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EMERGENT CONDITIONAL RELATIONS IN A GO/NO-GO PROCEDURE: FIGURE–GROUND AND STIMULUS-POSITION COMPOUND RELATIONS

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Past research has demonstrated emergent conditional relations using a go/no-go procedure with pairs of figures displayed side-by-side on a computer screen. The present study sought to extend applications of this procedure. In Experiment 1, we evaluated whether emergent conditional relations could be demonstrated when two-component stimuli were displayed in figure–ground relationships—abstract figures displayed on backgrounds of different colors. Five normally capable adults participated. During training, each two-component stimulus was presented successively. Responses emitted in the presence of some stimulus pairs (A1B1, A2B2, A3B3, B1C1, B2C2 and B3C3) were reinforced, whereas responses emitted in the presence of other pairs (A1B2, A1B3, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1 and B3C2) were not. During tests, new configurations (AC and CA) were presented, thus emulating structurally the matching-to-sample tests employed in typical equivalence studies. All participants showed emergent relations consistent with stimulus equivalence during testing. In Experiment 2, we systematically replicated the procedures with stimulus compounds consisting of four figures (A1, A2, C1 and C2) and two locations (left – B1 and right – B2). All 6 normally capable adults exhibited emergent stimulus–stimulus relations. Together, these experiments show that the go/no-go procedure is a potentially useful alternative for studying emergent conditional relations when matching-to-sample is procedurally cumbersome or impossible to use.

Key words: go/no-go procedure, compound stimuli, conditional discrimination, stimulus equivalence, figure–ground, button press, humans

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In the vast majority of stimulus equivalence research studies, matching-to-sample procedures are used for teaching stimulus–stimulus relations and testing for emergent relations (e.g., Sidman, 1994). Other procedures, however, have also been used in stimulus equivalence research, such as the contiguous pairing and recombination method of Leader, Barnes and Smeets (1996) and the go/no-go method recently reported by Debert, Matos, and McIlvane (2007).

In the latter study, two abstract black-and-white figures were displayed side-by-side on the screen of a computer that controlled all experimental operations. For example, when A1B1 compound was displayed, A1 was a circle on left side and B1 was a figure similar to an inverted letter ''L'' on the right side. During go/no-go training, each two-component stimulus was presented successively for 4 s. Responses emitted in the presence of certain stimulus pairs (A1B1, A2B2, A3B3, B1C1, B2C2 and B3C3) were followed intermittently by reinforcers, whereas responses emitted in the presence of other compounds (A1B2, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1 and B3C2) were not. After accurate performances were established, probe tests in extinction displayed new compounds composed of different arrangements of the component stimuli—BA, CB, AC, and CA—following the logic of procedures used in typical equivalence studies. Five of six participants subsequently responded in a manner consistent with the ABC classes typical of such studies.

According to Sidman's (1994) definition, matching-to-sample procedures are not essential to generate equivalence classes. Indeed, he wrote (p. 381) that ''A potential equivalence

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relation can be thought of as a kind of bag that contains all the ordered pairs of events that constitute the relation … To document the relation, all we have to do is reach into the bag … and pull out its member pairs.''. Following Sidman's logic, given the appropriate context, *any* procedure that entails ordered pairs of related events might potentially establish equivalence relations. Nearly all studies in the equivalence literature, however, have used the same matching-to-sample context. The generality of equivalence class formation following other types of ordered-pair relations has not been studied systematically, and the possibilities suggested by Sidman's analogy have been evaluated only rarely.

The robust findings of the study by Debert et al. (2007) inspired further efforts to assess the limits of the go/no-go procedures in establishing equivalence classes. We assessed two procedural targets: (1) classical figure–ground relations similar to those that concerned Lashley (1938) and (2) stimulus-position relations.

Both experiments were conducted with normally capable adults. These two targets were selected in part to demonstrate another feature of go/no-go procedures' applicability with stimulus relations that cannot be studied with straightforward matching-to-sample methods: that is, that one cannot separate the constituent elements of figure–ground or stimulus-position compound relation into sample and comparison stimuli. Moreover, these two procedure targets seem to map well onto contingencies encountered outside the laboratory that require individuals to respond if and only if certain conditions are fulfilled and otherwise do nothing (e.g., soldiers are required to salute only when an officer enters the room). Laboratory go/no-go procedures may be useful as a simple way to model such procedures for controlled study.

EXPERIMENT 1: FIGURE–GROUND RELATIONS

METHOD

Participants

The participants were 2 males and 3 females aged 18–29 years. None had prior familiarity with the experimental analysis of behavior. Participants were fully debriefed when the experiment concluded.

