*ALL STIMULI ARE EQUAL, BUT SOME ARE MORE EQUAL THAN OTHERS:
MEASURING RELATIONAL PREFERENCES WITHIN AN EQUIVALENCE CLASS*

ERICA DORAN

QUEENS COLLEGE OF THE CITY UNIVERSITY OF NEW YORK

AND

LANNY FIELDS

THE GRADUATE CENTER OF THE CITY UNIVERSITY OF NEW YORK

Two experiments used post-class formation within-class relational assessment test performances to evaluate whether participants demonstrated preference for certain members of an equivalence class based on the type of relation that existed between class members. In Experiment 1, two 5-node 7-member equivalence classes, consisting entirely of nonsense syllables, were established using the simultaneous protocol. Only 1 of the 6 participants in Experiment 1 formed classes. After class formation, the effects of the different relations between stimuli were evaluated using within-class relational assessment tests, and the 1 participant showed an absolute preference for transitive over equivalence relations, and for baseline over symmetrical relations. Experiment 2 was identical to Experiment 1, except that one of the nonsense syllable stimuli in each class was replaced by a pictorial stimulus. Under these conditions, classes were formed by 5 of 13 participants. During the relational assessment tests, the 5 participants who formed classes demonstrated almost exclusive preferences for transitive relations over equivalence relations and for trained baseline relations over symmetrical relations. Thus, this research demonstrates that the members of equivalence classes are differentially related to each other based on relational type.

Key words: equivalence class, relational preference, within-class preference, matching-to-sample, college students

“All animals are equal, but some are more equal than others.” Like the characters inhabiting the Orwellian dystopia of *Animal Farm*, individual members of an equivalence class may be equally related and yet, paradoxically, not equally related. The precise parameters under which members of an equivalence class display properties suggesting nonequivalence have not been fully explored, nor has this phenomenon been widely recognized by researchers in this field. The goal of this research is to further the understanding of the differences in relational strength among class members.

An equivalence class contains a finite number of stimuli (N) that bear no overt perceptual similarity to one another (Fields & Reeve, 2001; Fields & Verhave, 1987; Sidman, 1994; Sidman & Tailby, 1982). The stimuli in a class become related to the others through

training of a limited number (N-1) of baseline conditional discriminations among the N stimuli. Following baseline training, tests that contain combinations of stimuli in a set are presented to determine the emergence of the untrained, or derived, stimulus–stimulus relations. When presentation of each stimulus in a test evokes selection of the other stimuli in the class without direct training, an equivalence class has been formed (Fields & Verhave, 1987). This mutual selection of stimuli indicates that the members of an equivalence class are functionally interchangeable (Sidman, 1994). Thus, it has been postulated that the members of an equivalence class are each equally related to each other. This view has been supported by tests that demonstrated functional equivalence, in which a function acquired by one member of the class generalizes to all other members of that class but not to members of other equivalence classes (Barnes, Browne, Smeets, & Roche, 1995; Barnes & Keenan, 1993; Fields, Adams, Verhave, & Newman, 1993; Rehfeldt & Hayes, 1998; Saunders, Wachter, & Spradlin, 1988;

Correspondence concerning this article should be addressed to Erica Doran, Department of Psychology, Queens College/CUNY, 65-30 Kissena Boulevard, Flushing, New York 11367 (e-mail: Erica.Doran@qc.cuny).

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Sidman & Tailby, 1982; Sidman, Wynne, Maguire, & Barnes, 1989).

This view has been challenged, however, by researchers who argue that, under some conditions, different pairs of stimuli can have different levels of relatedness. Fields and Verhave (1987) identified four atemporal variables that defined the structures of all equivalence classes: class size, number of nodes, training directionality, and nodal density. It is possible that any or all of these variables, either alone or in conjunction with each other, influence the level of relatedness between stimuli in an equivalence class.

To date, most of the inquiries into this possibility have focused on the effects of nodal differences on the relatedness of stimuli in equivalence classes. Nodal distance is defined as the number of nodes that link two stimuli within an equivalence class (Fields & Verhave, 1987). Thus, in a five-member equivalence class established by training $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$, and $D \rightarrow E$, resulting in an equivalence class with the structure of $A \rightarrow B \rightarrow C \rightarrow D \rightarrow E$, one node separates the A and C stimuli, while two nodes separate A and D and three nodes separate A and E. An inverse relation between nodal distance and relatedness has been found in a variety of measures, including order of emergence of derived relations when delayed emergence occurs (Bentall, Jones, & Dickens, 1998; Fields, Adams, Verhave, & Newman, 1990; Kennedy, 1991; Kennedy, Itkonen, & Lindquist, 1994; Sidman, Kirk, & Willson-Morris, 1985; Spencer & Chase, 1996), performance on function transfer tests (Fields et al., 1993), response speed (Bentall, et al.; Kennedy; Spencer & Chase, 1996; Tomanari, Sidman, Rubio, & Dube, 2006; Wulfert & Hayes, 1988), dual option function transfer tests (Fields, Landon-Jimenez, Buffington, & Adams, 1995; Fields & Watanabe-Rose, 2008), and within-class preference tests (Alligood & Chase, 2007; Fields, Adams, & Verhave, 1989; Fields et al., 1993; Moss-Lourenco & Fields, 2011). These findings all support the view, as proposed by Fields and Verhave (1987), that when the type of stimulus-stimulus relation is held constant, the relatedness of stimuli is an inverse function of the nodal distance that separates the stimuli in the class. The difference in relatedness among stimuli, however, does not imply that these same stimuli are not also still functioning as members of an

