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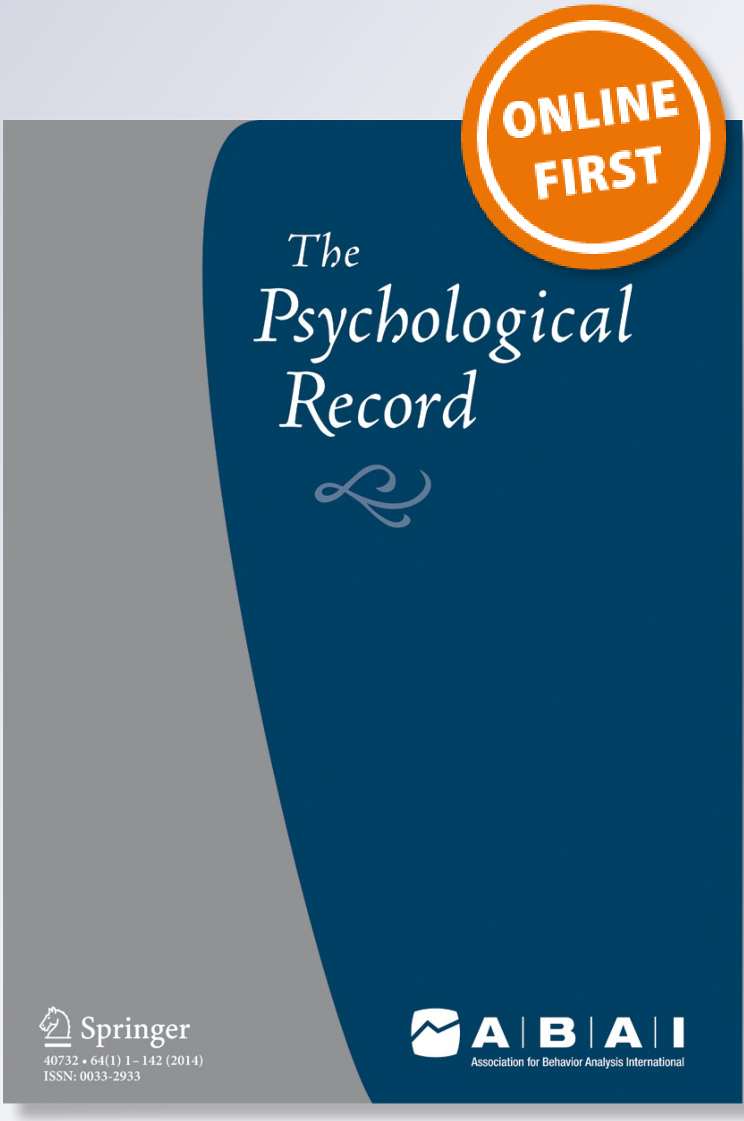

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ORIGINAL ARTICLE

Interactions Between Equivalence Relations and the Development of Analytic Units

Manish Vaidya · Ryan J. Brackney

Abstract Two experiments investigated possible interactions between existing equivalence relations among stimuli and the acquisition of simple discriminations involving the same stimuli. During the first phase of Experiment 1, two adult humans learned two sets of six conditional relations among arbitrary visual stimuli designed to produce two independent sets of three, three-member equivalence classes (Set 1 and Set 2). Subjects whose performance met accuracy criteria on tests for equivalence relations proceeded to a second phase in which subjects were taught, via reinforcement, to make the same response to a cluster of three stimuli (e.g., response 1 in the presence of A1, B1, and C1). The clusters of three stimuli were initially consistent with documented equivalence relations for both Set 1 and Set 2 stimuli. In the second half of this phase, the contingencies were realigned such that the simple discriminations being established were consistent with documented equivalence relations for Set 1 stimuli but inconsistent for Set 2 stimuli. Results showed that the simple discriminations were acquired faster for Set 1 stimuli than for Set 2 stimuli. Experiment 2 introduced a third set of stimuli as a control set and systematically replicated Experiment 1 with four subjects. This study found that three of four subjects acquired simple discriminations faster when the cluster of stimuli were drawn from within equivalence classes rather than across equivalence classes. The development of equivalence relations with Set 3 stimuli constrained the utility of the control condition in this experiment. The results are best interpreted as suggesting that existing equivalence relations among stimuli can interact with the development of analytic units such as simple discriminations to either facilitate or retard their development.

Keywords Stimulus equivalence · Transfer of function · Adult humans · Analytic units · Discrimination training · Interference

Sidman's most recent exposition of a theory of stimulus equivalence (1994, 2000) considerably expanded the scope and origins of stimulus equivalence relations relative to his earlier writings (cf. Sidman and Tailby 1982; Sidman 1986). In these early formulations, Sidman and his colleagues described equivalence relations emerging at the level of four-term contingencies of reinforcement and involving the reversal and recombination of the discriminative and conditional stimulus functions established during the baseline matching-to-sample training (cf. Sidman and Tailby 1982; Sidman et al. 1982). In contrast, Sidman's latest treatments (1994, 2000) suggest that equivalence relations are an outcome of reinforcement contingencies and involve all positive elements of the analytic unit, including the response and the reinforcer (Sidman 1994, 2000).

Specifically, Sidman (2000) proposes that reinforcement contingencies produce at least two outcomes – the development of the familiar units of analysis such as three-term simple discrimination or four-term conditional discrimination, and the development of equivalence relations. Unlike earlier formulations in which equivalence relations were limited to the third and fourth terms of a matching-to-sample contingency, Sidman (2000) suggests that all positive elements of a contingency, including responses and reinforcers, become members of an equivalence class as the result of the operation of reinforcement contingencies.

