NODALITY EFFECTS DURING EQUIVALENCE CLASS FORMATION: AN EXTENSION TO SIGHT-WORD READING AND CONCEPT DEVELOPMENT

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Three students with moderate disabilities were taught to read and match-to-sample sight words comprising stimulus sets based upon the four food groups. We taught students conditional discriminations within four four-member sets using a single-sample/four-comparison procedure. Students were taught A-B, B-C, and C-D conditional discriminations for each of the four potential stimulus classes. Subsequent probes tested for relations based upon symmetry and one-node and two-node transitivity. The performances for all students indicated that symmetric relations emerged before one-node transitive relations, and that one-node transitive relations emerged before two-node transitive relations. These results are consistent with a pattern of responding, referred to as a "nodality effect," in which relations with fewer nodes are demonstrated prior to the demonstration of relations with a greater number of nodes. These results extend this area of research to sight-word reading for students with moderate disabilities.

DESCRIPTORS: stimulus control, stimulus equivalence, nodality effects, restricted stimulus control, students with moderate disabilities

Equivalence relations are defined by the demonstration of specific properties among stimuli that do not share physical similarities. The relations defining equivalence include reflexivity (A-A; B-B; C-C), symmetry (if A-B, then B-A; if B-C, then C-B), and transitivity (A-C; C-A) (Saunders & Green, 1992; Sidman & Tailby, 1982). When each of these properties is demonstrated among a set of stimuli, an equivalence class is established. In laboratory settings, following the training of a set of unidirectional match-to-sample relations, initial testing often indicates the presence of the defining relations of equivalence (Sidman, 1992). However, demonstration of equivalence relations does not always occur when initial tests are conducted; instead, the relations are observed to evolve only after repeated testing (e.g., Sidman, Kirk, & Willson-Morris, 1985).

When one or more of the defining relations of equivalence are absent, a restriction in stimulus control is observed, not permitting the stimulus substitutability that is definitive of equivalence. For example, as part of instruction to teach the concept of *fruit*, a student might be taught the conditional discriminations: "if *apple*, select *orange*, not *carrot*," "if *orange*, select *lime*, not *onion*," and "if *lime*, select *banana*, not *squash*." Subsequent tests for untrained match-to-sample configurations may demonstrate that the student selects the comparison *apple* when *orange* is the sample, the comparison *orange* when *lime* is the sample, and the comparison *lime* when *banana* is the sample. Further, when presented with *lime*, the student selects *apple* (and vice versa). However, when presented with *banana* as a sample, the student may not consistently select the comparison *apple* (or vice versa). Such performance indicates that symmetry has been established (e.g., between *apple* and *orange*), but that transitivity has been only partially demonstrated. Although some untrained stimulus relations were demonstrated when tested, an equivalence class among the four members of the intended stimulus class *fruit* did not result. When such restrictions in stimulus relations occur, a student's understanding of what is, and is not, a *fruit* fails to meet the

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defining features of an equivalence class, and the concept has not been adequately learned.

From an educational perspective, such restrictions in stimulus function limit the formation of the intended concept (Engelmann & Carnine, 1982). An understanding of why such restrictions occur may assist in the development of more effective educational procedures to teach these concepts. Based upon the results of two laboratory experiments using arbitrary stimuli (Fields, Adams, Verhave, & Newman, 1990; Kennedy, 1991), it appears that restrictions in stimulus control may follow an orderly pattern. When restrictions occur among stimuli related by positive sample-comparison relations (Carrigan & Sidman, 1992; Saunders & Green, 1992), the phenomenon is referred to as a *nodality effect* (Fields, Verhave, & Fath, 1984). Nodality effects are based upon the presence of "nodes" that relate various members in a potential class of equivalent stimuli (e.g., *orange* or *lime* from the previous example). Nodality effects predict that the establishment of transitive relations is inversely related to the number of nodes separating the stimuli. For example, given the trained conditional discriminations "if *potato*, then *carrot*," "if *carrot*, then *onion*," and "if *onion*, then *squash*," the theory predicts that if restrictions in transitive relations occur, one-node transitive relations (e.g., "if *potato*, then *onion*") will be established prior to two-node transitive relations (e.g., "if *potato*, then *squash*"). Such a stimulus control arrangement is of interest because the pattern of emergence of specific relational properties provides information regarding the type of stimulus control that has been established as a result of training (e.g., symmetry and/or transitivity) and, potentially, how to improve instructional techniques to more readily establish the intended stimulus control (e.g., equivalence).