equivalence class. Moss-Lourenco and Fields (2011) addressed this issue by administering a post-preference equivalence test that demonstrated the intactness of the originally formed classes immediately after the administration of the within-class preference tests. The stimuli thus continued to function as equivalence class members while also displaying differing levels of relatedness based on nodal distance. Complimentary findings were obtained when using the semantic differential to assess the post-class formation effects of nodal distance on stimulus relatedness in equivalence classes (Bortoloti & de Rose, 2009).

Nodal distance, however, is only one of the four atemporal factors, mentioned above, that define the structure of an equivalence class. Thus, the other structural factors might also influence the relatedness of stimuli in an equivalence class. Of interest in the present research was training directionality. Directionality of training produces different derived relations between stimuli within the class. To illustrate this analysis, suppose a three-member class is to be formed by training $A \rightarrow B$ and $B \rightarrow C$. Following establishment of these baseline relations, different derived relations would emerge: $B \rightarrow A$ and $C \rightarrow B$ would be 0-node symmetrical relations in which the directionality of the trained relation is reversed, $A \rightarrow C$ would be a one-node transitive relation, and $C \rightarrow A$ would be a one-node equivalence relation, in which the directionality of the relation is reversed. In this example, no logical operations are required to evoke B when presented with A because it is a directly trained relation. On the other hand, one logical operation, symmetry, is required to evoke A when presented with B in the symmetrical relation BA. Similarly, one logical relation, transitivity, is required to evoke C when presented with A in the transitive relation AC. That is, to get from A to C, a participant needs to "connect" these stimuli by using the B stimulus as a node. In CA, an equivalence relation, to evoke A when presented with C requires two logical operations; a participant must use both the symmetrical property to connect $C \rightarrow B$ and $B \rightarrow A$ and the transitive property to then link C with A through the nodal stimulus, B. The need for these two logical operations has led some researchers to refer to equivalence relations as

combined symmetry/transitivity relations (Spencer & Chase, 1996).

This analysis suggests that relations requiring more logical operations might be said to be more "complex" than those requiring fewer logical operations. We propose that the strength of a relation, and thus preference for one relation relative to another, should be greater for relations that are simpler; that is, relations that require fewer logical operations to link the stimuli in the relation. It follows from this premise that a simpler relation such as a one-node transitive relation would be preferred to a more complex relation such as a one-node equivalence relation. In this comparison, the nodal separation of stimuli in each relation is held constant. Such an outcome would provide further support for the view that all stimuli in an equivalence class are not equally related to or interchangeable with each other.

This possibility has received some support (Alligood & Chase, 2007; Imam, 2001; Spencer & Chase, 1996). These experiments, however, contained certain confounds. For example, the researchers did not control for differences in nodal distances between class members, the number or type of functions served by the comparison stimuli during training, the serial order of the training in the simple-to-complex protocol, or the numbers of training and testing trials for each stimulus-stimulus relation. These confounds make it difficult to determine if differences in responding found in those experiments were due to differing relational strengths among class members or the other factors mentioned above. We are not aware of any data that have directly addressed the issue of whether stimuli within a class have differential strength of relatedness as a function of the different stimulus-stimulus relations without any such confounding variables.

One possible reason that such research has not been forthcoming is due to pragmatic difficulties. First, relatively large classes would need to be used for such research. As alluded to above, because of the size of the classes used in previous research, the relative strengths of the different within-class relations could not be tested without some confound, such as prior trained function of the stimulus or nodal distance. For example, if a class containing A1, B1, C1, D1, and E1 stimuli were used, a within-class relational assessment test could be

presented using the C1 stimulus as the sample and the A1 and E1 stimuli as comparisons. The C1→A1 relation would be a one-node equivalence relation, while the C1→E1 relation would be a one-node transitive relation. Selection of the E1 comparison might indicate a preference for the transitive relation but it could also reflect the fact that E1 had previously been presented as a comparison, whereas A1 was presented only as a sample. The present research avoided this confound by establishing larger equivalence classes with more nodal stimuli, which allowed for the use of comparison stimuli that had served identical functions in training.