There is now considerable empirical support for the suggestion that reinforcers become members of equivalence classes. For example, Dube et al. (1989) trained developmentally-delayed human subjects with a set of four, two-choice identity-matching relations using set-specific reinforcers. Specifically, A1-A1, B1-B1, C1-C1, D1-D1, A1-B1, and B1-C1

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relations were trained using reinforcer *R1* and a complementary set of relations (e.g., A2-A2, B2-B2,) were trained using reinforcer *R2*. The results of tests for equivalence showed the emergence of A-D relations. This outcome could only have been mediated by the common reinforcers programmed during training and suggested that the class-specific reinforcers had become a part of the equivalence classes (see also, Dube and McIlvane 1995; Schenk 1994). Taken together, this and other research has shown that a) programming common reinforcers for unrelated conditional discriminations can lead to the expansion of existing equivalence classes (e.g., Dube et al. 1989), and b) programming common reinforcers for unrelated conditional discriminations can lead to the emergence of new equivalence classes (Dube and McIlvane 1995; Schenk 1994). As a whole, these data are consistent with Sidman's suggestion that reinforcing stimuli become a part of the equivalence relation and can suffice to produce class development, expansion, and merger.

The provision that responses and reinforcers also enter into equivalence relations leads to the prediction that contingencies other than conditional discriminations may give rise to equivalence relations. Even two- and three-term contingencies may generate equivalence relations (Sidman 2000). For example, Sidman et al. (1989) arranged for repeated reversals of simple successive discrimination contingencies involving sets of stimuli and, for two of three subjects, documented the emergence of equivalence relations among those stimuli. In a similar vein, a recent study in our laboratory arranged simple successive discrimination contingencies in which sets of three stimuli were correlated with reinforcement for the same response and documented the development of equivalence relations among those stimuli in unreinforced probe trials (Vaidya, Maciver, & Eiliefsen, in prep). Other studies (de Rose et al. 1988; Carpentier et al. 2003) have similarly shown that three-term contingencies are sufficient to give rise to equivalence relations among stimuli.

The provision that all positive elements of a contingency enter into an equivalence relation suggests a mechanism by which the development of analytic units and equivalence relations can interact. For example, consider the prototypical simple discrimination procedure in which one response *(R1)* is trained to a discriminative stimulus *(A1)*, and second response *(R2)* is trained to a second discriminative stimulus *(A2)*, yet both responses produce the same reinforcer *(S^r)*. The provision that all elements of a contingency become equivalent requires the reinforcer to enter into equivalence relations with each element of both contingencies (e.g., *A1-R1-S^r1* and *A2-R2-S^r1*). The inclusion of the reinforcer as a common element, however, would predict a merger of the two classes or, in other words, equivalence relations among all elements of both contingencies (e.g., *A1-A2-R1-R2-S^r1)*. Under these circumstances, both A1 and A2 would set the occasion for R1 and R2 leading to a breakdown in discriminative control and resulting loss of reinforcement. Given that contingencies with common reinforcers (and responses) are effective in establishing discriminative control, Sidman's (2000) theory requires that elements that are common to two sets of otherwise mutually exclusive contingencies selectively drop out of the equivalence relation (pg. 132). Although these results have not yet been convincingly demonstrated (cf. Minster et al. 2006), they support the idea that equivalence relations and analytic units can interact during development.

In principle, the nature of the interaction between analytic units and equivalence relations is not constrained in Sidman's (1994, 2000) theory. The interactions could involve conflict such as when existing analytic units interfere with the development of equivalence relations or existing equivalence relations interfere with the development of analytic units. The interactions could also, however, be conflict-free and serve to facilitate the development of both equivalence relations and analytic units. For example, existing analytic units could facilitate the development of equivalence relations (e.g., acquired equivalence) or, alternatively, existing equivalence relations among stimuli could facilitate the development of analytic units (e.g., transfer of function).

In order to be relevant to behavioral interpretations, these interactions must be instantiated in the on-going behavior of individual organisms and be systematically related to the programmed contingencies of reinforcement. That is, the interactions should be reflected in some direct measure of behavior such as the rate at which behavior is acquired or the latency to respond. Such a body of results would suggest that the two outcomes of contingencies proposed by Sidman – the development of analytic units and the emergence of equivalence relations – interact and can influence each other during development. The purpose of the current study was to ask if the development of analytic units interacted with equivalence relations and to ascertain the nature of that interaction. Specifically, do equivalence relations facilitate or retard the development of simple discriminations and under what conditions are these effects produced?

Method

Subjects

Two undergraduate students at the University of North Texas served as subjects. Subjects were recruited via flyers posted around campus and were selected on the basis of their availability and naïveté with respect to the terms and concepts of the experimental analysis of behavior. Subjects received $2.00 at the end of each session and accumulated $0.02 per correct response throughout the study. The accumulated earnings were delivered contingent upon completion of the study. Each subject earned an average of $21.56 over an average of 3.5 hours, or approximately $6.16 per hour.

Setting and Apparatus

Sessions were conducted in a small room (2 m by 3 m) equipped with a chair, desk, and a Macintosh laptop computer with external mouse and keyboard with a ten-key number pad. Custom written software (MTS version 11.6.7, Dube and Hiris 1991) presented stimuli, recorded responses, and managed the experimental contingencies. Responses were made with a computer mouse for conditional discrimination training and testing, and on the number pad of the peripheral keyboard for the simple successive discrimination training (described below).

Procedure

Experiment 1 consisted of two distinct phases (see Table 1). The first phase (hereafter, the Conditional Discrimination Phase) trained the prerequisite baseline conditional discriminations and tested for the development of the derived conditional relations that define stimulus equivalence classes. The second phase (hereafter, the Simple Discrimination Phase) trained simple successive discriminations using the same stimuli in such a manner that common stimulus functions were programmed either within or across documented equivalence classes (described in detail below).

