The Psychological Record, 2009, 59, 187–206

EXCLUSION LEARNING AND EMERGENT SYMBOLIC CATEGORY FORMATION IN INDIVIDUALS WITH SEVERE LANGUAGE IMPAIRMENTS AND INTELLECTUAL DISABILITIES

Krista M. Wilkinson

Emerson College

Shriver Center of the University of Massachusetts Medical School

Celia Rosenquist

U.S. Department of Education

William J. McIlvane

Shriver Center of the University of Massachusetts Medical School

We evaluated formation of simple symbolic categories from initial learning of specific dictated word-picture relations through emergence of untaught or derived relations. Participants were 10 individuals with severe intellectual and language limitations. Three experimental categories were constructed, each containing 1 spoken word (Set A), 1 photograph (Set B), and 1 visual-graphic "lexigram" (Set C). Exclusion-based learning procedures were used to teach first the 3 auditory-visual relations (A-B relations) and then the 3 visual-visual relations (B-C relations) for each category. Seven participants acquired these initial relations. The untaught relations C-B and A-C were then assessed to evaluate the emergence of symbolic categories. Participants demonstrated virtually error-free performances on C-B and A-C derived relations. The study helps to define operationally a highly useful procedural path for systematic instruction in symbolic functioning for persons with intellectual and language disabilities associated with autism and other neurodevelopmental disorders.

A series of papers published over the last 10 years has described a theoretically inspired program of research to study lexical processes by bridging disciplinary boundaries between psycholinguistics, behavior

---

This research was supported by NICHD grants HD 25995, HD 35107, HD 39816, and HD 04147. We thank the research technicians involved in this project, including Jennifer Brooks, Kristen Lombard, Susan Kelledy, and Alison McVay. We are indebted to the students, families, and staff members from the Learning Center, the New England Center for Children, and the Mercy Center. Further information regarding Mayer-Johnson products can be found on www.mayer-johnson.com or by writing to PO Box 1579, Solano Beach, CA 92705.

Correspondence concerning this article should be addressed to Krista.Wilkinson@umassmed.edu or William J. McIlvane, UMMS Shriver Center, 200 Trapelo Rd, Waltham, MA 02452. E-mail: william.mcilvane@umassmed.edu

analysis, and developmental disabilities research (Wilkinson, Dube, & McIlvane, 1996, 1998; Wilkinson & McIlvane, 1997b, 2001). Two phenomena have been the primary foci for this program. The first concerns observations of rapid acquisition and retention of vocabulary, termed *learning by exclusion* by behavior analysts and *fast mapping* by psycholinguists (see, e.g., Wilkinson et al., 1996, 1998). The second area of interest concerns formation and retention of simple symbolic categories, which is often described in terms of *stimulus equivalence* within the behavior analytic tradition (Wilkinson & McIlvane, 1997b, 2001; see Sidman, 1994, for a description of the seminal work).

Studies of Learning by Exclusion and Stimulus Equivalence

Learning by Exclusion/Fast Mapping

The terms *learning by exclusion* and *fast mapping* refer to rapid acquisition of novel word-referent relations via a now well-defined set of learning opportunities. One typical method is to rely on learners' detection of the contrast of novel (or undefined) and known (or defined) stimulus relations (cf. McIlvane, Kledaras, Munson, King, de Rose, & Stoddard, 1987). The child is presented with an array of items, all but one of which is familiar to him/her (e.g., a spoon, a ball, and an item such as a garlic press). Two types of spoken words are presented on different trials. Sometimes a novel word is spoken (e.g., "Show me the 'dax'"), and at other times a known word is spoken (e.g., "Show me the spoon"). The phenomenon of primary interest is shown by emergent selections of unfamiliar items in response to unfamiliar names (i.e., selecting the garlic press in response to "dax" in our example) *and* reliable selections of familiar items in response to familiar names (i.e., selecting the spoon in response to "spoon"). Notably, most children with developmental ages of 18 months or greater choose the unfamiliar item in response to the unfamiliar spoken word (e.g., Carey & Bartlett, 1978; Dollaghan, 1985; Kagan, 1981; Markman, 1989). Similar outcomes have been reported with children with severe-to-profound intellectual disabilities and no appreciable language skills (e.g., McIlvane & Stoddard, 1981).

This phenomenon has attracted the attention of a number of different disciplines in the behavioral sciences—a fact that may be hard to detect given the different terminology used. The term *exclusion* was coined in the behavior analytic literature (Dixon, 1977). In the developmental literature, *disambiguation* has been used (see Wilkinson, 2007), with the implication that an initial or "fast" map between word and referent may have occurred. In their treatment of crossdisciplinary study of this phenomenon, Wilkinson, Dube, and McIlvane (1996) coined the process-neutral term *emergent mapping* to describe such emergent selections. By contrast, *learning by exclusion* refers to a reasonably well-defined set of experimental operations to promote acquisition of new mapping relations. For clarity in exposition, we will use this terminology in this article.

Learning by exclusion has received extensive recent study in our laboratories (e.g., Wilkinson, 2005, 2007; Wilkinson & Albert, 2001; Wilkinson & Green, 1998; Wilkinson & Mazzitelli, 2003; Wilkinson & McIlvane, 1997a; Wilkinson, Ross, & Diamond, 2003). Of greatest relevance for the study reported here is the *successive introduction* procedure (Wilkinson, 2005; Wilkinson & Green, 1998). This procedure, used in the current study, has produced rapid, reliably positive learning outcomes for teaching novel spoken word-referent relations in about 75% of participants with severe disabilities and limited language—a favorable success rate when compared to simple differential reinforcement and other extant methods for teaching auditory-visual relational performances to nonverbal individuals (cf. Carr & Felce, 2008; Serna, Jeffery, & Stoddard, 1996; Serna, Stoddard, & McIlvane, 1992).

Stimulus Equivalence

Complete analysis of lexical development demands study beyond mere acquisition of the simple one-to-one mapping relations established via the learning-by-exclusion procedure. A critical question concerns whether learning outcomes in persons with significant intellectual disabilities achieve true symbolic categorical status. A goal of the current research was to examine the status of such relations within a framework of derived or emergent relations that are consistent with equivalence relations.

The equivalence paradigm typically uses a matching-to-sample procedure in which participants choose among arrays of comparison stimuli in response to sample stimuli. The procedure does not require the complex verbal instructions that typically characterize tests of categorization in the cognitive sciences literature (see, e.g., Wilkinson & Rosenquist, 2006). As a result, the methods are appropriate for use even with individuals with severe language learning limitations. A key feature of the paradigm concerns the possibility of "emergent" relations between stimuli. As Sidman and Tailby (1982) analyzed comprehensively, teaching sample-comparison relations A-B and A-C may yield a number of further emergent relations (B-A, C-A, B-C, C-B) based on the symmetrical and transitive properties of equivalence relations. The paradigm and the behavioral functions exhibited thus seem to offer well-defined procedures for modeling the formation and expansion of simple, natural categories in individuals with substantial limitations in language and other aspects of intellectual development.