Apparatus

All sessions were conducted individually in a 4 m × 3 m room. An IBM computer with 256-mm (14-inch) color monitor was used. Each participant was seated facing the monitor and could respond directly to stimuli by positioning the mouse's cursor anywhere on it and depressing the button. A program developed in Visual Basic controlled all experimental operations including stimulus presentations and data recording.

Components of the two-component figure–ground stimuli could be any one of six abstract forms (after Markham & Dougher, 1993), designated as A1, A2, A3, C1, C2, and C3, and any one of three colors as backgrounds, designated as B1, B2, and B3. The designations were not displayed on the computer screen (see Figure 1). Each abstract form was centered within a colored background displayed in the center of the monitor's screen (see Figures 2 and 3). The experimental stimuli were judged physically dissimilar with respect to form and color; stimulus–stimulus relations were arbitrarily defined by the contingencies programmed by the experimenter.

Procedure

Phase I: Training baseline relations. In Phase I, a differential reinforcement procedure was used to establish button-pressing to some figure–ground stimuli (i.e., components to be related) and not pressing to others (i.e., components not-to-be related). At the beginning of this phase, each participant sat facing a monitor that displayed the following instructions (translated from the Portuguese):

> ''This study is not about intelligence testing, and will not evaluate any aspect of your intellectual abilities. When it is finished you will receive a full explanation. I will remain nearby to solve any technical problems that may arise with the equipment, but I will not be able to talk to you. *Your goal is to attain as many points as possible; these points will be shown on the upper left of the screen. In a defined area in the center of the screen, there will be symbols. Your task is to click in this area, with the mouse, when you think correct symbols are shown, and not to click when incorrect ones are shown.* In the beginning, you will receive points whenever you click correct symbols; later on, you will sometimes receive and sometimes not receive such points. The task will increase in difficulty as it goes along.

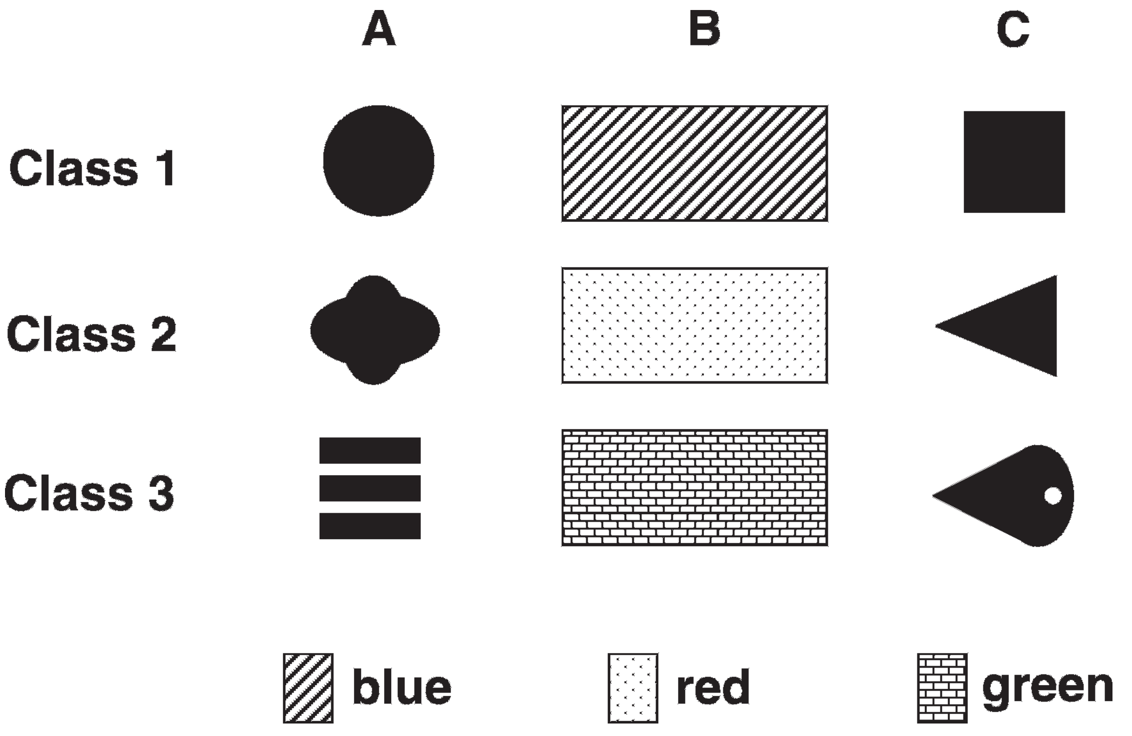

Fig. 1. Colored backgrounds and abstract form stimuli and their designations (A1, B1, C1, A2, B2, C2, A3, B3, C3) in Experiment 1.