EXPERIMENT 1

In Experiment 1, two 5-node 7-member classes, consisting entirely of consonant-vowel-consonant nonsense syllables, were trained. A simultaneous protocol with a linear structure was used ($A \rightarrow B \rightarrow C \rightarrow D \rightarrow E \rightarrow F \rightarrow G$) to allow for the use of within-class probes that held constant nodal distance and stimulus function while evaluating whether participants demonstrated a preference for certain stimuli based upon the directionality of training.

If members of an equivalence class are fully substitutable, indifference should be observed. If, on the other hand, the stimuli within an equivalence class were differentially related based upon directionality of training, participants should prefer the comparison stimulus that represented the derived relations that required fewer logical linking operations.

METHOD

Subjects

The 6 participants were students enrolled in a psychology course at Queens College. They were given partial course credit for completing a single 2–3 hr session.

Setting and Apparatus

The experiment was conducted in a quiet room on the Queens College campus. The room contained a table and chair. On the table was an IBM-compatible computer, 15" VGA monitor and a standard QWERTY keyboard. The experiment was controlled by custom software that programmed all stimulus

presentations and recorded all keyboard responses.

Stimuli

This experiment used two different types of stimuli: (a) words believed to be semantically linked and readily recognizable to subjects fluent in the English language; and (b) nonsense syllables that had no apparent "meaning" or little associative value, as determined beforehand through a reference/word association value test administered to a separate pool of participants.

The words were used in the keyboard familiarization and response training phases of the experiment only. The nonsense syllables were used in the equivalence class training and testing portions of the experiment, as well as the extreme difference and relational assessment tests. These stimuli were grouped into three sets, two equivalence sets and a "null" set, each of which contained seven nonsense syllables.

The null comparison was included for two reasons. First, some researchers have argued that presenting two comparisons is insufficient because participants might be forming only one equivalence class and a "reject" class, rather than forming two distinct classes (Sidman, 1987). The use of three comparisons, one from each class and a third comparison from neither of the two classes, averts this potential outcome. Second, prior researchers have found that inclusion of a null comparison appears to sensitize participants to the underlying structure of the equivalence classes they form (Moss-Lourenco & Fields, 2011).

The two sets of stimuli used in Experiment 1 were as follows: Set 1 contained *LEQ* (A1), *TYW* (B1), *MEV* (C1), *GIP* (D1), *HUK* (E1), *FOM* (F1), and *YUF* (G1), while Set 2 contained *XAH* (A2), *PYV* (B2), *JEP* (C2), *BUH* (D2), *GAZ* (E2), *BEW* (F2), and *XOL* (G2). The null comparison set contained *NIR* (A3), *TIJ* (B3), *ZUC* (C3), *WEX* (D3), *RAB* (E3), *XOL* (F3), and *COH* (G3).

PROCEDURE

Trial format and contingencies. All trials in the experiment were presented using the simultaneous matching-to-sample format (Cumming & Berryman, 1965). In each trial, one sample and either two or three comparisons were

presented. The samples were drawn from either Set 1 or Set 2. When two comparisons were presented, the positive comparison was from the same set as the sample and the negative comparison was from the other set. When three comparisons were presented, the third comparison was drawn from the "null" comparison set. In each trial, the sample was presented on the upper portion of the monitor and was centered horizontally. The comparisons were on the lower portion of the monitor, evenly spaced horizontally. The location of the positive comparison was randomly assigned across trials.

A trial began when "Press ENTER" appeared on the screen. Pressing the ENTER key cleared the screen and a sample stimulus was displayed. Pressing the "B" key on the keyboard added the comparison stimuli to the display. Participants selected a comparison stimulus by pressing the corresponding key. When two comparisons were presented, participants pressed the "1" key to select the comparison on the left and the "2" key to select the comparison on the right. In trials where three comparisons were presented, participants pressed "1", "2" or "3" to select the left, middle or right comparison, respectively.

A comparison selection cleared the screen and immediately displayed a feedback message centered on the screen. The message could be either informative ("RIGHT" or "WRONG") or noninformative. Informative messages remained on the screen until the participant pressed the R key (RIGHT) or the W key (WRONG), ensuring that the participant discriminated the feedback information. Non-informative messages consisted of a dashed line that bracketed the letter E (i.e., - - E - -) and remained on the screen until the E key was pressed. Correct key presses following a message cleared the message from the monitor, ended the trial, and started the next trial (Fields et al., 1995).