Rationale for Joint Study of Exclusion and Stimulus Equivalence

Although exclusion and stimulus equivalence have been amply studied separately, joint studies are notable by their absence (see McIlvane et al., 1987, for an early exception with adult participants and Lipkens, Hayes, & Hayes, 1993, for a related case study of a typically developing child). Joint studies seem especially necessary to an interdisciplinary account of lexical development, however, because effective word learning through exclusion/fast mapping would necessarily include integration of the new relations into broader categories (e.g., Wilkinson & McIlvane, 2001). Moreover, joint examination of exclusion and potentially emergent relations consistent with stimulus equivalence seems particularly important in individuals with substantial intellectual disabilities. As yet, no one has demonstrated a well-articulated path for combined use of the exclusion and equivalence paradigms to expand repertoires of functional symbolic relations. In this sense, the study that we report here is true *translational behavioral science* (cf. McIlvane et al., in press)—a first truly comprehensive attempt to verify the efficiency and effectiveness of a predictable but as yet undocumented path for establishing simple symbolic categories in persons with severe intellectual disabilities and limited language.

The rationale for formally researching this path is manifest in the literature. Although individuals with severe intellectual disabilities and limited language almost universally appear able to map a single novel word and its referent via exclusion (Chapman, Kay-Raining Bird, & Schwartz, 1990; Mervis & Bertrand, 1995; Romski, Sevcik, Robinson, Mervis, & Bertrand, 1996; Wilkinson, 2005), they show much poorer learning outcomes when compared with typically developing word learners matched for vocabulary size (Wilkinson, 2007). Also, they require greater instructional support to perform at comparable levels of learning-outcome accuracy when compared with such learners (Wilkinson, 2005). We sought specifically to examine whether minimally verbal individuals could learn up to six new relations via the exclusion procedure and whether derived relations consistent with stimulus equivalence and categorical functions would emerge from these procedures.

Methods

Participants

Ten participants (6 male, 4 female) with intellectual disabilities were enrolled. Table 1 presents information about participant gender, diagnostic/etiological information, intelligence quotient, and receptive vocabulary levels. Intelligence quotient scores were derived either from the Leiter International Performance Scale–Revised (Roid & Miller, 1997) or the Test of Nonverbal Intelligence (Brown, Sherbenou, & Johnson, 1997). The scores ranged from low/mild to severe levels of intellectual disability. Three individuals were not testable with these instruments.

Receptive vocabulary was evaluated with the Peabody Picture Vocabulary Test–Revised (Dunn & Dunn, 1985) or the Peabody Picture Vocabulary Test–Third Edition (Dunn & Dunn, 1997). All participants scored in the lowest 1% on these assessments. Participants received a mean raw score of 36, with 5 participants receiving raw scores under 20. When converted into standard scores (taking age as well as raw score into consideration), 9 of the 10 participants' performances were at floor level (standard score = 40). Thus, although there was a fairly broad range of overall intellectual functioning in the sample, virtually all participants exhibited severe disabilities in acquisition of vocabulary.

Diagnoses and etiological information were obtained through a review of participants' medical records after informed consent was obtained. Standardized testing was conducted at the outset of the study, in all but one case no more than 2 months before formal data collection commenced. All participants attended schools for individuals with developmental and/or behavioral disorders, and all had prior experience with matching-to-sample procedures.

Table 1
Participant Demographics

Participant	CA	Gender	Ethnicity	Diagnosis	PPVT raw and (standard) scores	IQ
ELK	11-4	F	C	Autism	40 (40)	36a
YER	17-2	M	AA	MR	20 (40)	63b
BRG	19-0	M	AA	PDD	56 (40)	63b
YCD	8-2	F	C	Autism	16 (40)	44a
WDI	15-9	F	AA	MR	11 (40)	61b
ESN	17-3	M	C	PDD	66 (40)	50a
SSM	17-5	M	C	Autism	55 (40)	n/a
ORO	9-9	M	C	Autism	14 (40)	n/a
DVS	12-7	M	C	Autism	18 (40)	n/a
SPN	10-0	F	C	FAS	59 (56)	72b

Note. Chronological age is given in years-months. CA = chronological age; C = Caucasian; AA = African American; MR = mental retardation; PDD = pervasive developmental delay; FAS = fetal alcohol syndrome; PPVT = Peabody Picture Vocabulary Test (Dunn, 1985, 1997); n/a = not available.
[a] Intelligence quotient derived from Leiter International Performance Scale–Revised (Roid & Miller, 1997).
[b] Intelligence quotient derived from Test of Nonverbal Intelligence–Third Edition (Brown et al., 1997).

Stimuli

Stimuli were either familiar (baseline) stimuli or novel (target) stimuli. All stimuli were presented on a computer screen and were contained within a 2 × 2-in. square. Baseline stimuli depicted familiar objects from everyday life. The baseline set consisted of spoken words, color photographs scanned into the computer, and black and white symbols taken from the Mayer-Johnson Picture Communication Symbols (PCS; Mayer-Johnson, 1992). Examples of these stimuli are presented in Figure 1. All participants underwent preliminary assessment to ensure that they could match the photographs and the line drawings to one another and to the spoken word (thus, photograph-to-line-drawing matching, described below). Only stimuli on which participants demonstrated reliable selections served as baseline stimuli.

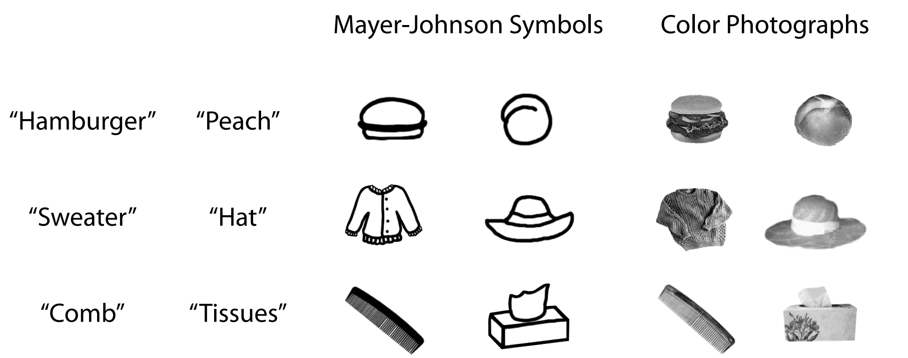

Figure 1. Baseline stimuli. *Note.* From Picture Communication Symbols, by R. Mayer-Johnson, 1992, Solana Beach, CA: Mayer-Johnson. Copyright 1981–2003 by Mayer-Johnson. Used with permission.