Baseline Training (BT) This part of the Conditional Discrimination Phase trained the prerequisite conditional discriminations for the development of two independent sets of three, three-member equivalence classes. Specifically, 18 Greek and mathematical symbols were divided into six putative equivalence classes such that there were two non-overlapping sets of three, three-member classes, hereafter referred to as Set 1 and Set 2 (see left panel of Fig. 1). The assignment of individual stimuli to a particular set or class was random and individually determined for each subject. The following instructions were presented on the screen immediately prior to the beginning of

Table 1 Experimental design

	Experiment 1			
	Conditional Discrimination Phase		Simple Successive Discrimination Training Phase	
	BT	ET	SSDT 1	SSDT 2
Set 1	A-B, B-C	B-A, C-B, A-C, C-A and baseline relations	CR-W	CR-W
Set 2	A-B, B-C	B-A, C-B, A-C, C-A and baseline relations	CR-W	CR-A

	Experiment 2		
	Conditional Discrimination Phase		Simple Successive Discrimination Training Phase
	BT	ET	SSDT
Set 1	A-B, B-C	B-A, C-B, A-C, C-A and baseline relations	CR-W
Set 2	A-B, B-C	B-A, C-B, A-C, C-A and baseline relations	CR-A
Set 3	No explicit relations trained	No explicit relations tested	CR-I

CR-W, CR-A, and CR-I indicates that common responses were trained within equivalence classes, across equivalence classes, and irrespective of any potential equivalence relations, respectively.

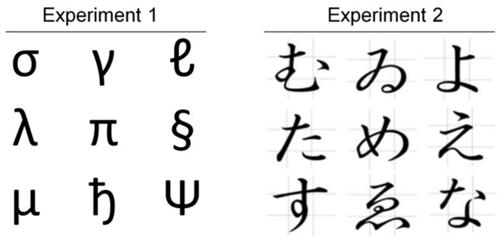


Fig. 1 Examples of stimuli from Experiment 1 (left panel) and Experiment 2 (right panel)

the first trial of the first session: "In this portion of the experiment, you will use the mouse to respond to stimuli. You will receive feedback on your responses. Please do not use the keyboard. When you are ready to begin, click 'continue.'"

A trial began with the presentation of a sample stimulus in the vertical and horizontal center of the screen. A single mouse click on the sample stimulus produced an array of three comparison stimuli randomly distributed in any three of the four corners of the screen. The position of each comparison stimulus, as well as the blank position, was randomly determined. A single mouse click on a comparison stimulus "selected" the stimulus and selection of the experimenter-designated correct comparison stimulus produced the word "Correct" on the screen for 1 s accompanied by two short tones. Selection of any of the incorrect comparison stimuli including the blank position produced a white screen with no accompanying sound for 1 second. Either consequence was followed by a 1.5 s intertrial interval (ITI) during which the screen was dark.

In the linear training structure used in this study, establishing the prerequisites for three, three-member classes involves training six conditional relations: A1-B1, A2-B2, A3-B3, B1-C1, B2-C2, and B3-C3. In the current experiment, four repetitions of each of these six trial types (or 24 trials) comprised one trial block. Trials within a block were presented randomly with the provision that the same trial type not be presented consecutively. Each trial block ended with the instruction: "You may now take a short break if you wish. Please do not leave the room. Click 'Continue' when you're ready to begin again." During the session, blocks of trials with Set 1 stimuli alternated with blocks of trials with Set 2 stimuli. Training sessions continued until the participants' accuracy met or exceeded 83.33 % for each of the two sets for a minimum of two blocks. Sessions typically consisted of 32 blocks of trials unless subjects met criteria within a session in which case the session was ended and the new condition begun on the following day.

Equivalence Testing (ET) The following instructions appeared on the screen prior to the first trial in the testing session: "In the next portion of the experiment, you will NOT receive feedback on your responses. *You will still receive bonus money for correct answers at the end of the experiment*. When you are ready to begin, click 'continue.'"

As in BT, testing trial blocks with Set 1 stimuli alternated with trial blocks with Set 2 stimuli. Two presentations of each training and testing trial type (or 36 trials) comprised a block of trials during testing. Specifically, test blocks presented 12 training trials (A-B, B-C), 12 symmetry trials (B-A, C-B), six transitivity trials (A-C), and six equivalence trials (C-A). No differential consequences were programmed following responding on any trial throughout the equivalence testing portion and trial blocks ended with the instruction: "You may now take a short break if you wish. Please do not leave the room. Click 'Continue' when you're ready to begin again." Testing conditions ended when a participant's performance was greater than 83.33 % correct for two consecutive trial blocks of each set. Participants who failed to meet this criterion were dismissed from the study.

Simple Successive Discrimination Training (SSDT)

In the Simple Successive Discrimination Training Phase, we sought to establish a simple discriminative function for each of the stimuli used in the Conditional Discrimination Phase (BT & ET). Within each set of nine stimuli (Set 1 or Set 2), subjects were taught to emit the same response in the presence of three different stimuli. For example, subjects were taught to press the "7" key in the presence of stimuli A1, B1, or C1 via differential reinforcement; pressing any other key in the presence of these stimuli produced a dark screen. In a similar manner, the other stimuli in the set also correlated with reinforcement for specific responses. Simple discrimination training occurred in two parts. In the first part (SSDT1), the groups of three stimuli correlated with reinforcement for the same response were drawn from the same equivalence class. These conditions were true for both Set 1 and Set 2. SSDT1 ended when the accuracy of a subject's performance exceeded 85 % for one trial block with both stimulus sets.

In the second part of the Simple Successive Discrimination Training phase (SSDT2), the contingencies correlated with Set 1 stimuli were rearranged such that the same group of stimuli was now correlated with reinforcement for a different response. For example, the stimuli A1, B1, and C1 might now be correlated with reinforcement for pressing "3" instead of "7". The contingencies correlated with Set 2 stimuli were also rearranged. For this set, however, the stimuli correlated with reinforcement for the same response came from different equivalence classes. For example, stimuli A4, A5, and A6 were correlated with reinforcement for pressing the "9" key; pressing any other key in the presence of these stimuli produced no programmed consequence except a dark screen.

