min. The number of days involved range from 25 to 35 with a mean of 30.

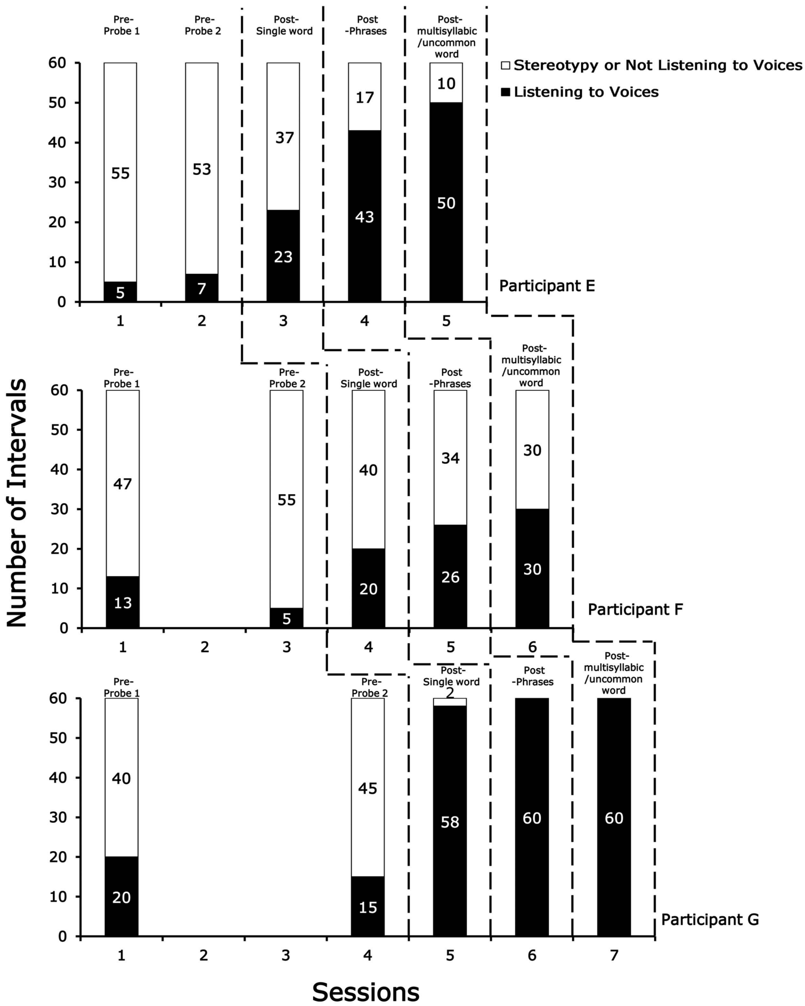

Figure 6. Number of intervals during which Participants E, F, and G chose to listen to recordings of voices in the pre- and postintervention probes as a measure of reinforcement for listening in Experiment 2.

General Discussion

The findings from these studies and prior related research (Chavez-Brown, 2005; Marion et al., 2003; Speckman-Collins et al., 2007) suggest that the training of auditory matching responses may result in several beneficial outcomes for children needing language interventions. Although additional replications are needed with more participants and across laboratories, the effects were promising and compelling. When these findings are combined with the body of research concerning the onset of verbal behavior developmental *cusps* (see summaries of research in Greer & Keohane, 2005; Greer & Longano, 2010; Greer & Speckman, 2009), it appears that identifying the presence or absence of these *cusps*, and being able to instantiate or induce them with children lacking critical *cusps*, are significant advances in how we should treat and educate children with verbal behavior developmental delays or children who lack verbal behavior. In this study, the presence of the target *cusp,* auditory match-to-sample, resulted in subsequent learning or emergent behavior changes such as listener literacy, echoic clarity,