For target stimuli, three simple three-stimulus categories were created, shown in Figure 2. Color photographs of unfamiliar/hard-to-name objects (Set B) were scanned into the computer and modified to have a white background. Lexigrams (Set C) were created by combining three graphical elements (e.g., a triangle, a horizontal line) from a small set of choices, through procedures described by Romski and her colleagues (1996). Spoken labels (Set A) were nonsense words that adhered to the phonology of English created by a speech–language pathologist. Auditory stimuli were prerecorded into the controlling software (described in the following section). Because three sets of relations between the stimuli in Sets A and B (see Figure 2) were taught, as well as three sets of relations between stimuli in Sets B and C, a total of six relations were targeted in this study (these six taught relations are indicated by plain arrows). Figure 2 also shows emergent relations that might be expected to occur as a result of training (these emergent relations are indicated by dashed arrows).

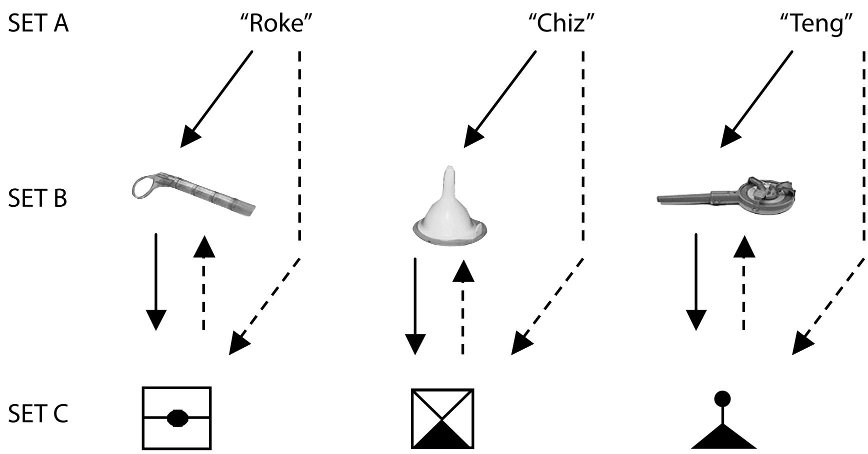

Figure 2. Three stimulus categories. Solid line arrows indicate relations directly taught and tested. Dashed arrows indicate emergent relations tested.

General Procedures

Participants were tested in a quiet room at school during regularly scheduled free time. During the sessions, the experimenter sat just behind the participant and interacted with the participant as little as possible. Participant responses were touches to a touch-sensitive computer screen mounted on a Macintosh computer monitor. Stimulus presentation and response recording were controlled by software designed for this research (Dube, 1991). When a stimulus appeared as a sample, it was presented in the center of the screen. Comparison stimuli appeared in the upper and lower corners.

Two types of feedback were given. First, computer-generated auditory feedback was provided through an external speaker to indicate whether or not a given response was correct. The type of auditory feedback depended in part on the protocol and the participant needs. In general, feedback ranged from prerecorded spoken words such as "wow" to computer-generated sounds like tones or musical notes. Participants also received tangible reinforcers on an individualized schedule that would maintain accurate responding for each participant. Table 2 presents the reinforcement schedule and type for each participant.

Table 2
Participant Reinforcers

Participant	Schedule	Reinforcer Type	
		Conditioned	Tangible
ELK	VR8	Verbal	Edibles
YER	VR8	Verbal	Edibles
BRG	VR8	Verbal	Edibles
YCD	VR8	Verbal	Edibles
WDI	FR1	Tokens	Edibles
ESN	VR8	Verbal	Money
SSM	FR1	Music	Edibles
ORO	FR1	Verbal	Edibles
DVS	VR8	Verbal	Edibles
SPN	VR8	Verbal	Edibles

Note. VR = variable reinforcement; FR = fixed ratio reinforcement.

Preliminary Assessments

Three sessions of preliminary assessment were conducted. Examples of trials in these sessions are presented in the top panel of Figure 3.

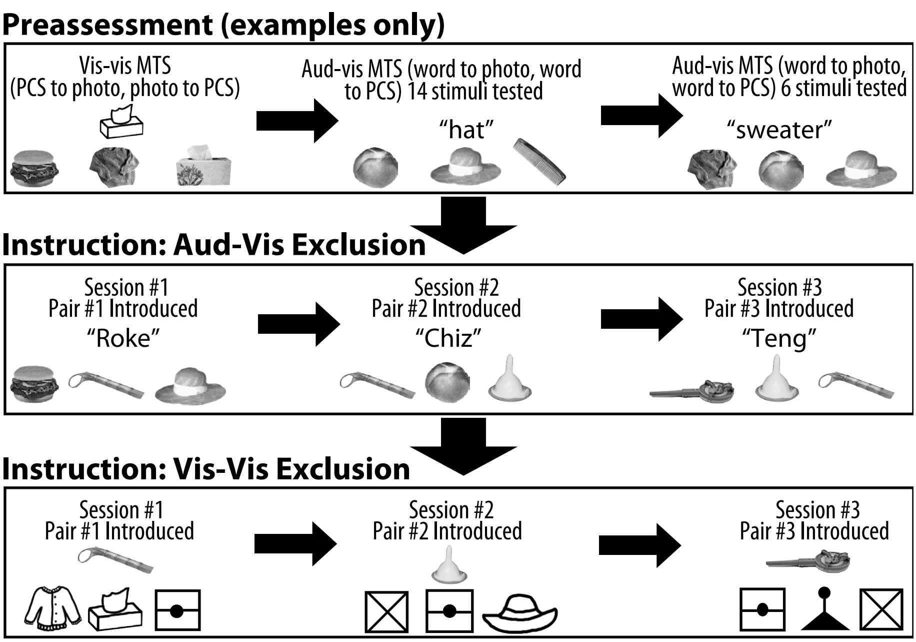

Figure 3. Trial structure in preliminary assessment and instruction sessions.

The first session tested the participants' ability to match the PCS symbols and the color photographs depicting the same referent. Referents included toothbrush, horse, hamburger, tissues, sunglasses, banana, sweater, guitar, hat, brownie, comb, bus, crayon, peach, and the familiar McDonald's symbol. Fifteen trials presented photographs of familiar objects as the sample and PCS symbols as comparisons. Fifteen other trials presented a PCS symbol as the sample and photographs as comparisons.