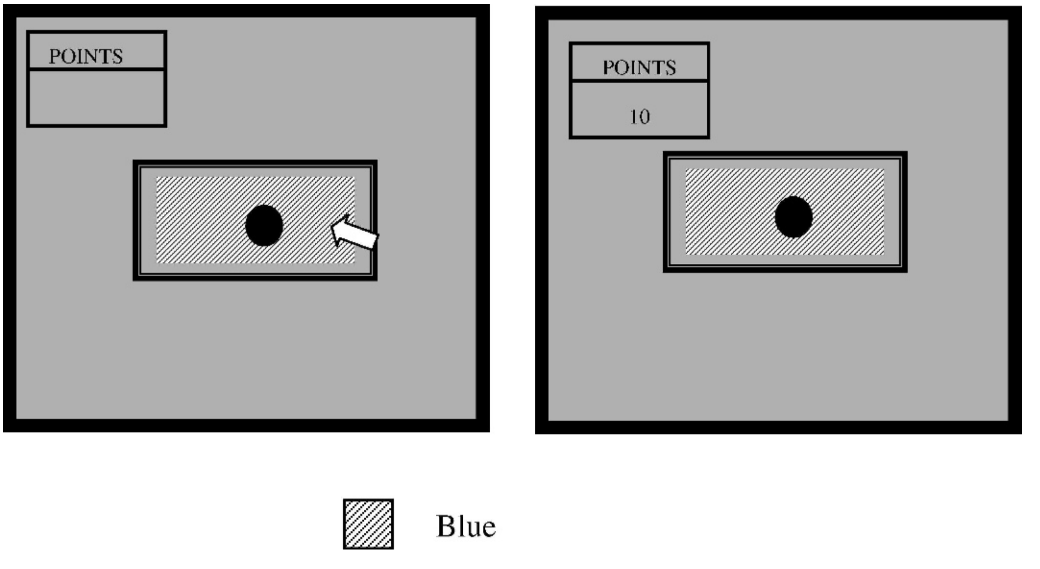

Fig. 2. Illustration of the screen during one example of a trial in Experiment 1. The drawing on the left shows the screen after a participant clicked the ''OK'' button. The drawing on the right shows the screen after a participant's correct response. The point counter is shown at the upper-left corner of the screen, and an example of a figure–ground stimulus (A1B1) is shown at its center.