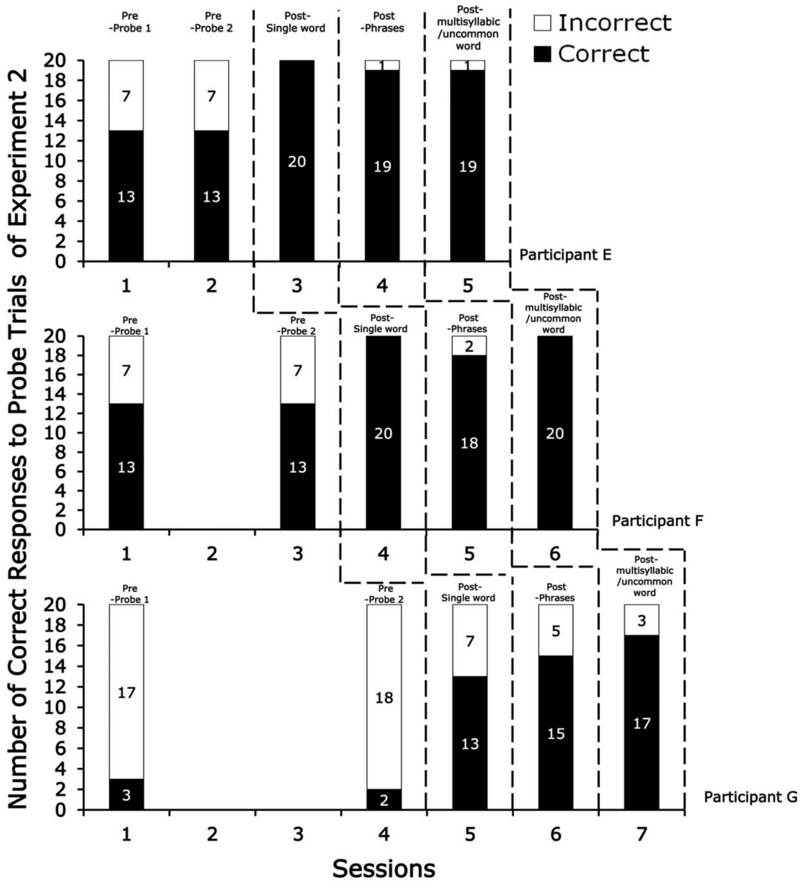

Figure 7. Number of correct responses to probe trials for 20 vocal directions which were simultaneously presented with a visual distracter prompt in Experiment 2.

and so forth. This capability appears crucial for the combinations of speech property that are foundational to phonemic awareness, responding by reproducing words as a speaker, and following directions fluently and discriminately.

In this research, the results for all participants showed that the auditory MTS procedure resulted in increases in full echoic responses for four-syllable English and unfamiliar Korean words that are difficult to pronounce with full point-to-point correspondence. The improvement in the full echoic responses to novel Korean speech-sound combinations was greater than the improvement of full echoic responses to English words, probably because the Korean words had fewer syllables. Also, Korean is a more phonemically transparent language. In both experiments, all of the participants' correct responses to the advanced listener literacy probe trials increased after the training. The advanced listener literacy probes showed that the participants were under greater vocal antecedent stimulus control rather than competing visual distracters (i.e., vocal instructions were paired with distractive visual gestures by the experimenter) after the auditory MTS procedure. Chavez-Brown (2005) and Speckman-Collins et al. (2007) speculated from their results that the auditory MTS procedure increased attending to voices and discrimination of speech sound combinations. The result of this study, in fact, showed the functional relation between the auditory MTS procedure and its effectiveness in responding accurately and discriminatively to the vowel-consonant combinations as listener responses. Based on these promising improvements, future research would investigate the effects of the ad-