The second session tested the ability to match the PCS symbols and the photographs to their spoken labels. This session consisted of 28 auditory-visual matching trials. Fourteen trials presented photographs as comparisons, and 14 trials presented PCS symbols as comparisons. One of the stimuli used in the first session (a toothbrush) was eliminated in this session.

The third session presented just six stimuli—those chosen to serve as baseline stimuli in subsequent testing. Most participants performed well with six of the stimuli used in the first two assessments: sweater, comb, hat, peach, hamburger, and tissues. The third session consisted of 27 auditory-visual matching trials with the photographs and PCS symbols randomly alternating as comparison sets. All but one participant performed without error during this session. Participant YCD, however, showed less reliable selections (81% accuracy). Consequently, she was tested on a different subset, including horse, bus, and guitar. Her performance on this assessment was satisfactory (98% accuracy), and she was tested with this baseline for the remainder of her participation.

Instruction Using the Exclusion/Adapted Fast-Mapping Procedure

Instruction was conducted in two components. The order of instruction is presented in the second and third panels of Figure 3, as are examples of important trials. In the first component (second panel), the targeted novel auditory-visual (photograph-to-word) relations were taught. After acquisition of these new auditory-visual relations, participants entered the second phase in which visual-visual (symbol-to-photograph) relations were taught (third panel).

Teaching auditory-visual relations. The successive introduction procedure described by Wilkinson et al. (1998) and Wilkinson and McIlvane (2001) was modified for the purpose of teaching three new dictated auditory-visual stimulus relations. Figure 4 illustrates the three critical trial types used. In the top panel is an example of a *disambiguation* trial, in which the first novel word is introduced (see Wilkinson, 2005, 2007, for a discussion of the use of this term). As in typical fast-mapping/exclusion procedures, exposure to the first novel word and referent made use of the contrast of the single novel item against well-established baseline items. The middle panel of Figure 4 illustrates *modified disambiguation* trials, in which the second novel word-referent relation is introduced. For this second word/referent pair, the contrast items in the array included one baseline item and the just-learned (just-labeled) item. To perform correctly on trials with the second novel word/referent, participants had to attend to the differences in the two novel stimuli. Finally, the bottom panel of Figure 4 illustrates the tests for learning/retention (i.e., *learning outcome* tests; McIlvane, Kledaras, Lowry, & Stoddard, 1992). In these learning outcome tests, both novel items are presented together and the participant is asked to select between them on the basis of each novel word (cf. Dixon, 1977; McIlvane & Stoddard, 1981).

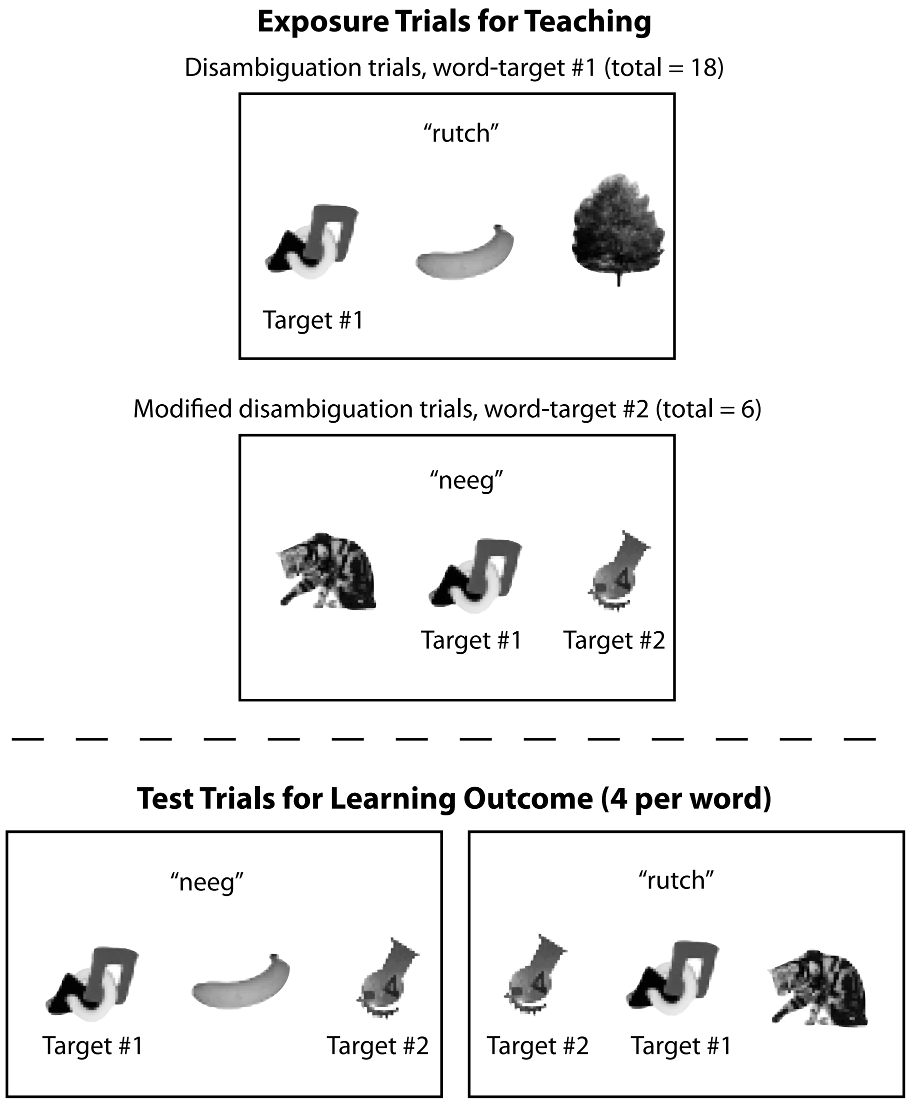

Figure 4. Illustration of the successive introduction procedure.

In the current adaptation of the original methods, five training phases were scheduled. In all sessions, disambiguation and modified disambiguation (exclusion teaching) trials were interspersed within baseline trials, the number of which was adjusted to reflect the teaching needs. Table 3 presents the total number of each trial type in each session. The first phase introduced the first target dictated word–visual stimulus pair. Six disambiguation trials for this pair (the stimuli under the "roke" class) were interspersed within 15 baseline trials (see Figure 3 for trial structures). The second phase reviewed the roke stimulus pair on three trials during the first half of the session and introduced the second target word–photograph pair (the stimuli under the "chiz" class) in the second half of the session. In this second block, three review trials for the roke class were interspersed within baseline trials and modified disambiguation teaching trials for the chiz stimulus pair (see Figure 3 for trial structures).