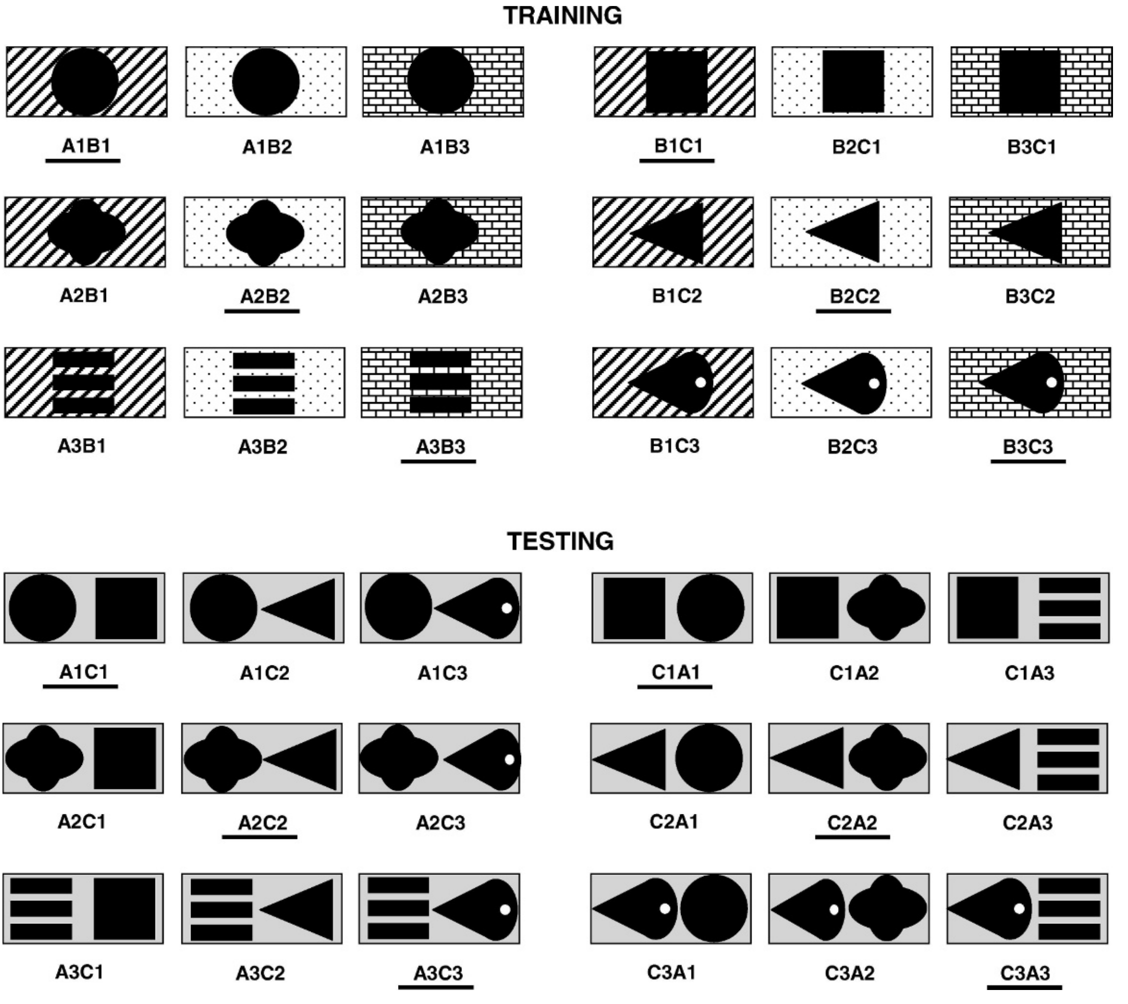

Fig. 3. Stimuli presented in each phase of Experiment 1. Stimuli with components To-Be-Related are underlined.

> Thus, pay attention even when the task seems very simple. Please, repeat to me the instructions you just read.''

When participants indicated that they understood the instructions, they received the following further instruction (also translated): ''When I tell you to start, click where it says 'OK'. Thank you very much for your participation!''

When the participants clicked the OK area, the experimenter left the room and training began. A two-component figure–ground stimulus was presented in the center of the screen, and the counter (initially set at zero) was displayed in the left upper corner (see Figure 2). Eighteen different figure–ground stimuli resulted from combinations of one of the six abstract forms and one of the three colored backgrounds (see Figure 3). ''Related'' components were A1B1, A2B2, A3B3, B1C1, B2C2 and B3C3. ''Not-related components'' were A1B2, A1B3, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1 and B3C2.

Each figure–ground stimulus with related and not-related components was presented for 4 s on each trial, independent of participant behavior following the procedure used by Debert et al. (2007). During each trial, participants could click one or many times with the mouse. In order to count as a valid response, however, the mouse cursor had to be positioned within the figure–ground stimulus and not in the surrounding area.

Table 1

Compound abstract stimuli presented in each of the phases in Experiment 1.

PHASE I TRAIN		PHASE II TEST	
Related	Not-Related	Related	Not-Related
A1B1	A1B2	A1C1	A1C2
A2B2	A1B3	A2C2	A1C3
A3B3	A2B1	A3C3	A2C1
B1C1	A2B3	C1A1	A2C3
B2C2	A3B2	C2A2	A3C1
B3C3	A3B1	C3A3	A3C2
	B1C2		C1A2
	B1C3		C1A3
	B2C1		C2A1
	B2C3		C2A3
	B3C1		C3A1
	B3C2		C3A2

The order of presentation of each trial type varied unsystematically across trials. The order was restricted such that no trial type could be presented more than three times successively. Each figure–ground stimulus with related components was presented twice in a block of trials, while each of the not-related figure–ground stimuli was presented once (see Table 1). Via this balancing procedure, also used by Debert et al. (2007), related and not-related figure–ground stimuli appeared equally often in a block. Sessions consisted of 12 blocks of 24 trials each (288 trials per session) and lasted about 30 min.

Valid responses to figure–ground stimuli with related components were followed by the sound of tokens falling and by the addition of 10 points on a counter positioned on the upper-left corner of the computer monitor. When points were added, the total accumulation flashed for 1.5 s. All trials were separated by an intertrial interval of 2 s. There were no stimuli displayed and no programmed consequences for responding during the intertrial interval.

During the first 36 trials, button presses to related figure–ground stimuli were immediately followed by points; thereafter, points came on a conjunctive fixed-ratio 1 variable-time 2.5 s schedule (i.e., at least one response was made to the related stimuli and 2.5 s, on average, had elapsed). The conjunctive schedule was used in order to discourage very rapid responding that might interfere with the development of stimulus control by the figure–ground stimuli. When not-related components were displayed, behavior was never followed by points.