Our goal in the present analysis was to extend basic research findings (Fields *et al.*, 1990; Kennedy, 1991) regarding the gradual demonstration of relational properties that define equivalence to students who were beginning to learn basic concepts such as those discussed above. Students with moderate disabilities were taught stimulus classes com-

prised of words based upon the four food groups. Using a single-sample/four-comparison procedure, A-B, B-C, and C-D conditional discriminations were trained for each of the potential stimulus classes. Subsequently, we probed for the presence of relational properties based upon reflexivity, symmetry, and one- and two-node transitivity to study possible restrictions in the demonstration of equivalence among stimuli comprising the four food groups and to assess the potential occurrence of nodality effects.

METHOD

Students, Settings, and Sessions

Three students with moderate disabilities participated in the study. Each was identified by their teacher as having educational objectives related to sight-word reading, meal planning, and food-group identification. Leilani was 19 years old and had an IQ score of 59 (Stanford-Binet) and an adaptive behavior estimate of 5.6 years (Vineland Adaptive Behavior Scales). Ann was 21 years old and had an IQ score of 47 (Wechsler Intelligence Scale for Children—Revised) and an adaptive behavior estimate of 5.4 years (Vineland). She received a daily dosage of 50 mg of Dilantin® for grand mal seizures throughout the investigation. Nate was 17 years old and had an IQ score of 58 (Leiter) and an adaptive behavior estimate of 4.3 years (Vineland). Neither Nate nor Leilani received prescription medication during the investigation.

Instruction occurred in rooms (9 m square) with several tables and chairs. An instructor and student were seated at a table across from each other in a corner during sessions that lasted approximately 40 min and occurred once per day (3 to 4 days per week). The number of baseline, training, and probe trials that occurred in each session varied across students and sessions because of performance accuracy, response pacing, and type of task.

Stimulus Classes

Potential stimulus classes consisted of four four-member sets of written words. As shown in Table 1, the four sets were based upon the four food

Table 1
Stimulus Classes (Numbers) and Stimuli (Letters)

	Food groups			
	Meats (1)	Dairy products (2)	Grains/ cereals (3)	Vegetable/ fruits (4)
A	bacon	cream	toast	onion
B	salami	yogurt	muffin	potato
C	flank	gouda	cookie	garlic
D	liver	butter	donut	squash

groups" (Page & Phipard, 1957; Senauer, Asp, & Kinsey, 1991), with four words from each group comprising the stimuli. Stimuli and potential stimulus classes were arranged so that each word was comprised of five to six letters, no stimulus within a set shared a common first letter, and each set contained the same overall number of letters across words. Because the focus of the study was on nodality effects, training was arranged so that it made possible the formation of potential derived relations with a varying number of nodes. Stimulus classes are referred to by numerals, and stimulus positions are referred to by upper-case letters. Figure 1 shows the trained conditional discriminations and potential derived relations. Leilani and Nate were exposed to the order of stimuli in Table 1; Ann was exposed to a reverse order within each stimulus class (i.e., A1 became D1, B1 became C1, and so on) to counterbalance for possible assignment bias. Training of A-B, B-C, and C-D conditional discriminations made possible relations based upon symmetry (B-A, C-B, D-C), one-node transitivity (A-C, C-A, B-D, D-B), and two-node transitivity (A-D, D-A).

Sight-Word Pretraining Procedure

A multiple baseline design across students was used to study the effects of time-delay training on sight-word acquisition. Responses were scored correct when a student accurately labeled the word presented to him or her without an instructor prompt; any other response (or the absence of a response) was scored as incorrect.

Baseline. Sample stimuli were the words listed

TRAINED CONDITIONAL DISCRIMINATIONS AND SYMMETRICAL DERIVED RELATIONS

1-NODE TRANSITIVE DERIVED RELATIONS

2-NODE TRANSITIVE DERIVED RELATIONS

Figure 1. Trained and derived relational properties used to analyze nodality effects. The top panel shows the trained conditional discriminations and the potential symmetrical relations (solid lines denote training; broken lines denote derived relations; arrows designate the direction of the relation). The middle panel shows the potential one-node transitive relations; the bottom panel shows the potential two-node transitive relations.

in Table 1. A trial consisted of the presentation of a piece of paper (22 cm high by 28 cm wide) with a sight word printed in 24-point Helvetica in the center. The student was then asked to label the word. No consequences were provided for responses. After a student made a response, the next trial was presented after 2 s. Students were praised occasionally for attending to task, staying in their seat, and other nontargeted responses. Each session consisted of 80 trials.