The following instruction was presented immediately prior to the first block of simple successive discrimination training trials: "In this portion of the experiment, only one stimulus will be presented at a time. You will use the number pad on the keyboard to make responses to stimuli. Your job will be to learn which number to press when each stimulus comes on the screen. You will receive feedback on your performance. As before, you will earn bonus money for responding correctly. When you are ready to begin, click 'continue.'"

A trial began with a single stimulus presented in the vertical and horizontal center of the screen. The order of trial presentations was random except for the provision that the same stimulus not be presented on more than two consecutive trials. A single key press on the operative keys on the 10-key number pad (marked with small red stickers) was required to end the current trial. Each of the stimuli in a given set was presented three times in one trial block (for a total of 27 trials). As in BT and ET, blocks of trials with Set 1 stimuli alternated with blocks of trials with Set 2 stimuli. Each block ended with the instruction: "You may now take a short break if you wish. Please do not leave the room. Click 'Continue' when you're ready to begin again." SSDT2 ended when a subject's accuracy exceeded 85 % for one trial block with both stimulus sets.

Results

Conditional Discrimination Training and Equivalence Testing

To reach the 85 % accuracy criterion during BT, S11, and S12 required six and eight trial blocks of each set, respectively. For S11, performance accuracy improved steadily for both sets of stimuli, although conditional discrimination of Set 1 stimuli improved at a faster rate. S11's performance with Set 1 stimuli met the accuracy criterion one trial block earlier than the performance with Set 2 stimuli. Because of a computer error, the first three trial blocks of each set for s50 were lost. However, S12's performance accuracy during the final four trial blocks for each set was similar (+4 %) and improved at roughly the same rate.

S11's performance was 100 % accurate for both sets of stimuli across both blocks of testing. S12's accuracy on derived trial types involving Set 1 and Set 2 stimuli ranged between 94 % - 97 % and 89 % - 97 %, respectively. Because of a programming error, S12 was exposed to one additional trial block for each set after the subject met the accuracy criterion.

Simple Successive Discrimination Training

Figure 2 presents each subject's accuracy on the SSDT trials as a function of trial block. The top row presents data from SSDT1 during which the contingencies for Set 1 and Set 2 stimuli taught common responses to stimuli that were documented members of the same equivalence classes. S11's and S12's performance on the simple successive discrimination trials met criterion in 11 and nine trial blocks, respectively. For S11, accuracy on simple discrimination trials increased gradually followed by a sudden change to highly accurate performance in the seventh block of trials. For S12, accuracy increased more rapidly but consistently across the first five blocks of trials. Because of a programming error, S12 was exposed to two additional trial blocks of each set after the subject met the accuracy criterion.

The bottom row of Fig. 2 presents data from SSDT2. In this part, common stimulus functions were established within equivalence classes for Set 1 stimuli but across equivalence classes for Set 2 stimuli (e.g., Set1: A1,B1, C1 trained to resp 7; Set2: B1,B2,B3 trained to resp 4). The results show that successive discriminations involving Set 1 stimuli were acquired considerably faster than successive discriminations involving Set 2 stimuli. S11's accuracy on trials with stimuli from Set 1 increased quickly, reaching 100 % by the third trial block. In contrast, performance accuracy on trials with stimuli from Set 2 reached 97 % by the ninth trial block. S12's performance with stimuli from Set 1 and Set 2 was similarly disparate. S12 achieved 100 % accuracy with Set 1 stimuli by the second block of trials. In contrast, the same level of accuracy wasn't achieved until the ninth block of trials for Set 2 stimuli.

Discussion

The study attempted to ascertain whether equivalence relations among stimuli would interact with the development of analytic units and facilitate or retard the acquisition of simple discriminative functions for those stimuli. In SSDT1, both subjects acquired the simple discriminations of stimuli from Set 1 and Set 2 at approximately the same rate. These data suggest that there were no obvious differences in set or class configurations that might have contributed to a greater likelihood of equivalence class formation or simple discrimination acquisition with either set. In SSDT2, both subjects learned the simple discriminations faster when the stimuli were drawn from within equivalence classes (see performance with Set 1 stimuli) rather than across them (see performance with Set 2 stimuli).

Although the difference in the rate of acquisition of simple discriminations was clear and in the direction predicted by the notion of transfer of function within equivalence classes, two procedural issues prevent a straightforward interpretation of these data. First, it's possible that the observed differences were not due to the inclusion or exclusion of stimuli in equivalence classes, but because the change in task requirements for SSDT2 was greater for the Set 2 stimuli than it was for the Set 1 stimuli. In SSDT1, training conditions arranged reinforcement for the same response to a cluster of three stimuli in both Set 1 and Set 2. During SSDT2 for Set 1 stimuli, the common response for which the three stimuli set the occasion changed but the collection of three stimuli remained the same. For example, A1, B1, and C1 may have been correlated with reinforcement for pressing the "7" key during SSDT1 but became correlated with reinforcement for pressing the "3" key in SSDT2 . For Set 2 stimuli on the other hand, the change in contingencies involved both a change in the response as well as a change in the