Table 3
Example of Trial Structure for Sessions

Phase	Number of trials/type/order	Auditory sample	Photograph comparisons (examples only)		
			1	2	3
1	15 Baseline	“hat”	hat	sweater	tissues
	6 Exposure	“roke”	roke	peach	hamburger
2	18 Baseline	“peach”	peach	hamburger	tissues
	6 Exposure	“roke”	roke	hat	sweater
	3 Modified	“chiz”	chiz	roke	peach
3	24 Baseline	“comb”	comb	sweater	hat
	6 Exposure	“roke”	roke	comb	peach
	3 Modified	“chiz”	chiz	roke	tissues
	3 Roke Outcome	“roke”	roke	chiz	hamburger
	3 Chiz Outcome	“chiz”	chiz	roke	peach
4	17 Baseline	“hamburger”	hamburger	tissues	comb
	4 Roke Outcome	“roke”	roke	chiz	sweater
	4 Chiz Outcome	“chiz”	chiz	roke	peach
5	18 Baseline	“sweater”	sweater	hat	comb
	6 Roke Outcome	“roke”	roke	chiz	tissues
	6 Chiz Outcome	chiz”	chiz	roke	hat
	6 Teng Exposure/ Outcome	“teng”	teng	roke	chiz

Note. Baseline trials were intermixed with exposure and outcome trials.

The third phase began with a review of the instruction and testing to determine how well participants were learning. The beginning of this session was structured identically to the second session, just described. Interspersed within 18 baseline trials were six exclusion teaching trials for the roke class and three for the chiz class. At the end of the session, however, was an additional block in which 6 trials presented the roke class stimulus and the chiz class stimulus together, and the participant was required to make selections between them based on the sample stimulus (learning outcome trials).

The fourth phase evaluated how well participants retained the Pair 1 versus Pair 2 relations when no review was presented. Only learning outcome trials were presented (interspersed within baseline trials), with no exclusion teaching review. If participants selected reliably between the roke and the chiz class stimuli, it indicated that they had learned the specific relations between each targeted stimulus pair. Up to this point, the procedures were direct replications of earlier successive introduction methods (Wilkinson & Green, 1998; Wilkinson, 2005).

Upon reliable selection in the fourth phase, participants continued to the fifth phase. This phase was conducted to teach the third new pair, from the "teng" class of stimuli. Because the roke and chiz class stimulus relations had been learned, they now could serve as contrasts in the exclusion teaching. Thus, the exclusion teaching trials for the teng class stimuli were structured identically to learning outcome trials; the teng stimulus was contrasted against the roke and chiz stimuli (see Figure 3). There were 36 trials in this phase. Interspersed among 18 baseline trials were 6 roke, 6 chiz, and 6 teng outcome trials. Participants were given three different variations of sessions during the fifth phase, in order to ensure that all three targeted auditory-visual stimulus relations were established prior to testing for emergent equivalence relations.

Teaching visual-visual relations. This teaching followed the same format as the teaching of the auditory-visual relations. The teaching goal was to establish relations between lexigram comparisons with photograph samples via exclusion of Mayer-Johnson symbols. In all phases, if one or two errors were made on exclusion or outcome trials, participants repeated the prior session to ensure they had learned the novel pair. After teaching was completed for both the auditory-visual and visual-visual relations, two "mixed" sessions were scheduled consisting of all of the taught relations. These sessions were given to familiarize participants with the baseline that was to be used during subsequent tests for defining properties of equivalence relations.

Testing for category formation. After the exclusion/adapted fast-mapping instruction, the formation of simple categories was evaluated using two defining properties of equivalence relations. Figure 5 illustrates how taught relations and potentially emergent relations were evaluated using the stimulus class roke as an example. *Symmetry* probes consisted of trials in which the sample and comparison positions were reversed from training; participants were required to select among photographs when presented with a lexigram sample. *Transitivity* probes consisted of trials in which the participant was required to select among lexigrams upon hearing dictated sample stimuli. All symmetry and transitivity probe trials were interspersed into a baseline of previously known and directly taught relations. Two symmetry test sessions and two transitivity test sessions were conducted. In each session, there were 24 baseline trials and 6 probe trials (2 per stimulus).

Tests were not conducted for the combined symmetry and transitivity test (cf. Sidman & Tailby, 1982). Doing so would have required a different design, for example, teaching relations A-B and A-C and testing for B-C and C-B or teaching relations A-B and C-B and testing for A-C and C-A. The former procedure would not have allowed an examination of both auditory-visual and visual-visual exclusion in the same participants and their staged use within an integrated teaching path—the primary purpose of the study. The latter procedure was not feasible because the auditory A stimuli could not be presented simultaneously as comparison stimuli while retaining their intelligibility. Thus, we can report here only behavioral patterns consistent with acquisition of equivalence relations rather than the full complement of

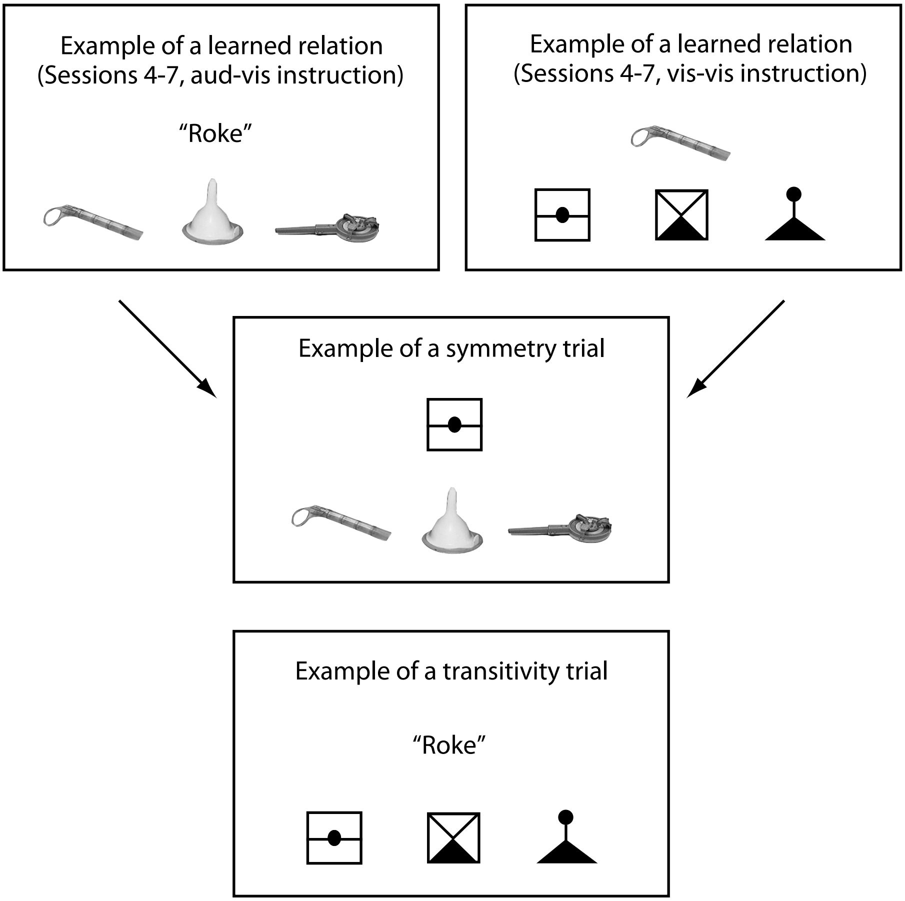

Figure 5. Trial structure for equivalence testing.