Phase I ended when participants completed a full session of responding to virtually all of related figure–ground stimuli and made virtually no responses to stimuli with not-related components (see Results).

Phase II: Equivalence tests. This phase was implemented to test for equivalence relations with the go/no-go procedure under extinction conditions involving new compounds with A and C components. We followed the general logic of defining equivalence in a manner consistent with the analysis of Stromer, McIlvane, and Serna (1993) and the ''combined'' tests for equivalence relations and their defining properties (i.e., reflexivity, symmetry, and transitivity) as outlined by Sidman and Tailby (1982). Equivalence relations would be shown if participants (1) responded to pairs of forms that had appeared with the same colors on figure–ground training trials (i.e., A1C1, A2C2, A3C3, C1A1, C2A2 and C3A3) and (2) did not respond to form pairs that had appeared with different color on such trials.

At the beginning of Phase II, the instructions were: ''This is a new phase and your task will be modified. Work according to what you have learned. No sounds or points will be presented. When you are ready to start, click the 'OK' button''. When the participants clicked the OK area, the experimenter left the room and testing began.

Phase II was conducted for one session only. Table 1 shows all trial types presented in this phase. Form stimuli were presented in side-by-side pairs within a neutral background on the screen (see Figure 3). Eighteen different stimulus pairs resulted from the combinations of all six forms (see Table 1). The order of presentation of stimulus pairs varied unsystematically across trials, again with the restriction that no trial type could appear more than three times in succession. Each stimulus pair with related components was presented twice in a block of trials, while each of the not-related components was presented once, again equating related and not-related component pairs within a block.

All test trials started with 8-s presentations of a two-component stimulus. Following the procedure suggested by Debert et al. (2007), the duration of stimulus presentation was

Table 2

Percentage of correct performances in each session for all participants of Experiment 1.*

PARTICIPANT		J	M	K	F	L
TRAIN	Session 1	71,8 (207/288)	59,0 (170/288)	73,0 (210/288)	66,7 (192/288)	78,9 (227/288)
	Session 2	96,5 (278/288)	93,8 (270/288)	94,5 (272/288)	97,2 (280/288)	99,6 (287/288)
	Session 3	99,3 (286/288)	98,9 (285/288)	100 (288/288)	100 (288/288)	—
	Session 4	99,3 (286/288)	100 (288/288)	—	—	—
TEST	Session 1	99,3 (143/144)	100 (144/144)	100 (144/144)	100 (144/144)	99,3 (143/144)

* Values in parentheses represent the number of trials with correct responses and number of trials per session.

increased in testing from 4 s to 8 s in order to capture responding that was merely delayed due to the appearance of new trial types in testing. Again, participants could click once or many times with the mouse, and valid responses had to be within the area of stimulus presentation and not in the surrounding area.

Six blocks of 24 trials were presented in a test session of about 30 min. The point counter was not displayed on any such trials.

Results and Discussion

Table 2 shows the percentage of correct performances during training and testing for each participant (i.e., the number of trials with one or more responses to figure–ground components defined as related added to the number of trials on which there were no responses to figure–ground components defined as not-related divided by the total number of trials). Three participants required three to four sessions to achieve 100% correct trials during training. Perfect performance was not required for 2 other participants (J and L), because each spontaneously verbalized correctly that they recalled making one or two errors in their session. These participants achieved accuracy levels of 99.3% correct and 99.6% correct in their fourth and second sessions respectively. All participants, then, immediately showed the emergence of equivalence relations within one testing session.

The positive findings are strongly in line with the ''separable compound'' account proposed by Stromer et al. (1993), who argued that equivalence relations could arise at the level of the three-term contingency (see Sidman, 2000, for further consideration of the relevant issues). Like the participants in the study by Debert et al. (2007), the present participants exhibited emergent behavior and equivalence relations with novel combinations of stimulus components (i.e., the figures) presented contiguously with other components (i.e., the grounds) during training. Indeed, this application of the go/no-go procedures was even more successful than in our first report, due perhaps to the procedure modification of allowing somewhat more time (8 s instead of 4 s) to respond on the test trials with related components.