Phase 1: Instructions, keyboard familiarization, and response training. The experiment began with the presentation of the following on-screen instructions:

Welcome. In this experiment you will be shown many trials. Each trial starts with the presentation of one cue at the top of the screen followed by the presentation of two cues at the bottom of the screen. Each cue is either a word, a picture or a 3-letter

string. Your task is to learn which cues go together. The first cue will appear after a short delay. Then press the B key to see the second two cues. If the cue at the top of the screen goes together with the cue on the bottom left, pressing the 1 key is correct. If the cue at the top of the screen goes together with the cue on the bottom right, pressing the 2 key is correct. If the feedback is "right", press the R key. If the feedback is "wrong", press the W key. If the feedback is "no feedback" press the E key. CALL THE EXPERIMENTER IF YOU HAVE QUESTIONS. If not, press "Enter" to continue.

Pressing the "Enter" key initiated the repeated presentation of a block of 16 trials. Trials contained three English words, such as KING, QUEEN, and CAMEL. The semantic relation between the sample word (e.g., KING) and one of the comparisons (e.g., QUEEN) was used to prompt the selection of the correct comparison. The word RIGHT or WRONG followed each comparison selection. Correct responding was facilitated by the presentation of instructional prompts (e.g., "Make your choice by pressing 1 or 2," "Press R to continue,"), which were systematically deleted across trials as long as the participant made correct responses (see Fields et al., 1990, 1997). Phase 1 ended when the sample and comparison stimuli were presented without prompts, and performance was at 100 % accuracy during a single block.

Phase 2: Establishment and maintenance of baseline relations using the simultaneous protocol. Training involved the establishment of the baseline relations necessary to form two 5-node 7-member equivalence classes. All baseline relations ($A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$, $D \rightarrow E$, $E \rightarrow F$, and $F \rightarrow G$) were presented in a single block of 36 trials, using the simultaneous protocol. The simultaneous protocol was used to equalize exposure to each baseline relation and to avoid confounding the order in which baseline relations were trained with the nodal distance that separated the stimuli in the class. Three comparisons were presented on each trial. The baseline relations were presented repeatedly until participants attained the mastery criterion of 100 % accuracy in the block.

Informative feedback was provided on all trials until participants reached the mastery criterion within a block. In subsequent blocks the percentage of trials that produced informative feedback was reduced to 75 %, 25 %, and finally to 0 %, across blocks. During feedback reduction, a random generator

determined the trials that produced informative feedback. If the mastery criterion was not achieved within three blocks at a given feedback level, the participant was returned to the previous feedback level in the next block. Participants were excused from the experiment if they had not attained the 100 % mastery criterion after 2 hrs of Phase 2 training.

Phase 3: Testing for equivalence class formation. In this phase, across three 28-trial blocks, tests of the following stimulus-stimulus relations were assessed: 12 trained baseline relations, 12 derived symmetrical relations, ten 1-node transitive relations, ten 1-node equivalence relations, eight 2-node transitive relations, eight 2-node equivalence relations, six 3-node transitive relations, six 3-node equivalence relations, four 4-node transitive relations, four 4-node equivalence relations, two 5-node transitive relations, and two 5-node equivalence relations. These 12 different relations were distributed as equally as possible across these three blocks. For example, each of the three blocks contained four 1-node transitivity probes and four 1-node equivalence probes. No informative feedback was provided during Phase 3. The three-block sequence was repeated up to four times, in the same order. The criterion for equivalence class formation was >96 % correct trials in a block for any three consecutive blocks. Participants who failed to demonstrate equivalence class formation after 12 blocks were excused from the remainder of the experiment.

Phase 4: Extreme-difference tests. Table 1 shows the two different tests arranged during Phase 4, each composed of two probes. Each test was designed to assess preferences for relations between each comparison stimulus and a prevailing sample stimulus where the relations differed across many dimensions: nodal distance, relational type, and trained versus untrained relations. The first letter in the probe refers to the sample stimulus and the second and third letters refer to the comparison stimuli related to the sample by simpler and more complex relations, respectively. For example, on probe ABG, A is the sample, B is a 0-node baseline relation and G is a 5-node transitive relation (the latter being the more complex relation). Each of the two extreme-difference tests was composed of 16 randomly sequenced trials: four of each of the probes

Table 1
Extreme difference tests in Phase 4

Test	Probe	Sample	Nodally Proximal Comparison			Nodally Distal Comparison		
			Comp	Nodes	Relation	Comp	Nodes	Relation
1	ABG	A	B	0	Baseline vs.	G	5	Transitive vs.
	GFA	G	F	0	Symmetric	A	5	Equivalence
2	ABF	A	B	0	Baseline vs.	F	4	Transitive vs.
	GFB	G	F	0	Symmetric	B	4	Equivalence

shown for each test in Table 1, multiplied times the two stimulus classes (e.g.,A1-B1-G1 and A2-B2-G2). A test was concluded when participants selected the simpler comparison on 15 of 16 trials or the sequence of 16 trials was completed three times, whichever came first.