Training sight-word labeling. The teacher used a time-delay procedure, beginning with a 0-s word prompt and then switching to a 4-s constant delay (Wolery, Ault, & Doyle, 1990). The 0-s delay was in place for the first two training sessions for Ann and Nate and for the first training session for Lei-

Table 2
Training Trial Configurations. Presentations Were Comprised of Single-Sample/Four-Comparison Displays

Trained relations								
A-B			B-C			C-D		
Sa	Co+	Co-	Sa	Co+	Co-	Sa	Co+	Co-
A1	B1	B2, B3, B4	B1	C1	C2, C3, C4	C1	D1	D2, D3, D4
A2	B2	B1, B3, B4	B2	C2	C1, C3, C4	C2	D2	D1, D3, D4
A3	B3	B1, B2, B4	B3	C3	C1, C2, C4	C3	D3	D1, D2, D4
A4	B4	B1, B2, B3	B4	C4	C1, C2, C3	C4	D4	D1, D2, D3

Note. Sa: sample stimulus; Co+: positive comparison stimulus; Co-: negative comparison stimuli.

lani. During the 4-s constant delay condition, the instructor verbally praised unprompted correct responses. All other procedures were the same as in baseline, except that starting in Session 24, Ann was able to earn a tangible reward (e.g., a soft drink) for completing each session (see Results).

Conditional Discrimination Training and Derived Relation Probe Procedure

A multiple baseline design across students was used to study the emergence of stimulus-stimulus relations. Sessions began when the student was seated at a desk across from the instructor. For each trial, the student was given a paper with a sample stimulus at the top center of the page (e.g., "salam") and four comparison stimuli located across the bottom of the page (e.g., "toast," "bacon," "onion," and "cream"). A single-sample/four-comparison conditional discrimination procedure was used throughout the study. Comparison stimuli were selected so that all four in any stimulus array shared a common generic class designation (e.g., B1, B2, B3, B4; D1, D2, D3, D4). The teacher began each session with an initial prompt to (a) circle the sample word at the top of the page, (b) say the sample word, (c) circle a comparison word at the bottom of the page, and (d) say the comparison word. If a student circled the positive comparison without a prompt, a positive comparison selection was scored; if a student circled the positive comparison with a prompt, a prompted positive comparison selection was scored; if a student circled any other comparison, a negative comparison selection was scored. Specific consequences for posi-

tive and negative comparison selections are described below.

Equivalence class baseline. All stimulus-stimulus relations presented in Tables 2 and 3 were tested during baseline. Each test consisted of mixed presentations of the arbitrary conditional relations in Tables 2 and 3. During each test, the student was exposed to 16 trials of training conditional discriminations and 24 trials of conditional discriminations from each of the symmetric and one-node and two-node transitive relations (for a total of 88 trials). Following this block of trials, the student was given a trial for each of the potential reflexive relations (for a total of 16 additional trials). Throughout baseline, arbitrary conditional relations (i.e., trained, symmetric, and transitive relations) were probed prior to reflexive relations. Equivalence class baseline consequences were the same as those used in the sight-word pretraining baseline.

Conditional discrimination training. A 4-s constant time-delay procedure was used during conditional discrimination training. Verbal praise was provided when the student selected, or was prompted to select, the positive comparison; if the student selected a negative comparison, the instructor said the selection was incorrect. A gestural prompt (i.e., pointing to the positive comparison) was presented after 4 s had elapsed without a response or following an incorrect response. Table 2 shows the conditional discriminations trained. Initially, the A-B relations were trained. Each of the four relations was interspersed during training in a random sequence. Once a criterion of 10 consecutive unprompted positive comparison selections had occurred, B-C relations

Table 3
Probe Trial Configurations. Presentations Were Comprised of Single-Sample/Four-Comparison Displays