In concluding discussion of this experiment, we note that the go/no-go trial balancing procedure used here was not the only balancing procedure possible. We balanced the trials such that requiring a ''go'' response occurred about equally often as those requiring a ''no-go'' response. As a mathematical consequence of presenting every trial type, stimulus pairs displayed on ''go'' trials appeared twice as often as pairs displayed on ''no-go'' trials during training. The alternative would have been presenting twice as many ''no-go'' trials to arrange that every trial type appear equally often, potentially introducing a bias toward ''no-go'' responding. With our normally capable participants, this bias potential was small, in part because the overall number of training trials was small. Moreover, our participants responded appropriately from the outset in a manner consistent with equivalence of certain ordered pairs and the nonequivalence of others, before the greater frequency of the former was detectable. Thus, our balancing procedure here appears to have been the appropriate choice. With other populations that would likely show less rapid acquisition (e.g., nonhumans), however, the potential for introducing response bias via the nature of balancing may be a greater concern.

EXPERIMENT 2: FORM–POSITION COMPOUNDS

This experiment addressed further extension of the go/no-go procedure to study

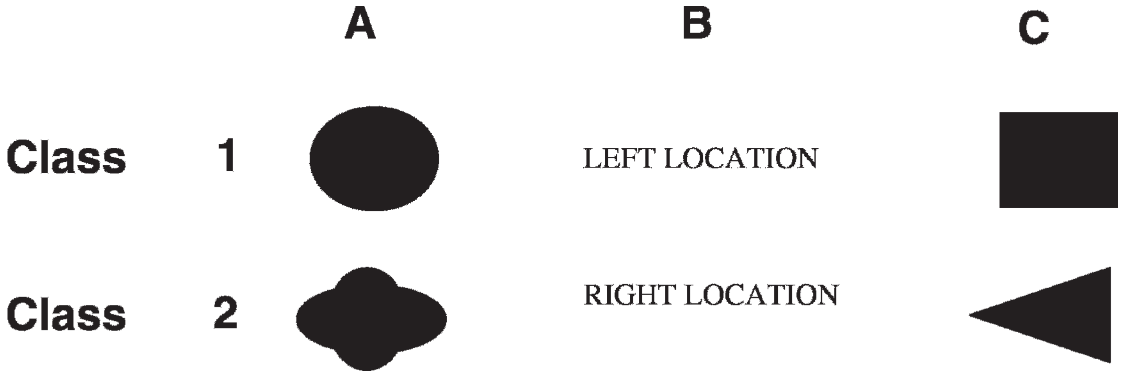

Fig. 4. Abstract form stimuli, their positions, and their designations (A1, B1, C1, A2, B2, C2) in Experiment 2.

potentially emergent behavior using form–position compound stimuli. The positions served the same role in this experiment as the colored grounds in Experiment 1, but there was no added stimulus component—the nodal stimulus was merely the position of the form in the display.

METHOD

Participants

Participants were 2 males and 4 females aged 20–26 years. None had prior familiarity with the experimental analysis of behavior and were debriefed afterwards.

Apparatus and Stimuli

Apparatus was the same as in Experiment 1. Compound stimuli were composed of four abstract forms (designated A1, C1, A2 and C2) presented on the left position (designated B1) or right position (designated B2) on the computer monitor (see Figure 4). Each abstract form was presented in left or right location centered in an area at the bottom of the monitor's screen (see Figure 5).

Procedure

This experiment had the same two-phase structure as Experiment 1: Phase I – Training and Phase II – Equivalence Tests. The difference was the number of compounds and trials.

In Phase I, eight different compound stimuli resulted from the combinations of one of the four abstract forms and one of the two locations (see Figure 5). Compounds with related components were A1B1, A2B2, B1C1 and B2C2. Compounds with not-related components were A1B2, A2B1, B1C2 and B2C1. Each compound appeared equally often within a block. Sessions consisted of 12 blocks of 8 trials (96 trials per session). Each compound was presented for 4 s and each session lasted for about 10 min.

In Phase II, the equivalence tests displayed two forms side-by-side for the first time. Compounds with related components were A1C1, A2C2, C1A1 and C2A2. Compounds with not-related components were A1C2, A2C1, C1A2, and C2A1. Eight different compound stimuli resulted from the combinations of the four abstract forms (see Table 3). Eight equivalence tests were intermixed in unsystematic order within each of 12 test blocks (i.e., 96 total test trials). These tests were conducted under extinction conditions. Each compound was presented for 8 s and each session lasted for about 13 min.

RESULTS AND DISCUSSION

Table 4 shows the percentage of correct performances during training and testing for each participant in Experiment 2. Correct performance was defined in the same manner as in Experiment 1.