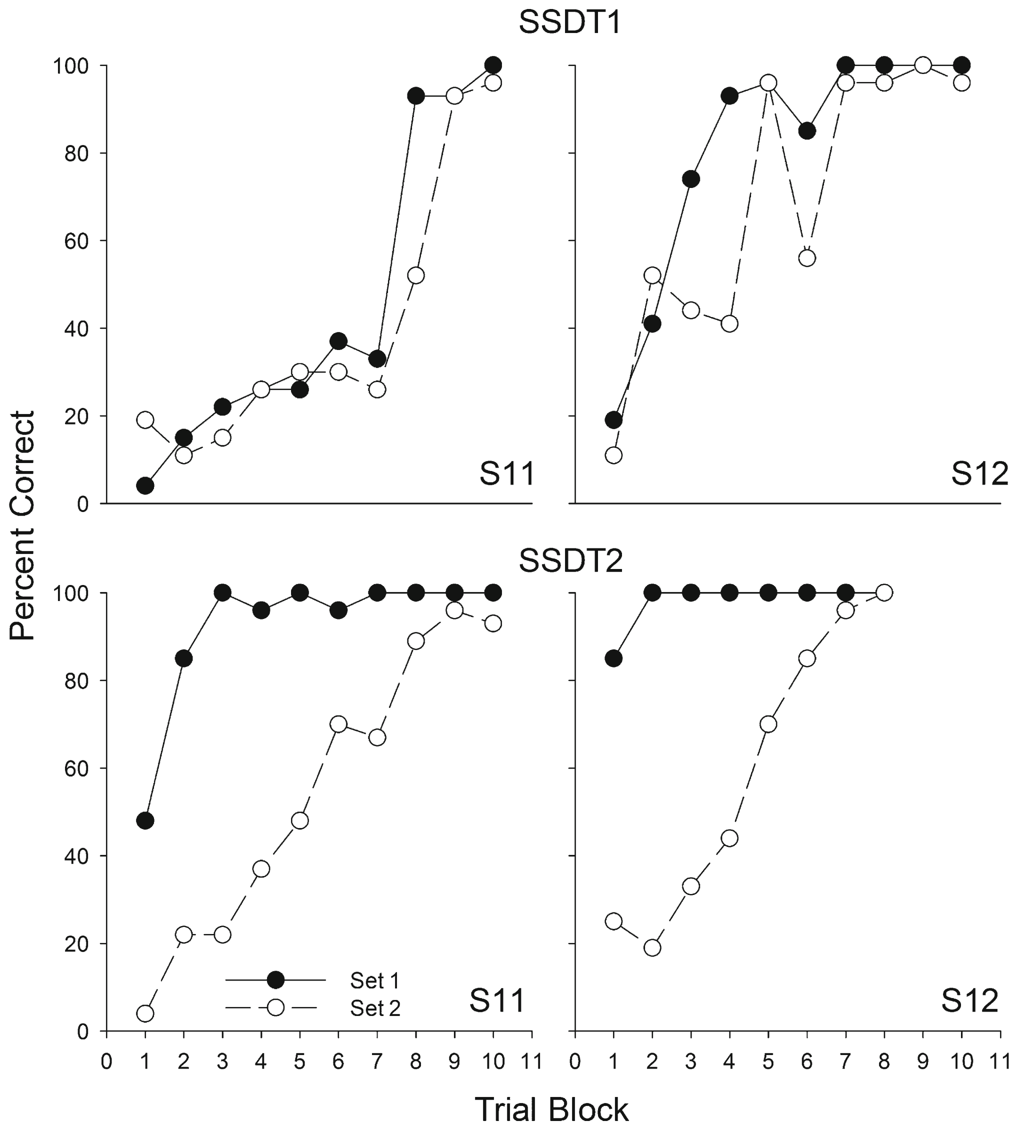


Fig. 2 Experiment 1 – Percent of correct responses during simple successive discrimination training. Common responses were trained within equivalence classes for Set 1 and across classes for Set 2

collection of three stimuli which set the occasion for the response. For example, A4, B4, and C4 may have been correlated with reinforcement for pressing the “9” key during SSDT1. During SSDT2, A4, A5, and A6 were arranged to be correlated with reinforcement for pressing the “2” key. It is possible that these changes in the task requirements, irrespective of the equivalence classes established in BT and ET, were the source of differential rates of acquisition seen in SSDT2.

A second obstacle to interpreting the results from this study was our inability to unequivocally characterize the differentiation observed as facilitation or an increased rate of acquisition with Set 1 stimuli (when training within equivalence classes) or as retardation or a decreased rate of acquisition with Set 2 stimuli (when training across equivalence classes). Figure 2 shows that simple discriminations involving Set 2 stimuli were learned at comparable rates during SSDT1and SSDT2 whereas simple discriminations involving Set 1 stimuli were learned much faster during SSDT2 relative to SSDT1. These data suggest that existing equivalence relations among Set 1 stimuli facilitated the acquisition of common stimulus functions during SSDT2 (but see the qualifier about differing changes in task requirements above). What is needed to allow cleaner interpretation of the results, is a third set of stimuli for which no explicit equivalence relations are established to serve as a comparator condition. For example, faster and slower rates of acquisition with Set 1 and Set 2 stimuli relative to performance with this third set would more cleanly suggest a facilitation and retardation effect.

Experiment 2

In Experiment 1, the difference in task requirements in SSDT1 and SSDT2 could have accounted for the differences in rates of acquisition across the two sets (as discussed in detail above), and the data could not be unambiguously interpreted in terms of an interaction between equivalence relations and the development of analytic units. Accordingly, Experiment 2 subjects were exposed to the critical phase in which simple discriminations were trained within and across documented equivalence classes immediately following equivalence testing. In addition, a third set of nine stimuli were added to serve as a control set in an effort to better characterize the effects of equivalence classes on the development of analytic units. The contingencies for this third set of stimuli involved non-differential reinforcement of any comparison choice on every trial during baseline training. We anticipated that such training would fail to create the baseline conditional discriminations and thereby preclude equivalence class formation. Relative to this third set of "uncategorized" stimuli then, faster acquisition with Set 1 stimuli would suggest a facilitative effect of equivalence relations. Also, slower acquisition for Set 2 stimuli, relative to Set 3 stimuli, would suggest a disruptive effect of equivalence relations.

Finally, several studies have noted that the extinction programmed during test trials may be responsible for observed failures in the development of equivalence relations (e.g., Pilgrim and Galizio 1990, 1995; Sidman and Tailby 1982; Sidman 1994). The gradual lowering of reinforcement probability during the final stages of training has, therefore, become a common feature of equivalence research. In an effort to minimize the potential deleterious effects of a sudden change in reinforcement and to better align the procedures used in this study with other studies in the archival literature, the probability of reinforcement on training trials was slowly reduced in Experiment 2.