Generic relation	Sa	Co+	Co-	Sa	Co+	Co-	Sa	Co+	Co-	Sa	Co+	Co-
Symmetrical relations												
B-A	B1	A1	A2, A3, A4	B2	A2	A1, A3, A4	B3	A3	A1, A2, A4	B4	A4	A1, A2, A3
C-B	C1	B1	B2, B3, B4	C2	B2	B1, B3, B4	C3	B3	B1, B2, B4	C4	B4	B1, B2, B3
D-C	D1	C1	C2, C3, C4	D2	C2	C1, C3, C4	D3	C3	C1, C2, C4	D4	C4	C1, C2, C3
One-node transitive relations												
A-C	A1	C1	C2, C3, C4	A2	C2	C1, C3, C4	A3	C3	C1, C2, C4	A4	C4	C1, C2, C3
C-A	C1	A1	A2, A3, A4	C2	A2	A1, A3, A4	C3	A3	A1, A2, A4	C4	A4	A1, A2, A3
B-D	B1	D1	D2, D3, D4	B2	D2	D1, D3, D4	B3	D3	D1, D2, D4	B4	D4	D1, D2, D3
D-B	D1	B1	B2, B3, B4	D2	B2	B1, B3, B4	D3	B3	B1, B2, B4	D4	B4	B1, B2, B3
Two-node transitive relations												
A-D	A1	D1	D2, D3, D4	A2	D2	D1, D3, D4	A3	D3	D1, D2, D4	A4	D4	D1, D2, D3
D-A	D1	A1	A2, A3, A4	D2	A2	A1, A3, A4	D3	A3	A1, A2, A4	D4	A4	A1, A2, A3
Reflexive relations												
A-A	A1	A1	A2, A3, A4	A2	A2	A1, A3, A4	A3	A3	A1, A2, A4	A4	A4	A1, A2, A3
B-B	B1	B1	B2, B3, B4	B2	B2	B1, B3, B4	B3	B3	B1, B2, B4	B4	B4	B1, B2, B3
C-C	C1	C1	C2, C3, C4	C2	C2	C1, C3, C4	C3	C3	C1, C2, C4	C4	C4	C1, C2, C3
D-D	D1	D1	D2, D3, D4	D2	D2	D1, D3, D4	D3	D3	D1, D2, D4	D4	D4	D1, D2, D3

Note. Sa: sample stimulus; Co+: positive comparison stimulus; Co-: negative comparison stimuli.

were trained. Once the same criterion as the A-B relations had been met for positive comparison selection for B-C relations, C-D relations were trained using the same criterion and arrangement. Following the completion of C-D training, a training review was conducted. The review presented intermixed A-B, B-C, and C-D relations until 10 consecutive unprompted positive comparison selections occurred.

Probes for derived relations. We probed for derived relations following successful completion of the A-B, B-C, and C-D review. All potential derived relations based upon symmetry and one-node and two-node transitive relations are presented in Table 3. No feedback regarding comparison selection was provided. A total of 88 trials, presenting a mixed set of potential derived relations in a random sequence, occurred during each test (the same number and type as in baseline). Following this block of trials, the instructor presented a trial for each of the potential reflexive relations (for a total of 16 additional trials). Prior to each test following training, a review of A-B, B-C, and C-D conditional relations was conducted. The test sequence

consisted of (a) training review, (b) probe for potential derived relations, and (c) probe for reflexive relations.

Data Collection and Interobserver Agreement

During sight-word pretraining, the instructor used an event-recording procedure to record the accuracy of sight-word labeling. Throughout the investigation, interobserver agreement was calculated on a trial-by-trial basis by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100%. On 25% of sessions, a second observer separately recorded the accuracy of the student's labeling with an interobserver agreement score of 99% (range, 99% to 100%). During conditional discrimination training and probes for derived relations, a permanent-product recording procedure was used to document the accuracy of the student's matching-to-sample performances. A second observer separately scored performances for 25% of the sessions, and using the same formula given above, an interobserver agreement score of 100% was obtained.

Figure 2. Results of sight-word training. Data are presented as the percentage of sight words correctly labeled across baseline and training phases.

RESULTS

Sight-Word Pretraining

Figure 2 shows the percentage of sight words labeled correctly by each student. Following baseline patterns demonstrating varying levels of sight-word labeling accuracy across students, the introduction of training coincided with (a) a rapid acquisition of sight-word labeling for Leilani, (b) a more moderate acquisition slope for Nate, and (c) a slower rate of acquisition for Ann. Because Ann's performance was beginning to decline by Session 23, tangible rewards were introduced for completing each session, and her accuracy subsequently increased.