Participants took from two to six sessions to reach 100% of correct performances during training. All participants showed the emergence of equivalence relations within one or two testing sessions. Unlike the results of Experiment 1, however, 3 participants (A, E, G) achieved initially low scores (25%) on Equivalence Test trials presented in the first test session. Table 5 presents an analysis of responding in this session, which shows that all participants responded to C1A2 and A1C2 and

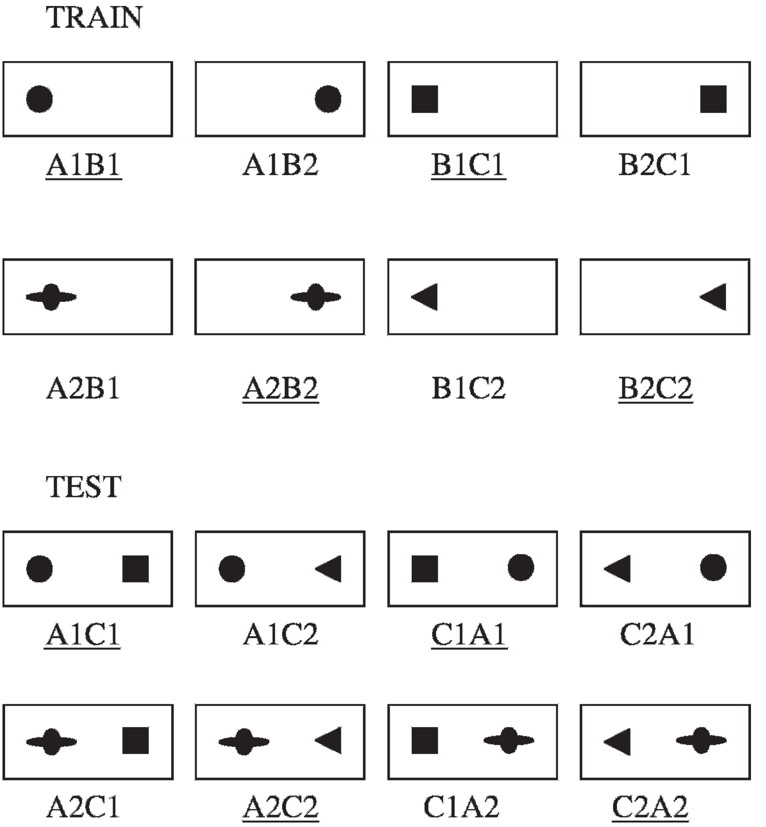

Fig. 5. Stimuli presented in each phase in Experiment 2. Stimuli with components To-Be-Related are underlined.

not to any of the other pairs of forms. These orderly data may have been due in part to effects of the training and the circumstances of testing. Test trials presented forms on the left and right positions for the first time. Participants A, E, and G responded initially only to displays in which the left and right positioning of the stimuli were compatible with previously reinforced choices. That is, both C1 and A1 on the right and A2 and C2 on the left were on the positions that they were on trials that were followed by reinforcers. In the second test session, however, the response pattern changed abruptly. Participants A, E and G immediately displayed performances that were 100% consistent with the form–position-based equivalence relations. One question may be why the other 3 participants apparently ignored the conflict. Perhaps the participants as a group were presented with two equally

Table 3

Compound abstract stimuli presented in each of the phases in Experiment 2.

PHASE I TRAIN		PHASE II TEST	
Related	Not-Related	Related	Not-Related
A1B1	A1B2	A1C1	A1C2
A2B2	A2B1	A2C2	A2C1
B1C1	B1C2	C1A1	C1A2
B2C2	B2C1	C2A2	C2A1

Table 4

Percentage of correct performances in each session for all participants in Experiment 2.*

PARTICIPANT		A	B	C	D	E	G
TRAIN	Session 1	65,6 (63/96)	50,0 (48/96)	55,2 (53/96)	50,0 (48/96)	74,0 (71/96)	75,0 (72/96)
	Session 2	94,8 (91/96)	70,0 (67/96)	70,0 (67/96)	39,6 (38/96)	94,8 (91/96)	100 (96/96)
	Session 3	94,8 (91/96)	83,0 (80/96)	99,0 (95/96)	55,2 (53/96)	94,8 (91/96)	—
	Session 4	100 (96/96)	100 (96/96)	100 (96/96)	94,8 (91/96)	99,0 (95/96)	—
	Session 5	—	—	—	95,9 (92/96)	96,9 (93/96)	—
	Session 6	—	—	—	100 (96/96)	100 (96/96)	—
TEST	Session 1	25,0 (24/96)	94,8 (91/96)	100 (96/96)	100 (96/96)	25,0 (24/96)	25,0 (24/96)
	Session 2	100 (96/96)	—	—	—	100 (96/96)	100 (96/96)

* Values in parentheses represent the number of trials with correct responses and number of trials per session.

possible solutions to the test trial challenges: (1) ignore the conflict and respond according to the form–position history, or (2) match the behavior to the conflict situation by responding only when the stimulus display presented no conflicts with past training. Perhaps it is not surprising that there was a 50%-50% split in the initial responding. Why the 3 participants who initially exhibited the latter behavior pattern immediately switched to the former pattern in the second test session is not immediately obvious. Perhaps the entire test session of extinction for the latter pattern was a variable in occasioning that switch.