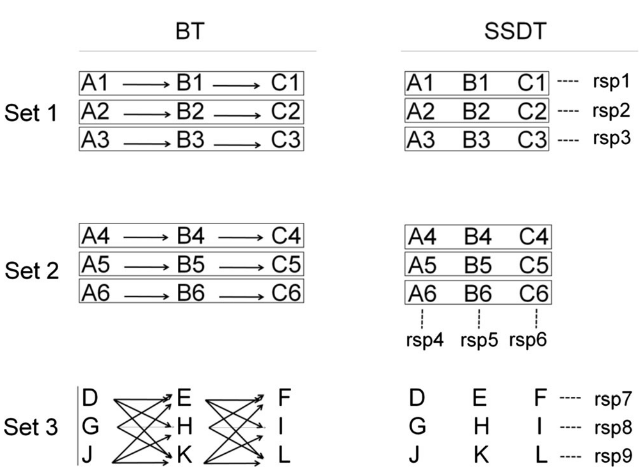


Fig. 3 Experiment 2 - stimulus-stimulus & stimulus-response schematic. The arrows indicate stimulus-stimulus relations directly trained. The boxes indicate predicted equivalence classes. The dashed lines indicate stimulus-response relations trained (e.g., A1-B1-C1 - resp1 indicates response option 1 was reinforced in the presence of stimuli A1, B1, or C1). Note that in Phase 2, common response training with Set 1 is considered "within" classes, while common response training with Set 2 is considered "across" classes. Set 3 is considered the "control" stimulus set

Method

Subjects

Four female undergraduate students, ages 18 – 27 years with a mean age of 20.25 years, participated in Experiment 2. Each subject earned an average of $46.66 over an average of 5.25 hours, or approximately $8.89 per hour.

Setting and Apparatus

The setting and apparatus were identical to Experiment 1 with the exception of the addition of a peripheral number pad on which subjects made responses (described below).

Procedure

Baseline Relations Training (BT) The prerequisite conditional discriminations were trained with 27 Hiragana characters, divided into three sets of three, three-member equivalence classes (see Fig. 3 and Table 1). These stimuli were used in all phases and parts of Experiment 2. Blocks of trials looped linearly between Set 1, Set 2, and Set 3 stimuli, such that Set 1 trials preceded Set 2 trials which preceded Set 3 trials before the sequence repeated.

Training contingencies for trials involving stimuli from all three sets were identical to those arranged during Experiment 1 with the exception that, for trials involving Set 3 stimuli, the selection of any comparison stimulus was non-differentially reinforced. The probability of reinforcement for correct comparison choices was reduced from 100 % to 50 %, then 25 %, and then 0 % when the subject's performance accuracy met or exceeded 83.3 % on two consecutive trial blocks with Set 1 and Set 2. Failure to meet the accuracy criterion for four consecutive blocks with either set resulted in a return to the previous step. ET began once a subject's performance exceeded 83.3 % correct with 0 % probability of reinforcement for one trial block of each set.

Equivalence Testing (ET) Equivalence testing proceeded as in Experiment 1, but with the three sets of stimuli instead of two. Blocks of trials alternated between Set 1, Set 2, and Set 3 stimuli. Testing conditions ended when a participant's performance was greater than or equal to 83.3 % correct for 2 consecutive trial blocks each of Set 1 and Set 2. A failure to meet or exceed accuracy criteria in four blocks of equivalence testing trials resulted in a return to training followed by another test for equivalence.

Simple Successive Discrimination Training (SSDT) The simple successive discrimination training phase was identical to SSDT2 in Experiment 1. That is, common functions were established either for stimuli within equivalence classes (Set 1) or for stimuli across equivalence classes (Set 2). In addition, common functions were also explicitly established for stimuli in a third set. With Set 3, the contingencies could not be arranged with respect to equivalence classes as no equivalence classes were explicitly trained. Instead, each group of three stimuli correlated with reinforcement for the same response contained one stimulus that had only served as a sample during baseline training, one that had only served as a comparison, and one that had served as both. The emergent conditional relations for Set 3 stimuli were not considered when the contingencies for SSDT were programmed. See Fig. 3 for a schematic representation of these arrangements.

Participants responded on 16 keys marked with gold stickers in the center of the laptop keyboard, although responses to only nine of the keys were ever reinforced. (The seven additional keys were provided to prevent responding via exclusion). For S101, S102, and S103 training continued until the subject achieved 83.3 % correct for at least one trial block with Set 1 and Set 2. For S104, training was terminated after 28 trial blocks of each stimulus set (see below).

Results

Baseline Training

S101, S102, S103, and S104's performance met the accuracy criterion in 12, 17, 14, and 29 trial blocks, respectively. Three of the four subjects (S104 was the exception) also cycled through the gradual reduction in reinforcement probability in the minimum number of allowed trial blocks. Following the initial transition from 100 % reinforcement probability to 50 %, S104's performance failed to meet the accuracy criterion after four trial blocks of each set. The subject was then returned to the 100 % reinforcement probability condition until the accuracy criterion was met again. S104's performance then met or exceeded the 83.3 % accuracy criterion for the 50 %, 25 %, and 0 % reinforcement probability steps of baseline training in the minimum number of trial blocks allowed.

Performance on trials with Set 3 stimuli varied across subjects. Two subjects (S102, S103) began making consistent comparison-stimulus choices given certain sample stimuli in the absence of differential reinforcement during the baseline training condition. For those two subjects, the following conditional discriminations emerged (without explicit training) in Set 3: for S102, G-H, D-K, E-L, H-I, and K-I; for S103, D-K, G-H, E-F, and H-L. There was little evidence of such regular choices in the remaining two subjects' (S101, S104) performance during training, although S104 did consistently select several comparison stimuli (K, I, and F) more often than others (*). *Footnote: Stimuli in Set 3 were designated using the letters D-L without numeric postscripts to indicate that there were no contingencies programmed to produce particular conditional discriminations)*.