Conditional Discrimination Training and Probes for Derived Relations

Table 4 presents the test results for all students. Each student performed at (or near) chance levels

of positive comparison selection across all types of arbitrary relations during baseline; however, each student consistently selected the positive comparison during probes of reflexive relations without training. Table 5 shows that each student acquired the A-B, B-C, and C-D conditional discriminations during training, although the number of trials varied across students. Subsequent tests for derived relations (Table 4) indicated the presence of nodality effects for each student. For Leilani, Test 3 showed lower percentages of positive comparison selection for two-node transitive relations than for one-node transitive relations; a similar pattern was present between one-node transitive relations and symmetric relations. This pattern was replicated for Leilani on Test 4. Nate also showed a pattern of positive comparison selection that demonstrated stimulus control by stimuli separated by fewer nodes before multinode relations (Test 6). Ann's performance also showed a pattern indicating an inverse relation between the emergence of derived relations and the number of nodes separating stimuli (Tests 7 and 8). All students eventually demonstrated equivalence classes by consistently selecting positive comparisons across all types of derived relations.

DISCUSSION

The variability observed during the testing of derived conditional discriminations appears to be related to, at least in part, the number of nodes separating stimuli. The results of our investigation help to demonstrate that variability in positive comparison selection during the formation of equivalence classes follows predictable and orderly patterns. If restrictions in stimulus control are demonstrated following conditional discrimination training, specific patterns of errors may be suggested based upon our results. Specifically, transitive relations separated by one node were demonstrated prior to transitive relations separated by two nodes. In addition, derived relations without a node (i.e., symmetry) were demonstrated prior to derived relations with one or two nodes. Our findings have implications for constructing stimulus classes comprised of stimuli without physical similarities (such

Table 4

Students' Performance on Baseline and Probe Trials for Trained and Derived Relations. Data Are Presented As the Number of Positive Comparison Selections/Total Comparison Selections (Percentage of Positive Comparison Selections)

Student	Baseline		Posttraining probes								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11
Leilani											
Trained	5/16 (31%)	3/16 (19%)	79/80 (99%)	80/80 (100%)	80/80 (100%)	80/80 (100%)	80/80 (100%)				
Symmetric	9/24 (38%)	6/24 (25%)	18/24 (75%)	23/24 (96%)	24/24 (100%)	24/24 (100%)	24/24 (100%)				
One node	5/24 (21%)	7/24 (29%)	8/24 (33%)	18/24 (75%)	24/24 (100%)	24/24 (100%)	24/24 (100%)				
Two node	3/24 (13%)	7/24 (29%)	3/24 (13%)	11/24 (46%)	23/24 (96%)	24/24 (100%)	24/24 (100%)				
Reflexive	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)				
Nate											
Trained	4/16 (25%)	5/16 (31%)	3/16 (19%)	6/16 (38%)	78/80 (98%)	80/80 (100%)	79/80 (99%)	80/80 (100%)	80/80 (100%)		
Symmetric	2/24 (8%)	9/24 (38%)	5/24 (21%)	7/24 (29%)	7/24 (29%)	22/24 (92%)	23/24 (96%)	24/24 (100%)	24/24 (100%)		
One node	8/24 (33%)	6/24 (25%)	2/24 (8%)	6/24 (25%)	6/24 (25%)	19/24 (79%)	22/24 (92%)	24/24 (100%)	23/24 (96%)		
Two node	7/24 (29%)	5/24 (21%)	5/24 (21%)	6/24 (25%)	8/24 (33%)	11/24 (46%)	22/24 (92%)	23/24 (96%)	24/24 (100%)		
Reflexive	16/16 (100%)	15/16 (94%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)		
Ann											
Trained	3/16 (19%)	5/16 (31%)	6/16 (38%)	4/16 (25%)	7/16 (43%)	4/16 (25%)	79/80 (99%)	80/80 (100%)	80/80 (100%)	80/80 (100%)	80/80 (100%)
Symmetric	9/24 (38%)	8/24 (33%)	4/24 (17%)	2/24 (8%)	7/24 (29%)	5/24 (21%)	19/24 (79%)	23/24 (96%)	24/24 (100%)	24/24 (100%)	23/24 (96%)
One node	4/24 (17%)	5/24 (21%)	9/24 (38%)	5/24 (21%)	7/24 (29%)	4/24 (21%)	11/24 (46%)	17/24 (71%)	22/24 (92%)	24/24 (100%)	24/24 (100%)
Two nodes	5/24 (21%)	6/24 (25%)	8/24 (33%)	6/24 (25%)	4/24 (17%)	7/24 (29%)	5/24 (21%)	8/24 (33%)	20/24 (83%)	24/24 (100%)	23/24 (96%)
Reflexive	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	14/16 (88%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)	16/16 (100%)

as the classification of foods into the four food groups) and the analysis of error patterns associated with restrictions in relational properties defining equivalence. Further, the findings may have implications for how instructional sessions can be structured to minimize restrictions in stimulus control and how to remedy incomplete stimulus control when restrictions are observed.