documenting tests. This limitation, however, does not seriously compromise our main intent—to demonstrate successively emergent auditory-visual and visual-visual relations via exclusion learning in persons with intellectual and related language disabilities. Moreover, we think it likely that seemingly alternative associative and/or Pavlovian process accounts of data like ours may be explained ultimately in terms of stimulus equivalence and associated transfer and/or transformation of functions (cf. Sidman 1994, 2000).

Results

Seven of the 10 participants successfully completed both the adapted fast-mapping training procedure and subsequent learning outcome and equivalence testing. Data will be reported separately for the 3 unsuccessful participants.

Successful Participants

The following data were calculated as the percent-correct selections on each trial type. Because performance was uniformly high and for economy in presentation, we provide group means and ranges rather than participant-by-participant data. Mean accuracy for baseline trials was 99% (range = 88%–100%).

Table 4 presents the mean accuracy of participants' performances on exclusion and/or learning outcome testing trials in each of the sessions in which the new relations were taught and tested via the adapted fast-mapping procedures. Mean accuracy was reliably above 90%. Most participants received a single session in each of the components of the teaching/testing phases.

Table 4
Mean Percentage Correct for Exclusion and Learning Outcome Trials

Phase	Percent correct	Repeats	Number
	Auditory - Visual		
1	99% (95–100%)	3	2–4
2	99% (94–100%)	3	2–4
3	95% (85–100%)	3	2
4	99% (95–100%)	1	7
5.1	99% (96–100%)	3	5
5.2	98% (94–100%)	1	2
5.3	99% (97–100%)	0	1
	Visual - Visual		
1	98% (90–100%)	1	2
2	99% (96–100%)	1	2
3	99% (98–100%)	1	2
4	98% (97–100%)	3	2–5
5.1	97% (90–100%)	3	2–3
5.2	97.11% (89–100%)	2	2–3
5.3	97.96% (93–100%)	1	2

Note. Percentages in parentheses represent the range of mean percent correct on exclusion trials. "Repeats" represents the number of participants having to repeat a session within a phase. "Number" represents the number of times, or range, the session was repeated.

Symmetry and transitivity. Five of the 7 participants performed errorlessly on the first symmetry probe (six of six probe trials correct); the remaining 2 participants made one error each (five of six correct). Six of the 7 participants performed errorlessly on the first transitivity probe; the remaining participant made one error. In the second session, only one error was made by any participant, on a transitivity probe. This translates to a mean accuracy of 98%, on both symmetry and transitivity probes.

Unsuccessful Participants

Three participants were unable to complete the protocols. One participant (SPN) was eliminated due to challenging behaviors that emerged during the study. The other 2 unsuccessful participants, ORO and DVS, demonstrated good accuracy during auditory-visual teaching but not during visual-visual teaching.

The average auditory-visual performance during teaching for ORO was 97% (range = 87%–100%) on baseline trials and 95% (range = 83%–100%) on exclusion and learning outcome trials. During visual-visual instruction, by contrast, ORO performed poorly from the outset. Accuracy during the first session was 67% on baseline trials and 0% on exclusion trials. The inaccurate performance on baseline trials was surprising because accuracy during the preliminary assessment was high (91%). After subsequent reevaluation of the baseline indicated continued difficulties (79%), we substituted three new baseline stimuli from the preliminary assessment and repeated the instructional sequence with new novel stimuli. During this procedure, accuracy on baseline trials was maintained (mean = 95%, range = 80%–100%), but exclusion was inaccurate (mean = 53%, range = 0%–83%). Thus, this instructional sequence was a clear failure with ORO, and studies were discontinued at this point.

The average auditory-visual performance during teaching for Participant DVS was 100% on baseline trials and 92% (range = 67%–100%) on exclusion and learning outcome trials. Like ORO, the visual-visual baseline became inaccurate (61%) during the first exclusion session, and accuracy on exclusion trials was very low (16%). Unlike ORO, accuracy improved to 100% on both types of trials in the second session. In subsequent sessions, accuracy on baseline trials remained at 100% but accuracy on exclusion trials was poor (mean = 57%, range = 16%–100%). Procedural variations subsequently were employed with the goal of improving performance, but these were unsuccessful. To establish whether DVS could still demonstrate reliable exclusion, a new set of baseline and novel auditory-visual relations was introduced. The average performance accuracy on baseline and exclusion trials was high, 99% (range = 96%–100%) and 98% (range = 83%–100%), respectively. When we subsequently returned to the visual-visual format, the procedures were again unsuccessful (86% on baseline and 50% on exclusion trials). DVS's participation was discontinued at this point.

Discussion

Our study brings together two lines of research, integrating current themes in behavior analysis with questions germane to the psycholinguistics of developmental language disorders—modeling the relationship between fast-mapping processes and the development of simple categories in persons with intellectual disabilities and severe language delays. The results seem noteworthy along certain dimensions of current interest within these various disciplines.

Themes in Behavior Analysis

Our demonstration of robust exclusion- and equivalence-class formation in persons with severe developmental delays is not surprising given the history of the field (McIlvane & Stoddard, 1981; Sidman, 1994), but the inclusion of a well-defined cohort of children with documented language disorders of this magnitude is a noteworthy contribution. We find it particularly interesting that 3 children with the lowest possible language scores (raw scores < 20, age equivalent estimates < 1 year, 9 months) achieved virtually perfect scores on equivalence-class formation. These data thus add to a growing body of findings questioning a close relationship between language development and the capacity to exhibit emergent stimulus-stimulus relations characterized by stimulus equivalence (Carr, Wilkinson, Blackman, & McIlvane, 2000; Lionello-DeNolf, Casanovas, de Souza, Barros, & McIlvane, 2008; Luciano, Gomez Becerra, & Rodriguez Valverde, 2007; Schusterman & Kastak, 1993).