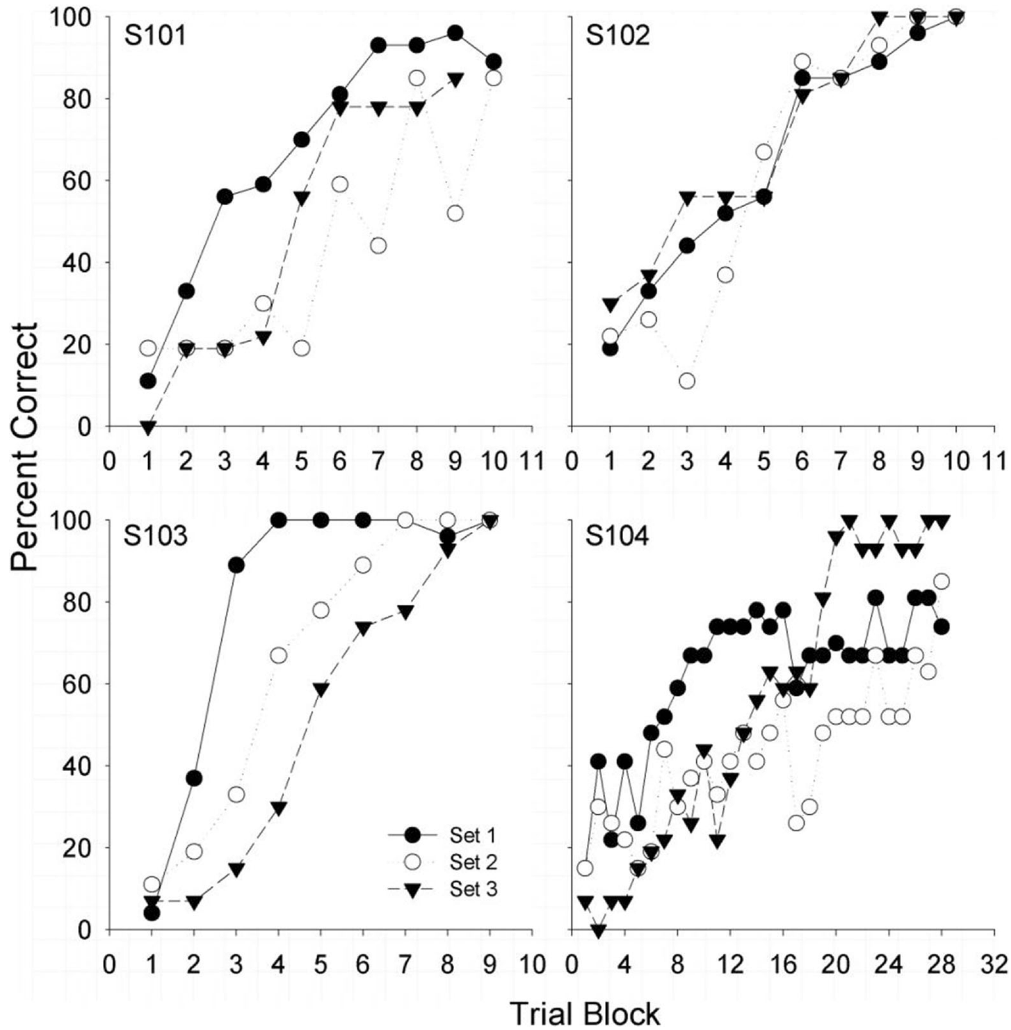
Equivalence Testing Three of the four subjects (S101, S102, and S103) met or exceeded the 83.3 % accuracy criterion for equivalence testing for trials with Set 1 and Set 2 stimuli within the first two trial blocks of each set. Accuracy for S101 was at 100 % for all trial blocks except one with Set 1 at 97 %. For S102, accuracy was between 86 % and 92 % for Set 1 and at 100 % for both trial blocks of Set 2. S103's accuracy varied between 94 % and 100 % across both sets. S104's performance accuracy varied between 64 % and 83 % across both sets, with slightly lower overall accuracy with Set 1 and no distinguishable upward or downward trend in the performance with either set of stimuli. S104 failed to meet the accuracy criterion within the first four trial blocks of equivalence testing and was re-exposed to baseline training conditions with 0 % reinforcement probability for each set for one trial block. The subject's performance immediately exceeded the accuracy criterion during this condition and the subject was transitioned back to equivalence testing where performance once again fell short of the accuracy criterion by one trial. At this point, S104 was transferred to SSDT2 of the study despite the failure to meet the accuracy criterion on equivalence testing trials.

Subjects' performance during the trials with Set 3 stimuli was varied. Three of the four subjects (S104 was the exception) chose particular comparison stimuli exclusively and consistently on particular trial types to some extent during testing. For example, S101 chose stimulus K consistently when stimulus D was presented as the sample. S101, S102, and S103 made consistent comparison choices on six, 15, and 16 of the 18 trial types presented in a block. Furthermore, some of the subjects' consistent choices were reversible and recombinative, suggesting equivalence-like relations among stimuli. For S102, for example, six of the 15 trial types on which consistent choices were made were reversible – e.g., S102 chose K given D and D given K. For S103, 14 of the 16 trial types on which consistent choices were made were shown to be reversible or recombinative. In fact, S103's performance suggested the development of two distinct equivalence classes – D-K-I and G-E-F. S101's choices did not indicate that sample and comparison roles had become reversible on any of the trials.