Nodality effects appear to be a stimulus control phenomenon that readily occurs when testing for intended equivalence classes indicates restrictions in stimulus control (e.g., Fields et al., 1990; Fields,

Adams, Verhave, & Newman, 1993; Kennedy, 1991; Saunders, Wachter, & Spradlin, 1988; Sidman et al., 1985; Wulfert & Hayes, 1988). Our current findings indicate that even when conditional discriminations were trained to consistent levels of positive comparison selection (i.e., 10 consecutive correct trials for each set of conditional discriminations), restrictions still occurred in relational properties consistent with equivalence. From an instructional perspective, this implies that training students to initial criterion levels may be insufficient to achieve all relevant equivalence relations. In the

Table 5
Trials to Criterion During Training of Conditional Discriminations

Conditional discrimination	Leilani	Nate	Ann
A-B	80	86	123
B-C	88	63	74
C-D	45	98	47
A-B, B-C, and C-D	63	119	211
Total	276	366	455

current study, this restriction occurred not only for transitive relations but also during initial probes for symmetric relations. Apparently, the trained conditional relations were not equivalence relations when initially tested and demonstrated the relational properties consistent with equivalence only after repeated testing. That is, upon initial testing, only unidirectional conditional discriminations were demonstrated as relational properties. Following subsequent tests, symmetric relations were demonstrated, followed by transitive relations separated by one node; finally, two-node transitive relations were demonstrated.

From an instructional perspective, if nodality effects are to be minimized, careful attention needs to be given to training methods. At least three parameters of training protocols appear to be related to the restriction in relational properties associated with nodality effects: (a) the number of stimuli in stimulus classes, (b) the extent of training a student receives, and (c) the arrangement of trained conditional discriminations. Based upon previous and current analyses, each of these parameters appears to be related to nodality effects. However, research is needed to directly demonstrate the actual quantitative effect the parameters have on the demonstration of relational properties. In regard to the number of stimuli, it seems reasonable to speculate that the greater the number of stimuli included in sets, the more probable the occurrence of nodality effects. What is unclear at this juncture is how the overall number of stimuli interact with the number of sets (potential stimulus classes) used. Analysis of the interrelations among the number of stimuli in a set, the number of sets, and the overall number

of stimuli will help to resolve the question of what conditions are optimal for initially demonstrating relations consistent with equivalence. For example, is it more efficient to begin training by establishing stimulus classes with only the minimal number of stimuli necessary to demonstrate equivalence (i.e., three) and then gradually expand the classes, or is it more efficient to attempt to establish larger stimulus sets initially?

In regard to training, the number of training trials per stimulus-stimulus relation appears to be inversely related to the demonstration of nodality effects. If instructors provide more extended training for one potential stimulus class versus another, is the one receiving less training more likely to show nodality effects? Each of these parameters, as well as other possible parameters relating to the effects of training (Fields *et al.*, 1993), deserve further investigation. Of importance for educational personnel is the degree to which "overtraining" (i.e., continued training after a criterion level has been achieved) is necessary to facilitate the demonstration of equivalence classes. Apparently, more research on the effects of overtraining on concept development and the demonstration of various relational properties is warranted (Haring, 1988).

Another variable related to the occurrence of nodality effects may be the arrangement of the stimuli that are used to train the initial conditional discriminations. If the number of nodes separating stimuli is inversely related to the demonstration of specific types of relational properties, as the current experiment suggests, minimizing the number of nodes established during training may be one means of attenuating nodality effects. For example, a set of six stimuli (e.g., A, B, C, D, E, F) can be arranged in six different ways to link all stimuli via conditional discriminations (excluding isomorphic arrangements; see Lipschutz, 1976). Of the various means of arranging conditional discrimination training, arrangements with the lowest (i.e., A-B, A-C, A-D, A-E, A-F) and greatest (i.e., A-B, B-C, C-D, D-E, E-F) numbers of different nodes would be likely to differ in the potential for disruption by nodality effects. Such a relation between the training arrangements and the presence of nodes warrants

further applied and basic investigation. Further research is also necessary to establish how various training parameters influence trained conditional relations and various derived relational properties associated with equivalence.