This study also provides perhaps the clearest demonstration to date of a within-subject difference between performance on auditory-visual and visual-visual exclusion tasks (participants ORO and DVS). One cannot attribute their failure to a general inability to discriminate successively between sample visual stimuli. The preexclusion baselines were reliable and accurate, and it appears that the exclusion trials in fact disrupted these baselines. Also, the failure cannot be attributed to the inability to exclude more generally; auditory-visual exclusion was verified prior to and, in one case (DVS), after unsuccessful performance on the visual-visual task. It may be that the unsuccessful participants did not detect the difference between the novel and baseline visual comparison stimuli, but that seems unlikely given the fairly gross differences between the lexigrams to be selected and the Mayer-Johnson symbols to be excluded. It is also possible that the participants did not recognize the lexigrams as acceptable selections. The stimuli in the baseline relations—Mayer-Johnson symbols and corresponding photographs—shared many physical features (rendering it a similarity-matching task rather than a purely arbitrary match).

Perhaps the unsuccessful children failed the exclusion task because the lexigrams did not resemble the photographs to which they were to be related in any way except in being visual stimuli (a suggestion consistent with the very low scores). In this interpretation, it may not be surprising that they chose stimuli with prior reinforcement histories instead. If so, however, then why did 7 of our participants differ from the others, responding virtually without error on the same visual-visual matching tasks? One possibility is that they initially related the photographs with the lexigrams on the basis of novelty (Dixon, Dixon, & Spradlin, 1983). The former were novel as samples, whereas the latter were entirely novel. Whatever the explanation, these data as a whole seem consistent with recent analyses that suggest that interparticipant (and perhaps intraparticipant) variations in the stimulus-control basis for responding during baseline training (*stimulus control topographies*; McIlvane and Dube, 2003) may be at the heart of behavioral variability observed on tests for emergent behavior of the type addressed in this study.

Themes in Psycholinguistics of Developmental Language Disorders

Although some aspects of the task were different (number of trials, individualized reinforcement procedures, etc.), this study shows how the psycholinguistic tradition of research on fast mapping can be adapted for evaluation of lexical processes relating to developmental disabilities. One goal was to expand traditional fast-mapping methodologies beyond one or two new target words. For the participants who exhibited reliable disambiguation/exclusion, each of the six matching relations was established quickly with few or no errors. Thus, there appeared to be no obstacle to learning more than two relations.

All participants except SPN demonstrated learning of the auditory-visual relations through the successive introduction procedure, including a number of children who scored at the lowest possible level on the PPVT receptive vocabulary tests. These outcomes differ somewhat from those reported by Wilkinson (2005), who showed a relation between receptive vocabulary and success in learning two new words via successive introduction. We attribute these findings to differences in the procedures used here. Wilkinson's (2005) study sought to compare performance across the procedures and groups targeted in that study, and universal procedures were necessarily maintained across all participants. Thus, all participants in that study received the same consequences for matching selections (a variable reinforcement schedule of nondifferential verbal feedback during the session, plus a sticker at the end). Moreover, individual procedural modifications were not made (e.g., changing of baseline stimuli, session repetition as necessary). In the present study, however, the goal was different: to examine the results of exclusion learning rather than the process itself. Thus, participants received both verbal and primary reinforcers, and 3 participants were kept on a continuous reinforcement schedule. Repetition of sessions also was allowed, although few participants required it. Perhaps as a result of these changes, we observed greater success in learning auditory-visual relations even in individuals with vocabulary-age estimates below that of the prior study.

Beyond simply demonstrating success at teaching up to six new relations through exclusion, the current study offers an important insight into the product of this new learning. That is, the emergent symmetry and transitive relations between the members of the three simple categories were clearly demonstrated immediately upon testing without further instruction. Participants who learned through exclusion that "roke" mapped to one object and that the object mapped to a lexigram then demonstrated that they understood the relationship between "roke" and the lexigram, thus indicating the formation of simple categories consequent to learning through exclusion/disambiguation. This finding demonstrates the utility of the stimulus-equivalence approach for studying early simple category formation. Using a method that is accessible even to individuals with very restricted vocabulary repertoires, we were able to evaluate reliably both learning by exclusion and the products of that learning (the emergent relations consistent with stimulus equivalence). Thus, these outcomes support our arguments concerning the potential contributions of stimulus-equivalence methodology (e.g., Wilkinson & McIlvane, 2001) in psycholinguistic research. In addition, our findings further support the use of these procedures with individuals with intellectual and developmental disabilities and suggest potentially profitable application to study very young children at the beginning of linguistic development (e.g., Luciano et al., 2007).

References

BROWN, L., SHERBENOU, R. J., & JOHNSON, S. K. (1997). *Test of nonverbal intelligence* (3rd ed.). Austin, TX: PRO-ED.

CAREY, S., & BARTLETT, E. (1978). Acquiring a single new word. *Papers and Reports on Child Language Development*, *15*, 17–29.

CARR, D., & FELCE, J. (2008). Teaching picture-to-object relations in picture-based requesting by children with autism: A comparison between error prevention and error correction teaching procedures. *Journal of Intellectual Disability Research, 52*, 309–317.

CARR, D., WILKINSON, K. M., BLACKMAN, D., & MCILVANE, W. J. (2000). Equivalence classes in individuals with minimal verbal repertoires. *Journal of the Experimental Analysis of Behavior, 74*, 101–114.

CHAPMAN, R. S., KAY-RAINING BIRD, E., & SCHWARTZ, S. E. (1990). Fast mapping of words in event contexts by children with Down syndrome. *Journal of Speech and Hearing Disorders, 55*, 761–770.

DIXON, L. S. (1977). The nature of control by spoken words over visual stimulus selection. *Journal of the Experimental Analysis of Behavior, 27*, 433–442.

DIXON, M. H., DIXON, L. S., & SPRADLIN, J. E. (1983). Analysis of individual differences of stimulus control among developmentally disabled children. In K. D. Gadow & I. Bialer (Eds.), *Advances in learning and behavioral disabilities* (Vol. 2, pp. 85–110). New York: JAI Press.

DOLLAGHAN, C. (1985). Child meets word: "Fast mapping" in preschool children. *Journal of Speech and Hearing Research, 28*, 449–454.

DUBE, W. V. (1991). Computer software for stimulus control research with Macintosh computers. *Experimental Analysis of Human Behavior Bulletin*, *9*, 28–30.

DUNN, L. M., & DUNN, L. M. (1985). *Peabody picture vocabulary test* (Rev.). Circle Pines, MN: American Guidance Service.

DUNN, L. M., & DUNN, L. M. (1997). *Peabody picture vocabulary test* (3rd ed.). Circle Pines, MN: American Guidance Service.