Simple Successive Discrimination Training

Figure 4 presents subjects' accuracy on the SSDT trials across trial blocks. For three out of four subjects – S101, S103, and S104 – accuracy with Set 1 stimuli improved at a greater rate than with Set 2 stimuli across trial blocks. For S102, there was no difference in the rate at which stimuli from Sets 1, 2, and 3 acquired discriminative functions. The relation between accuracy with Set 3 stimuli and accuracy with Sets 1 and 2 varied across all other participants. For S101, accuracy with Set 3 stimuli improved at a rate intermediate to that observed with stimuli from Set 1 and Set 2. For S103, accuracy with Set 3 stimuli improved more slowly than that observed with stimuli

Fig. 4 Experiment 2 – Percent of correct responses during simple successive discrimination training. Common responses were trained within equivalence classes for Set 1, across classes for Set 2, and irrespective of equivalence relations for Set 3 (the control set)



from Set 1 or Set 2. For S104, accuracy with Set 3 stimuli improved more slowly than that observed for stimuli from Set 1 or Set 2 during the first four trial blocks, but improved more quickly for the last nine trial blocks of each set. For S101, S102 and S103, training was terminated when accuracy exceeded 83.3 % with all three stimulus sets following the 10th, 10th, and ninth trial blocks, respectively. Training for S104 was terminated after 28 trial blocks, when the maximum accuracy for Sets 1, 2 and 3 had reached 81 %, 84 % and 100 %.

Discussion

For S101 and S103, common stimulus functions were consistently acquired faster for stimuli drawn from within documented equivalence classes as compared to stimuli drawn from different equivalence classes. Although, S104 failed to meet the accuracy criterion during the equivalence testing condition, his performance during successive simple discrimination training was similar to S101 and S103 suggesting perhaps S104's incomplete equivalence relations were sufficient to produce the learning rate differentiation in SSDT. For S102, no difference was observed in the rates at which simple discriminative functions were acquired across stimuli from the three sets. Taken together, these data show that equivalence relations among stimuli differentially facilitated the acquisition of common stimulus functions for three of the four subjects.

The inclusion of Set 3 stimuli was designed to serve as a control condition. It was expected, because of the non-differential reinforcement during baseline training, that subjects would fail to develop specific conditional relations precluding the development of specific equivalence relations among Set 3 stimuli. Three of the four subjects, however, developed relatively consistent conditional relations during the BT condition with stimuli from Set 3 which were then shown to be reversible and recombinative in the ET conditions suggesting equivalence-class like organization (cf. Harrison and Green 1990). Although no systematic effects of these relations were detectable in their performance on the simple successive-discrimination training trials, there may have been unmeasured influences.

In retrospect, these data are not surprising given previous research demonstrating the development of systematic equivalence-like performances in the absence of systematic baseline contingencies (Harrison and Green 1990). It is not clear, however, whether the consistent conditional relations demonstrated are the result of the reinforcement contingencies encountered early during BT with Set 3 stimuli or the result of diffuse contextual control exerted by the systematic contingencies programmed for Set 1 and Set 2 stimuli. Future research should attempt to develop procedures to reliably inhibit equivalence class formation such that the unique influence of equivalence relations on the organization of other behavior can be better understood. In future studies, reduction in the probability of reinforcement associated with choices on Set 3 trials (like Sets 1 and 2) may be programmed to preclude the development of consistent responses. Another possibility might be to idiosyncratically change contingencies of reinforcement for the third set to preclude the development of stable conditional discriminations and potentially block the development of specific equivalence relations.

General Discussion

The two experiments in this study investigated potential interactions between the development of analytic units and equivalence relations by training simple discriminations within or across documented equivalence classes. Results from both experiments suggest that common stimulus functions were acquired faster for stimuli related via equivalence than for stimuli drawn from different equivalence classes (Experiment 1 and Experiment 2) or for uncategorized stimuli (Experiment 2). For S103 in Experiment 2, existing equivalence relations among stimuli appeared to retard the acquisition of simple discriminations that were inconsistent with the documented equivalence relations. These data suggest that the development of analytic units and the development of equivalence relations can and do interact during development.

These data are interpretable in terms of Sidman's (2000) account of stimulus equivalence in which equivalence relations are seen as a direct outcome of the reinforcement contingency and include all positive elements in a contingency including the responses and reinforcers. Recall that the theory also requires that any elements that conflict with the development of analytic units must selectively drop out of the equivalence relation. According to this account, the responses trained during the simple discrimination training phase of the current studies would be expected to become equivalent with other elements of the programmed contingencies. For Set 1, this would mean that each of the three equivalence classes would gain a response as a class member. For Set 2, however, this would mean that each (existing) equivalence class would gain three new responses as members (see Fig. 3) that were shared across three different equivalence classes. The shared responses would be expected to promote merger and, thus, interfere with the development of the analytic units. This would lead to those elements selectively dropping out of the equivalence relations thereby allowing the analytic units to develop without conflict (see Sidman 1994, pg 410-414, for a discussion of these issues). If additional time is required for the elements to come into conflict, selectively drop out, and develop new analytic units, one may expect a slower rate of acquisition for Set 2 stimuli relative to Set 1 stimuli.

An alternative account of the observed results can be offered in terms of the transfer of stimulus functions across members of an equivalence class. Hayes and colleagues (i.e., Hayes et al. 2001) suggest that the transfer (or, rather, transformation) of stimulus functions across members is a defining feature of an arbitrarily-applicable relational frame. According to this account, the transfer of stimulus functions within equivalence classes but not across equivalence classes would explain the relatively faster acquisition of class-consistent simple discriminations. Although considerable evidence exists for the transformation of stimulus functions across relational frames (e.g., Dougher et al. 1994), the procedures and results of the current study do not allow an interpretation in favor of either of the proposed mechanisms.

Taken together, the results of both experiments suggest that existing equivalence relations can influence the development of analytic units. By implication, the data suggest that a variety of different interactions between the development of analytic units and the development of equivalence relations may be possible. Specifically, as reported in the literature on acquired equivalence (e.g., Hall 1991), existing analytic units could facilitate or interfere with the development of equivalence relations (see also Stewart et al. 2002). Conversely, these data suggest that existing or developing equivalence relations can facilitate or interfere with the development of analytic units. Future studies along these lines should test whether the common discriminative functions established during SSDT for Set 2 stimuli result in a new set of equivalence relations among the stimuli as would be predicted by the literature on acquired equivalence. By learning how to predict the effects of equivalence classes on the development of new behavioral relations, we may further our understanding of the nature of the equivalence relation, extend its generality, and enhance our ability to control behavior.

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