In the first extreme-difference test preferences for the comparison more simply related to the sample could be interpreted in different ways because the comparison stimuli differed in terms of the number and type of functions they served during training. For example, in the ABG probe, the B comparison served two functions, sample and comparison during training, while the G comparison served only as a comparison during training. Thus, selection of B over G may reflect preference for the simpler relation but it may also reflect a preference for the comparison that served more functions (and consequently was presented in more trials) during training. Therefore, in the second test (see Table 1) both of the comparisons arranged in a trial had previously served as sample and comparison stimuli during training. In addition, to rule out the possibility that choices reflected unconditioned preferences for a comparison stimulus (e.g., stimulus B), the second probe in this test (GFB) reversed the nodal distance and complexity of the relations between sample and comparisons. Choosing B on both the ABF and GFB trials would reveal such a bias, whereas choosing B and F on these trials, respectively, would demonstrate a systematic preference for the nodally proximal and less complex relation. As before, participants completed up to three blocks of 16 trials unless they chose the simpler comparison on 15 of 16 trials within a block.

Phase 5: Within-class relational assessment tests. Next, participants chose between two compar-

ison stimuli, each with a different relation to the sample stimulus, but separated from the sample by the same number of nodes. As shown in Table 2, three tests were conducted, each containing a pair of probes. The first probe was of primary interest (henceforth referred to as the target probe) and the second (the companion probe) served to clarify the nature of the preference (see below). Trial blocks and the criterion for advancing to the next test within Phase 5 were as in Phase 4.

The comparison stimuli arranged in the DGA target probe had served the same number of functions during training, but they were different functions. The G stimulus had served as a comparison only, while the A stimulus had served as a comparison only. Interpreting the selection of G would be difficult because it could reveal control by the complexity of the relation (transitivity as opposed to equivalence), by the function it had served during training (comparison as opposed to sample), or by an unconditioned preference for the stimulus. Thus, the companion probe (BAG) included the same comparison stimuli, but with different nodal distances to the sample (A has a 0-node symmetrical relation with B, while G has a 4-node transitive relation with B). Given the previous finding that participants prefer the nodally proximal stimulus over the nodally distal one (Moss-Lourenco & Fields, 2011), one would expect participants to choose the A comparison on these companion probe trials. Selecting A would argue against the possibility that selecting G in the DGA probe was controlled by an unconditioned preference for G or a preference for the comparison stimulus that had served as a comparison during training.

Table 2
Within-class preference probes in Phase 5

Test	Probe	Sample	Predicted Preferred Comparison			Predicted Non-Preferred Comparison		
			Comp	Nodes	Relation	Comp	Nodes	Relation
1	DGA	D	G	2	Transitive	A	2	Equivalence
	BAG	B	A	0	Symmetric	G	4	Transitive
2	DFB	D	F	1	Transitive	B	1	Equivalence
	CBF	C	B	0	Symmetric	F	2	Transitive
3	DEC	D	E	0	Baseline	C	0	Symmetric
	BCE	B	C	0	Baseline	E	2	Transitive

In the second test of Phase 5, on the target probe, DFB, the comparisons were related to the sample by a smaller nodal distance. This allowed for the use of comparisons that had each served two functions (sample and comparison) during training. The companion probe, CBF, arranged the same comparisons, but with B nodally more proximal to the sample than F. Selection of B would argue against the possibility that F was selected on the DFB probe because of an unconditional preference for that stimulus.

In the final test of Phase 5, the target probe, DEC, assessed preference between comparisons with 0-node baseline or symmetrical relations to the sample. As in test 2, both comparison stimuli had served two functions during baseline training. Therefore, the companion probe, BCE, held the comparison stimuli constant while varying nodal distance. This was used to assess whether such selection reflected an unconditioned preference for a stimulus while further assessing the effects of sample-comparison relation on participants' preferences by manipulating nodal distance. Given the nodally proximal relation, one would expect selection of C over E.

Phase 6: Derived relations test. To determine if the previously established equivalence classes were disrupted by the within-class extreme difference and relational assessment tests, Phase 3 was repeated. Participants who achieved 96 % correct selections on any three consecutive trial blocks were deemed to have intact equivalence classes.

RESULTS AND DISCUSSION

Of the 6 participants in this experiment, 3 did not learn the baseline relations during the training procedure described in Phase 2 and were dismissed from further participation.

Two more participants acquired the baseline relations in Phase 2 but were dismissed after Phase 3 when they did not demonstrate equivalence class formation. The remaining participant, NW, acquired the baseline relation in eight blocks and then demonstrated the formation of equivalence classes by the immediate emergence of the derived relations in the minimum of three testing blocks.