KAGAN, J. (1981). *The second year: The emergence of self-awareness.* Cambridge, MA: Harvard University Press.

LIONELLO-DENOLF, K. M., CASANOVAS, D., DE SOUZA, D., BARROS, R. S., & MCILVANE, W. J. (2008). Reversal learning set and contingency class formation in children with and without autism. *The Psychological Record*, *58*, 15–36.

LIPKENS, R., HAYES, S. C., & HAYES, L. J. (1993). Longitudinal study of the development of derived relations in an infant. *Journal of Experimental Child Psychology, 56*, 201–239.

LUCIANO, C., GOMEZ BECERRA, I., & RODRIGUEZ VALVERDE, M. (2007). The role of multiple-exemplar training and naming in establishing derived equivalence in an infant. *Journal of the Experimental Analysis of Behavior, 87*, 349–365.

MARKMAN, E. M. (1989). *Categorization and naming in children.* Cambridge, MA: MIT Press.

MAYER-JOHNSON, R. (1992). *The picture communication symbols.* Solana Beach, CA: Mayer-Johnson.

MCILVANE, W. J., & DUBE, W. V. (2003). Stimulus control topography coherence theory: Foundations and extensions. *The Behavior Analyst*, *26,* 195–213.

MCILVANE, W. J., DUBE, W. V., LIONELLO-DENOLF, K. M., SERNA, R. W., BARROS, R. S., & GALVÃO, O. F. (in press). Some current dimensions of translational behavior analysis: From laboratory research to intervention for persons with autism spectrum disorders. In J. Mulick & E. Mayville (Eds.), *Behavioral foundations of effective autism treatment.* Cambridge, MA: Cambridge Center for Behavioral Studies.

MCILVANE, W. J., KLEDARAS, J. B., LOWRY, M. J., & STODDARD, L. T. (1992). Studies of exclusion in individuals with severe mental retardation. *Research in Developmental Disabilities, 13,* 509–532.

MCILVANE, W. J., KLEDARAS, J. B., MUNSON, L. C., KING, K. A., DE ROSE, J. C., & STODDARD, L. T. (1987). Controlling relations in conditional discrimination and matching by exclusion. *Journal of the Experimental Analysis of Behavior, 48,* 187–208.

MCILVANE, W. J., & STODDARD, L. T. (1981). Acquisition of matching-to-sample performances in severe retardation: Learning by exclusion. *Journal of Mental Deficiency Research*, *25*, 33–48.

MERVIS, C. B., & BERTRAND, J. (1995). Acquisition of the novel-name-nameless-category (N3C) principle by young children who have Down syndrome. *American Journal on Mental Retardation, 100,* 231–243.

ROID, G. H., & MILLER, L. J. (1997). *Leiter international performance scale* (Rev.). Wood Dale, IL: Stoelting.

ROMSKI, M. A., SEVCIK, R. A., ROBINSON, B. F., MERVIS, C. B., & BERTRAND, J. (1996). Mapping the meanings of novel visual symbols by youth with moderate or severe mental retardation. *American Journal on Mental Retardation, 100*, 391–402.

SCHUSTERMAN, R. J., & KASTAK, D. (1993). A California sea lion (*Zalophus californianus*) is capable of forming equivalence relations. *The Psychological Record, 43*, 823–839.

SERNA, R. W., JEFFERY, J. A., & STODDARD, L. T. (1996) Establishing go-left/go-right auditory discrimination baselines in an individual with severe mental retardation. *The Experimental Analysis of Human Behavior Bulletin, 14,* 18–23.

SERNA, R. W., STODDARD, L. T., & MCILVANE, W. J. (1992). Developing auditory stimulus control: A note on methodology. *Journal of Behavioral Education, 2,* 391–403.

SIDMAN, M. (1994). *Equivalence relations and behavior: A research story.* Boston: Authors Cooperative.

SIDMAN, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 74*, 127–146.

SIDMAN, M., & TAILBY, W. (1982). Conditional discrimination vs. matching-to-sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*, 5–22.

WILKINSON, K. M. (2005). Disambiguation and mapping of new word meanings by individuals with intellectual/developmental disabilities. *American Journal on Mental Retardation, 110,* 71–86.

WILKINSON, K. M. (2007). The effect of 'missing' information on retention of fast mapped labels by individuals with receptive vocabulary limitations associated with intellectual disability. *American Journal on Mental Retardation, 112,* 40–53.

WILKINSON, K. M., & ALBERT, A. (2001). Adaptations of "fast mapping" for vocabulary intervention with augmented language users. *Augmentative and Alternative Communication, 17*, 120–132.

WILKINSON, K. M., DUBE, W. V., & MCILVANE, W. J. (1996). A crossdisciplinary perspective on studies of rapid word mapping in psycholinguistics and behavior analysis. *Developmental Review, 16,* 125–148.

WILKINSON, K. M., DUBE, W. V., & MCILVANE, W. J. (1998). Fast mapping and exclusion (emergent matching) in developmental language, behavior analysis, and animal cognition research. *The Psychological Record, 48,* 407–422.

WILKINSON, K. M., & GREEN, G. (1998). Implications of "fast mapping" for vocabulary expansion in individuals with mental retardation. *Augmentative and Alternative Communication, 14*, 162–170.

WILKINSON, K. M., & MAZZITELLI, K. (2003). The effect of "missing" information on children's retention of fast mapped labels. *Journal of Child Language, 30,* 47–73.

WILKINSON, K. M., & MCILVANE, W. J. (1997a). Blank comparison analysis of emergent symbolic mapping by young children. *Journal of Experimental Child Psychology, 67,* 115–130.

WILKINSON, K. M., & MCILVANE, W. J. (1997b). Contributions of stimulus control perspectives to psycholinguistic theories of vocabulary development and delay. In L. B. Adamson & M. A. Romski (Eds.), *Communication and language acquisition: Discoveries from atypical development* (pp. 25–48). Baltimore, MD: Paul H. Brookes.

WILKINSON, K. M., & MCILVANE, W. J. (2001). Methods for studying symbolic behavior and category formation: Contributions of stimulus equivalence research. *Developmental Review, 21,* 355–374.

WILKINSON, K. M., & ROSENQUIST, C. (2006). Demonstration of a method for assessing semantic organization and category membership in individuals with autism spectrum disorders and receptive vocabulary limitations. *Augmentative and Alternative Communication, 22*, 242–257.

WILKINSON, K. M., ROSS, E., & DIAMOND, A. (2003). Fast mapping of multiple words: Insights into when "the information provided" does and does not equal "the information perceived." *Journal of Applied Developmental Psychology, 24,* 739–762.