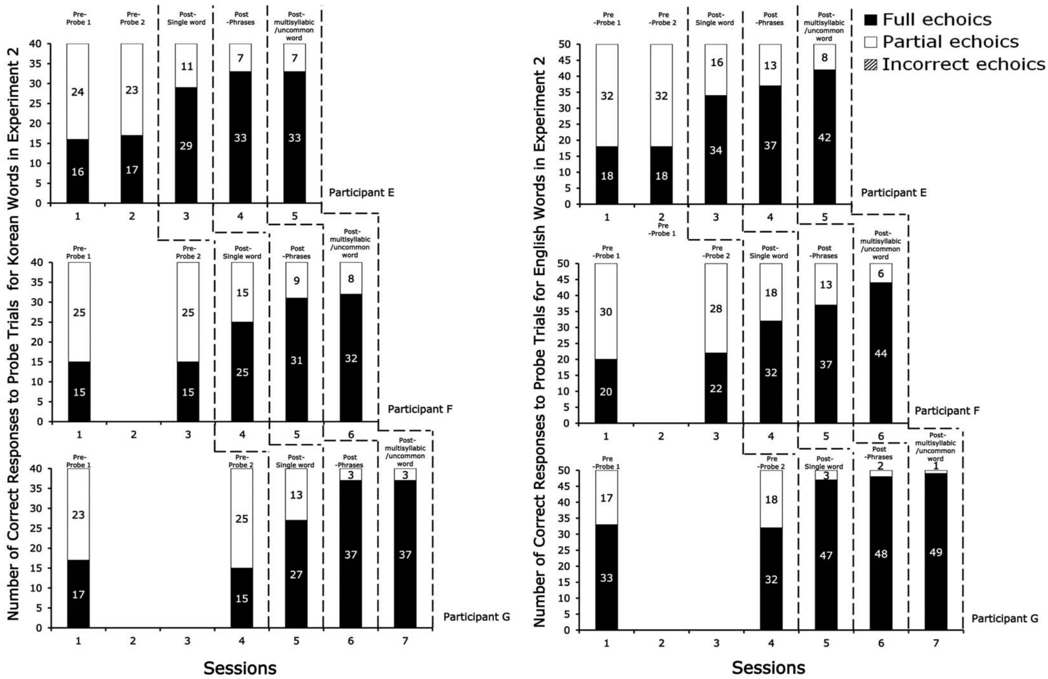

Figure 8. Number of full, partial, and incorrect echoic responses to 40 Korean words (left column) and 50 English words (right column).

vanced auditory MTS procedure on generalized listener literacy in a generalized classroom setting. For example, a teacher would present more complicated vocal instructions (e.g., "Please go find your science text book and open Chapter 5") requiring a student to respond more discriminatively. The current probe vocal direction list for listener literacy was designed to identify the competing stimulus control levels between vocal directions and visual distractor.

Whereas Chavez-Brown (2005) found in her first experiment that a few children without speaker responses did begin to emit partial echoics after the intervention, it is not likely that the auditory MTS procedure used herein would be useful for that purpose. The participants in the present study were significantly more advanced than the participants in the Chavez-Brown (2005) studies. It is likely that the two different MTS versions represent trainings that are effective for developmentally different participants. The current training is likely more useful for participants like the ones in the studies reported herein, whereas less advanced participants, like those in the Chavez-Brown (2005) study, would more likely profit from her procedure.

Findings from Speckman-Collins et al. (2007), and Longano and Greer (2014) suggested that the auditory MTS procedure might have established adult voices as conditioned reinforcers by incidentally providing stimulus-stimulus pairings that functioned to condition speech sounds as conditioned reinforcers for listening in addition to improving listener literacy. Greer et al. (2011) found that conditioning voices as a reinforcer affected the learning of instructional objectives involving vocal instructions, general awareness of other persons in classroom environments, and choosing to listen to stories in free-time settings. If the auditory MTS acted to increase the reinforcement effects of listening to speech episodes, it is possible that the conditioning effect plays a key or foundational role for positive changes in the listener and speaker behaviors. The result of Experiment 2 showed that the auditory MTS procedure could result in the conditioning effects for voices.