Figure 1 depicts the outcomes of the within-class extreme-difference and relational assessment tests for participant NW. In the first extreme-difference test of Phase 4, NW exclusively preferred the comparisons that were nodally more proximal and required fewer logical operations to relate the sample and comparison stimuli. In the second test, the comparison stimuli in both probes were identical. Participant NW demonstrated a consistent preference for the nodally simpler relations (AB over AF and GF over GB) and selected a different comparison stimulus in each test (thereby ruling out an unconditioned preference for a single comparison stimulus). This finding suggests differential strength of stimulus-stimulus relations in the same equivalence class.

In the portion of Phase 5 in which the participant chose between a comparison stimulus related to the sample via transitivity versus a comparison related to the sample via equivalence (center portion of Figure 1), the participant exclusively preferred the comparison stimuli that were transitively related to their respective samples. This was observed in two tests, both of which held constant the nodal distance across comparison stimuli, but varied nodal distance across tests. These preferences reveal a relational difference between the less complex transitive relation, which involves only one logical operation, and

Fig. 1. Performance on within-class extreme-difference and relational assessment tests in Experiment 1 for Subject NW. The boxes over the bars, each containing a single letter, indicate the predicted outcomes for each of the probes in each test. The letters beneath each pair of bars indicate samples and comparisons used in the target and companion probes that are presented in each test.

the more complex equivalence relation, which involves two logical operations.

The final test revealed exclusive preference for a 0-node baseline relation (DE) over a 0-node symmetrical relation (DC). As with the prior relational assessment tests, because preference tracked relational complexity rather than any single comparison stimulus (i.e., BC was chosen to the exclusion of BE), this preference reveals a difference in the strength of relations within an equivalence class. In Phase 6, the participant made correct choices on all trials in the first three trial blocks, thereby demonstrating that the original equivalence classes remained intact.

Overall, the single participant who formed the stimulus equivalence classes consistently preferred the comparison stimulus that was nodally more proximal to the sample stimulus. This replicates findings reported by Alligood and Chase (2007); Fields, Adams, and Verhave (1989); Fields et al. (1993); and Moss-Lourenco and Fields (2011). In addition, we provided evidence suggesting (for the first time) that the stimuli within an equivalence class are differently related based upon the number of derived operations required to form the relations. This outcome is contrary to the view advanced by various researchers, such as Sidman (1994, 2000)

and McIlvane & Dube (2003), who contended that all members of an equivalence class are interchangeable. Importantly, our participant demonstrated that the equivalence classes remained intact after the preference tests. Thus, the differential relations among stimuli in a class would appear to be always present but their expression depends on the sensitivity of the test to detect these differential strengths.

A significant shortcoming of Experiment 1 was that only one participant passed the initial equivalence test and completed the preferences tests. Given this low yield, gathering adequate data required either an untenably large number of participants or else a somewhat different experimental protocol.

EXPERIMENT 2

The simultaneous protocol used in Experiment 1 allowed us to minimize confounds and measure the effects of structural variables on relations among stimuli in equivalence classes. This protocol, however, resulted in a low yield, 1 of 6 participants (see also Buffington, Adams, & Fields, 1997; Fields et al., 1995). To extend the findings of Experiment 1 and better evaluate the outcomes with a larger pool of participants, Experiment 2 incorporat-

ed changes to the simultaneous protocol designed to improve the yield obtained. Specifically, Fields, Arntzen, Nartey, and Eilefson (2012) demonstrated that yields in the simultaneous protocol could be increased from 20% to 80% by including a single pictorial stimulus in each stimulus set. Although these researchers used five-member sets, such an approach might enhance participants' ability to form seven-member equivalence classes. Therefore, a nameable pictorial stimulus was included in each set used in Experiment 2, which was otherwise identical to Experiment 1.

METHOD

Subjects

Thirteen Queens College students served as participants in Experiment 2.

Stimuli & Procedures

This experiment used the same stimuli as Experiment 1, but the nonsense syllable used as the D stimulus in each class was replaced with a pictorial representation of a commonly recognizable object. The pictorial stimuli are represented as Dp, and were as follows: Church (D1p), Crown (D2p), and Mailbox (D3p), the latter being the null comparison stimulus. All other procedures were identical to those used in Experiment 1.

RESULTS AND DISCUSSION

Three of the 13 participants did not acquire the baseline relations in Phase 2 and were excused from the remainder of the experiment. Five of the remaining 10 participants demonstrated equivalence class formation and, therefore, completed the remainder of the experiment. Of these 5 participants, 3 showed immediate emergence of equivalence relations, achieving mastery in the minimum of 3 blocks required to probe all possible derived relations. The other 2 participants showed delayed emergence, requiring five and nine blocks to reach mastery.

Figure 2 depicts the outcomes of the within-class extreme difference and relational assessment tests for the 5 participants who formed the two 5-node 7-member equivalence classes. The data are presented in a manner similar to that in Figure 1. Data for each participant are presented in separate panels.

In the first test of Phase 4, participants exclusively preferred the 0-node comparison stimulus over the multi-node comparison. The same was true in the second test of Phase 4 but participants selected a different comparison stimulus (F instead of G) to demonstrate preference for the simpler relation.