In future studies with the go/no-go procedure and form–position compounds, the conflict situation in the present test procedures and perhaps the delayed emergence might be avoided by presenting test stimuli in a central vertical position or perhaps closely spaced horizontally in the center of the display. In both cases, the procedure would avoid presenting specific test stimuli in exactly the same positions as they appeared during training, perhaps reducing or eliminating the conflict created by stimulus-position compounding.

Results from this experiment and from another recent study (Perez, Campos, & Debert, in press) address the trial-balancing issue that was raised in Experiment 1. These data demonstrate that emergent stimulus equivalence relations can be established even when ''go'' and ''no-go'' trials are presented equally often. Together with the immediate emergence of stimulus equivalence relations shown in Experiment 1, the data from Experiment 2 support the suggestion that unbalanced procedures are not the source of emergent equivalence relations in go/no-go procedures. As noted earlier, however, this assertion may depend upon our use of normally capable humans as participants. Indeed, other populations will be needed to address the role of preexperimental history, for example, the ability to label positions independently of the stimuli that appear in them (an important generalized skill in human development and functioning).

Table 5

Percentage of compound stimuli to which Participants A, E and G responded in the first session of Phase II of Experiment 2.*

	Participant A	Participant E	Participant G
A1C1	0 (0/12)	0 (0/12)	0 (0/12)
A1C2	100 (12/12)	100 (12/12)	100 (12/12)
A2C2	0 (0/12)	0 (0/12)	0 (0/12)
A2C1	0 (0/12)	0 (0/12)	0 (0/12)
C1A1	0 (0/12)	0 (0/12)	0 (0/12)
C1A2	100 (12/12)	100 (12/12)	100 (12/12)
C2A2	0 (0/12)	0 (0/12)	0 (0/12)
C2A1	0 (0/12)	0 (0/12)	0 (0/12)

* Values in parentheses represent the number of trials with responses and number of trials per session.

GENERAL DISCUSSION

The present results further support the suggestion by Debert et al. (2007) that one might profitably reexamine analyses of separate discriminative stimulus functions for sample and comparison stimuli in matching-to-sample procedures: samples may act as ''selectors'' of the discriminative stimulus functions of comparisons (Cumming & Berryman, 1965) in a conditional discrimination. Previous investigators have argued on the basis of parsimony that one need not posit that conditional discrimination tasks such as matching-to-sample involve separately defined conditional and discriminative stimuli with special and different functions (cf. Stromer et al., 1993; Thomas & Schmidt, 1989). This issue seems highly relevant in considering the findings of the present experiments. How would one assign, for example, different functions for figure–ground stimuli or form–position compounds in our two experiments? If separately defined sample and comparison functions are not logically necessary in our procedures, why should they be postulated in standard matching-to-sample procedures of the type studied by Sidman and Tailby (1982) and many others? Indeed, results from both experiments described here and from research involving simple discriminations question whether going beyond the three-term contingency relations is necessary to the analysis of equivalence relations (Sidman, 2000). As Sidman has suggested, however, certain preparations and behavioral histories may in fact require analysis in terms of 4-, 5-, and perhaps n-term contingencies (Sidman, 1986). Studies of the type reported here may help in conceptualizing when specification of such higher-level contingencies are and are not logically necessary.

Clearly, the go/no-go procedure succeeds as an alternative to matching-to-sample for study of emergent stimulus–stimulus relations when training involves stimuli of the type employed in the present experiments. An issue for future research is whether procedures of the type reported here will produce similar results when used with nonhumans or humans with developmental limitations that tend not to show emergent relations with matching-to-sample procedure. On their face, such procedures seem to have the advantage of simplicity in the stimulus displays—one reason that they were deemed attractive in early research in comparative cognition (Mallot, Mallot, Svinicki, Kladder, & Ponicki, 1971; Zentall & Hogan, 1975). Whether these procedures will prove ultimately satisfactory is a cause for some concern in their future applications with nonhuman and very young and/or nonverbal humans given some possible complicating factors (e.g., the requirement to avoid responding largely or entirely on no-go trials). That acknowledged, go/no-go procedures have not received the same very extensive study and methodological development as matching-to-sample procedures. Perhaps a program of research focusing on these procedures specifically might overcome these possible complicating factors, permitting their other possible advantages to come to the forefront.

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