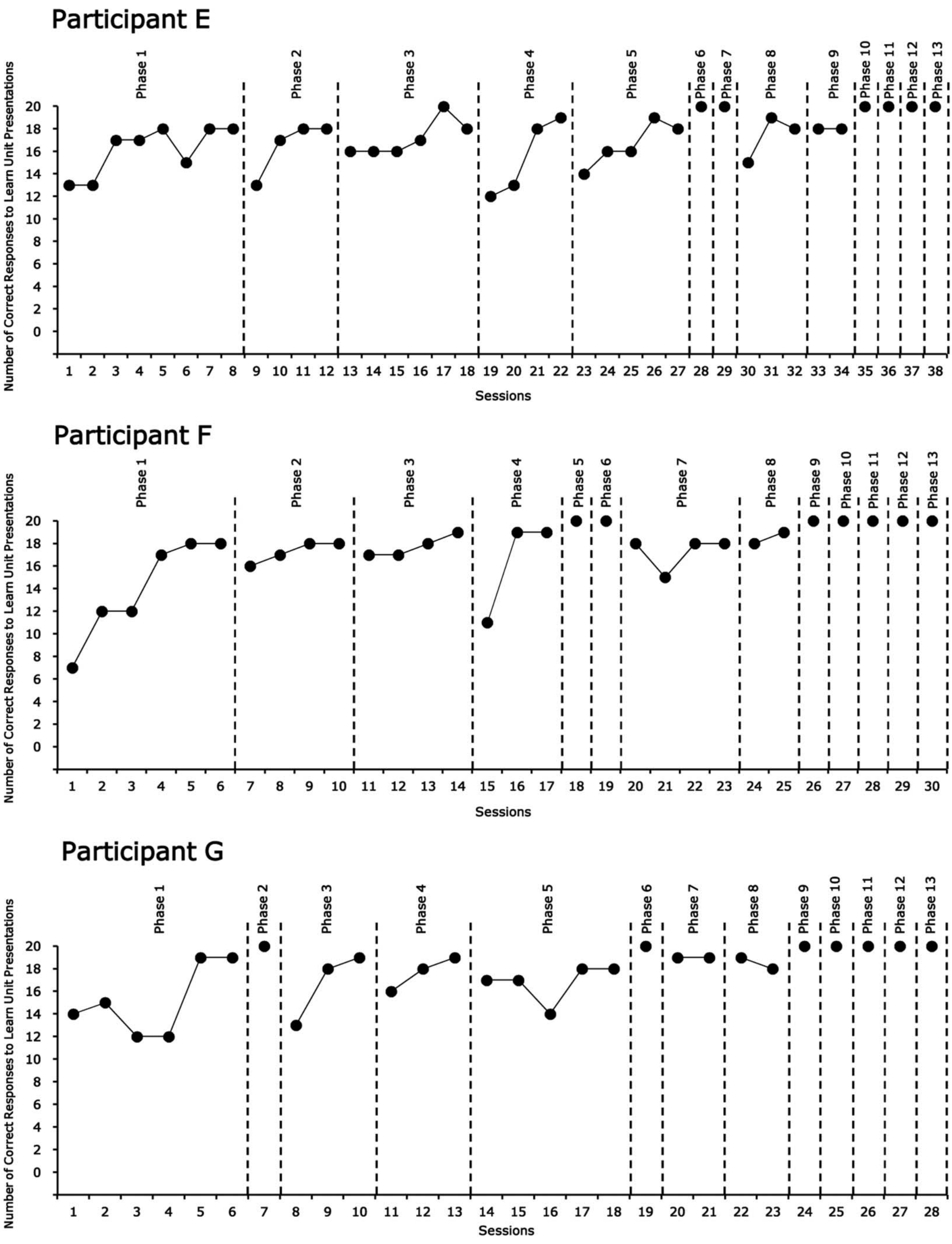

Figure 9. Number of correct responses emitted by the participants during the auditory MTS sessions of Experiment.

There were major effects on Participants E and G and less dramatic increases in intervals of choosing to listen to voices for Participant F. In Experiment 2, the results suggest that it is feasible to argue that the auditory MTS procedure provided a history of reinforcement that functioned to condition adult voices as reinforcers for listening to speech. As the advanced auditory MTS procedure progressed, the participants were differentially reinforced for careful attention to the spoken stimuli. This apparently simultaneously acted to condition speech as a reinforcer for attending. Once observing responses are present discriminations may be significantly enhanced consistent with prior research (Dinsmoor, 1985; Greer et al., 1973, 2011; Greer & Han, in press; Tsai & Greer, 2006). Future research should pursue the relation between conditioned reinforcement for various observing responses and the completion of the auditory MTS procedure. That is, when children cannot master the auditory MTS procedure, it may be prudent to implement the procedure for conditioning voices as reinforcement for the listener observing response (Greer et al., 2011). Additionally, future research should investigate whether the improvement of participant's listener literacy would maintain even after the auditory MTS procedure is completely withdrawn.

The design for each experiment had its limitations. For example, the delayed multiple probe design used in Experiment 1 controlled for instructional history, but did not control for maturation. Thus, the reliability or stability of the dependent variable measure was not tested. On the other hand, this type of design avoided repeated measures of preintervention tests of learning that might have provided an additive effect to the intervention, and hence controlled for the possibility of additive effects of repeated probes to the effects of the intervention. The second experimental design was a multiple probe design. All participants received the initial probes at the same time and all received two preintervention probes showing stability or the reliability of responding compensating for the limitation of the design of the first experiment. But, the limitation of that design indicated that the repeated tests might have functioned as an additive effect for the intervention. In summary, the use of the two designs helped alleviate the limitations of each and utilize the idiosyncratic strengths of each. Thus, the internal validity was improved by the use of both designs. As to the external validity, the generality to other similar participants may be restricted to participants who receive behavior analytic instruction like the instruction that the participants received. Only continued research can determine the various ontogenetic, epigenetic, and phylogenic factors that interact with this procedure or others like it.

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Received June 1, 2014
Revision received December 22, 2014
Accepted December 23, 2014 ■