In Phase 5 tests in which the participants chose between a comparison stimulus related to the sample via transitivity versus a comparison related to the sample via equivalence, 4 of the 5 participants demonstrated a consistent preference for the comparison representing the transitive relation when the sample and comparisons were separated by two nodes, and all 5 participants demonstrated this relational preference when the sample and comparisons were separated by one node. Participant DF was the exception in the DGA probe. This participant selected the comparison on the right side of the display on every trial (regardless of stimulus class); a pattern of choice that did not continue into the 2-node DFB probe.

In the final target test of Phase 5 in which participants chose between a comparison related to the sample via direct training (DE) versus one related to the sample via symmetry (DC), all participants preferred the E comparison. In the companion probe, all participants exclusively chose the nodally more proximal C comparison, thereby demonstrating that the prior preference for E was not due to an unconditioned bias.

In Phase 6, all 5 participants passed the final derived relations test. Moreover, they each did so in the first three blocks, the minimum number of blocks required to demonstrate mastery in this phase. These results show that the intactness of the underlying equivalence classes was not influenced by exposure to the within-class relational assessment tests that showed differential strengths of stimuli within the class.

GENERAL DISCUSSION

We expected that the relational strength of the stimuli in an equivalence relation would be inversely related to the number of logical operations required to link the two stimuli in the relation. In contrast, previous researchers have asserted that, once an equivalence class is fully formed, all members of the class are

Fig. 2. Performance on within-class extreme-difference and relational assessment tests in Experiment 2. Data for each participant are presented in a separate panel while the participant is identified by the two letters in the box to the right of the panel. The format of each panel is the same as that used in Figure 1.

equally related and fully substitutable for each other (McIlvane & Dube, 2003; Sidman, 1994, 2000; Sidman & Tailby, 1982). If this were correct, one would expect that on the within-class probes, participants would have chosen

each comparison on approximately 50% of the trials. This, however, was not the case. The participants in Experiments 1 and 2 showed a clear and consistent preference for the comparison stimulus that, in relation to the sample

stimulus, represented the relation requiring fewer derived or logical operations. These performances provide credible support for the hypothesis that the individual stimuli within an equivalence class are differentially related, based on the complexity of the stimulus-stimulus relations linking the different class members.

It might be argued that other sources of stimulus control, such as nodal distance, unconditional preference for a given comparison stimulus, or a preference for a comparison stimulus based on the number or type of functions that stimulus served during the training of baseline relations, may have controlled responding. Each of these possibilities was controlled for, however, by the combination of target and companion probes administered in the within-class preference portions of the experiments. Indeed, if these factors were exerting control, participants would have chosen each comparison on 50% of the trials.

The results of these tests, however, were quite different. In total, 6 individuals from Experiments 1 and 2 formed equivalence classes. Each of these participants completed the two within-class relational assessment tests that evaluated preferences for stimuli representing the transitive relation to that representing the equivalence relation. On 11 of these 12 probes, participants demonstrated a clear preference for the transitive relations, which require only one logical operation, over the equivalence relations, which required two logical operations. For each probe, which contained eight trials per test block, the likelihood of selecting comparisons that indicated a preference for the transitive relations by chance was 0.5 to the 8th power for a given probe. The likelihood of obtaining our results by chance would be .5 to the 88th power. Thus, this consistent selection of the stimuli that defined the less complex transitive relations provides convincing evidence that participants differentiated between the stimuli within an equivalence class based upon the nature of the derived stimulus relations within that class.

The relational strength of stimulus pairs that pitted trained baseline relations against symmetrical relations was also evaluated. On five of these six probes (one for each of 6 participants), each of which contained eight trials per block, participants demonstrated a preference for the trained baseline relation

over the symmetrical relation. The likelihood of obtaining these results by chance would be .5 to the 40th power. These results provide further convincing evidence that participants differentiated between the stimuli within the equivalence classes based upon their relation to the sample stimuli.

When the cumulative performance of all 6 participants on all three within-class relational assessment tests are considered, 16 of 18 probes resulted in the consistent selection of the comparison stimulus that was linked to the sample stimulus by fewer logical operations. Thus, the type of relation that existed between the stimuli in an equivalence class influenced the relatedness of the stimuli; the stimuli in the less complex relation are more strongly related to each other than are the stimuli in a more complex relation and that the members of an equivalence class are not, in fact, functionally interchangeable as theorized by Sidman & Tailby (1982).

In general, a theory can be evaluated empirically only with tests that can produce data which can disconfirm the predictions of the theory. The within-class test trials used in the present experiments are of that sort; because they do not preordain any particular performance, the performances on the test trials could either disconfirm or be in accordance with the predictions set forth in our theoretical analysis. The fact that virtually all test trials produced performances that accorded with our theoretical analysis then strengthens the case for differential strengths of relations among the stimuli in an equivalence class.