If restrictions in stimulus control are observed following training, the current results suggest a number of steps that instructors may follow to assist in their remediation. First, instructors may consider repeated training and testing of the relations to which a student was exposed. Previous research has indicated that repeating an individual's exposure to initial training and testing conditions can facilitate the demonstration of intended relations (e.g., Sidman et al., 1985). A related strategy is to focus additional training efforts only on those previously trained relations that demonstrated restrictions in stimulus control when tested. For example, if a symmetric relation failed to be demonstrated between a specific B-C pair of stimuli, further training efforts could focus on that particular pair of relations. Such an iterative training strategy may prove to be more efficient than providing additional training for all previous stimulus relations that had received exposure to systematic instruction. However, further analyses are necessary to ascertain which of these strategies will be most effective in remedying deficiencies in stimulus control. Finally, if continued testing fails to demonstrate the intended relations, training of additional relations (i.e., previously untrained relations) may be warranted. Perhaps the direct training of individual symmetric (e.g., A1-B1 *and* B1-A1) and/or transitive relations (e.g., A1-B1, B1-C1, *and* C1-A1) may lead to further demonstration of previously restricted stimulus relations (e.g., B2-A2; C2-A2). However, when adopting such a strategy, instructors need to consider the costs and benefits of additional training efforts to achieve the intended stimulus control (Engelmann & Carnine, 1982; Horner, Bellamy, & Colvin, 1984; Stokes & Baer, 1977).

Two methodological points warrant brief discussion. First, two-node transitive relations, although they were the last relational properties to be observed, received twice the exposure during testing than did one-node transitive relations. That

is, for each intended stimulus class, four one-node transitive relations and two two-node transitive relations were made possible; however, one- and two-node transitive relations were given an equal number of probe trials, providing participants with exposure to twice the number of trials presenting two-node transitive relations. Despite this difference in exposure, clear and consistent patterns demonstrated nodality effects. It is possible, then, that if the number of trials during testing had been consistent across all derived stimulus relations, nodality effects may have been more pronounced.

We should also note that our study is methodologically conservative in its analysis of nodality effects. Because we used four-comparison displays that consistently presented the same stimuli across the entire study (Harrison & Green, 1990; Sidman, 1987), it appears that the stimulus-stimulus relations that emerged were based upon control by positive comparisons being related to the sample (Carrigan & Sidman, 1992; Saunders & Green, 1992). The concern that our findings reflect control by negative comparisons (i.e., exclusion) appears to be unlikely. That is, the positive tests for reflexive relations, along with the eventual demonstration of various derived relations, indicate that students' selections of comparison stimuli were based on a relation between samples and positive comparisons.

Although artifactual control by negative comparison relations does not appear to be a concern with the current investigation, concerns about the training outcomes should be noted. The primary concern is the extent to which we established categories or concepts based upon the four food groups. Only four examples per stimulus class were taught, no actual physical examples of items were trained (e.g., an actual container of cream), and no category labels (e.g., dairy products) were introduced. Future efforts should consider each of these aspects of the training protocol as important means of establishing generative categories. Subsequent research may also investigate the interrelated roles of stimulus equivalence, primary stimulus generalization, and other stimulus control phenomena as they relate to instances of stimulus class formation and concept development (Fields, Reeves, Adams, & Verhave,

1991; Hayes & Hayes, 1992; Herrnstein, 1990; Sidman, 1986). Yet to be studied is how equivalence relations interrelate with other stimulus control phenomena to comprise concepts that are based upon culturally defined stimulus classes (e.g., vegetables, birds, or trees).

As researchers continue to investigate the determinants of nodality effects, more will be known about how equivalence classes are established and the variables that influence the demonstration of stimulus control with various relational properties associated with equivalence. The current investigation provides evidence that nodality effects can be demonstrated with sight words given specific cultural definitions and that relational properties associated with equivalence can be demonstrated in an orderly pattern if initial tests do not provide evidence of equivalence. It also indicates some areas for future research regarding parameters that influence nodality effects and strategies for reducing the probability of restrictions in complex stimulus control.

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