The results of the present experiments extend support for the model of differential relatedness among stimuli in an equivalence class to include not only nodal distance but now also the types of relations that exist among stimuli in the equivalence class. This result does not, however, imply that the stimuli in a class cannot also function in an interchangeable or substitutable manner. Although all of the stimuli in an equivalence class are differentially related, they are still more closely related to each other than to any stimuli in other classes, as evidenced by participants' performance on the final derived relations tests.

Participants' performance on both the within-class preference trials and the cross-

class equivalence class formation trials suggests that control over responding changed with the types of test trials presented, in the absence of any explicit instructions or training in this regard. That is, between- and within-class stimulus control topographies co-existed but were evoked differentially. Another way to look at this phenomenon would be to examine the effects of cross- and within-class contingencies throughout the various phases of these experiments. During training of baseline relations, the trained contingencies established cross-class discriminations. The training structure, however, resulted in different levels of within-class relatedness. During between-class tests in this phase, the trained contingencies overshadowed the structural effects, resulting in responding in a class-consistent manner indicative of equal relatedness among class members. Similarly, during the phases that tested for equivalence class formation and maintenance, these contingencies again overshadowed the training structure within the class, resulting in performance on between-class tests that indicated equal relatedness among class members. On the within-class tests administered during the preference phases of these experiments, however, the training structure overshadowed the trained contingencies, resulting in performance that indicated differential relatedness among class members. Thus, depending on the nature of the trial, the same stimulus can act as a discriminative stimulus for either equal relatedness (on between-class trials) or differential relatedness (on within-class trials). This may explain why some research has supported the theory of equal relatedness and complete substitutability, even though the current research demonstrates that this theory is correct only in certain testing conditions; in the present experiments, the stimuli were functioning as members of an equivalence class, as evidenced by participants' performances on the derived relations tests, while still being distinguishable and not wholly interchangeable, as evidenced by participants' performances on the within-class extreme differences tests. To paraphrase George Orwell, all members of an equivalence class are equal (as evidenced by performance on cross-class tests), but some are more equal than others (as evidenced by performances on within-class tests).

The current research established that stimuli within an equivalence class are differentially related based on two atemporal factors: nodal distance and relational type. What is not known is the relative influence of these two structural parameters when used together. This issue can be addressed in future research that pits transitive relations of various nodal distances against equivalence relations with nodal distances that do not match those for the transitive relations. The identification of these interactions would make more comprehensive our knowledge of structural factors that influence relatedness of the stimuli in equivalence classes.

Finally, we will briefly discuss procedural issues related to the use of a nameable picture as the D stimulus in Experiment 2. The likelihood of equivalence class formation is usually very low when training and testing are conducted using the simultaneous protocol, often being less than 20% (Buffington, et al., 1997; Fields et al., 2012; Fields et al., 1995). Moreover, the yield obtained under the simultaneous protocol is generally an inverse function of class size (Fields et al., 2000). Consistent with these findings, when all of the stimuli were nonsense syllables (Experiment 1) 50% of the participants acquired the baseline discriminations and only one participant (17%) formed large multinodal equivalence classes. In Experiment 2, when a nameable pictorial stimulus was substituted as the D stimulus, the percentage of participants who acquired the baseline discriminations increased to 77% and 38% formed equivalence classes.

How the inclusion of the pictures enhanced the acquisition of baseline discriminations and the formation of equivalence classes is unclear. A number of studies have shown that once an equivalence class has been formed, its expansion is probable (Fields, Newman, Adams, & Verhave, 1992; Saunders et al., 1988). In the present experiment, it is plausible that the nameable pictures were actually members of already existing generalized equivalence classes. Thus, the "formation" of each new seven-member equivalence class that included a picture might actually have involved the expansion of an already existing class by six more members.

Not all participants in Experiment 2, however, successfully expanded the classes; in fact,

the 50% yield (i.e., percentage of participants who acquire baseline discriminations who also demonstrate equivalence relations) obtained here was notably lower than the 80% yield obtained in the research conducted by Fields et al. (2012), in which classes were expanded by four members. This result suggests that the likelihood of successful expansion is an inverse function of the amount by which the class is to be expanded.

While the inclusion of a pictorial stimulus in each set increased the percentage of participants who formed classes, and thus were able to complete the within-class relational assessment tests, the use of a pictorial stimulus was not necessary for the primary finding of this research, that participants discriminate between members of an equivalence class and demonstrate a preference for the stimuli representing the less complex relations. This is apparent from the fact that the only participant to form equivalence classes in Experiment 1 performed in an identical manner on the within-class tests as participants in Experiment 2. Thus, the inclusion of nameable stimuli did not influence participants' performance on the within-class preference probes.

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