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CONDITIONAL RELATIONS WITH COMPOUND ABSTRACT STIMULI USING A GO/NO-GO PROCEDURE

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The aim of this study was to evaluate whether emergent conditional relations could be established with a go/no-go procedure using compound abstract stimuli. The procedure was conducted with 6 adult humans. During training, responses emitted in the presence of certain stimulus compounds (A1B1, A2B2, A3B3, B1C1, B2C2, and B3C3) were followed by reinforcing consequences (points); responses emitted in the presence of other compounds (A1B2, A1B3, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1 and B3C2) were not (i.e., extinction). During subsequent tests of emergent relations, new configurations (BA, CB, AC, and CA relations) were presented, formed by the recombination of training stimuli and structurally resembling tests usually employed in stimulus equivalence studies. Results showed that all 6 participants displayed immediate emergence of relations consistent with symmetry. Four participants exhibited emergent relations consistent with both transitivity and equivalence. These results indicate that a go/no-go procedure with compound stimuli can establish emergent conditional relations, thus providing a procedural alternative to the matching-to-sample procedures commonly used in studies of stimulus equivalence.

Key words: go/no-go procedure, compound stimuli, conditional discrimination, stimulus equivalence, matching-to-sample, button press, humans

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The establishment of directly taught and potentially emergent conditional relations has been studied extensively with the matching-to-sample procedure (e.g., Sidman, 1994). In a typical procedure, a sample stimulus is presented and, after an observing response to it, two or more comparison stimuli are presented—one of which is to be selected by the subject (e.g., Cumming & Berryman, 1961). Although there has been much success in demonstrating emergent matching-to-sample performances in humans, there has not been comparable success with nonhumans, perhaps due in part to competing control by stimulus location (cf. Cumming & Berryman, 1961, 1965; Iversen, 1993, 1997; Iversen, Sidman, & Carrigan, 1986; Sidman et al., 1982; but see Frank & Wasserman, 2005; García & Benjumea, 2006; Urcuioli, Lionello-DeNolf, Michalek, & Vasconcelos, 2006).

One potential alternative to a matching-to-sample procedure is suggested by research using go/no-go procedures that present all of the stimuli to be compared (i.e., related) in the same location (Mallot, Mallot, Svinicki, Kladder, & Ponicki, 1971; Zentall & Hogan, 1975). Such studies have typically been conducted with pigeons and have sought to provide evidence of identity relations. In a typical procedure, stimuli were displayed on two halves of the same response key. If both halves were the same colors, reinforcers followed responses to the key; no reinforcers followed when the two halves were different colors.

After subjects mastered the original go/no-go discrimination, new colors were introduced. Some trials presented the same new color on both halves of the key. Other trials presented different new colors on each half. Pigeons responded more often to the former

This article reflects an inspiring collaboration with the late Maria Amelia Matos. The final version of the manuscript was completed in her memory. Professor Matos, a fascinating, prodigiously productive, exemplary teacher and scholar, was a leading figure in behavior analysis in Brazil since its early days.

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displays—results interpreted by the investigators as evidence that pigeons could exhibit emergent relational discriminative performances (on the basis of identity in this case). Carter and Werner (1978), however, argued that the results could have been the product of simple discriminations, controlled by homogeneously and nonhomogeneously illuminated fields. They judged the evidence for truly emergent stimulus–stimulus relations to be equivocal at best.

The present study involved arbitrary stimulus–stimulus relations of the type employed by researchers interested in stimulus equivalence. The procedure was inspired by Zentall and Hogan's (1975) study but the procedures were such that the distinction between homogeneous versus heterogeneous illumination was not relevant. The stimuli were abstract black-and-white forms. The main purpose of the study was to evaluate whether a single-key go/no-go procedure could provide a workable alternative to the matching-to-sample procedures typically employed in stimulus equivalence research. In this study, the participants were adult humans. If stimulus–stimulus relations consistent with equivalence could be demonstrated, then the procedure might ultimately be adapted for use with nonhumans.

There is precedent in the literature for predicting that the simple pairing of stimuli may establish stimulus–stimulus relations. For example, work on so-called ''respondent-type'' procedures (Leader, Barnes, & Smeets, 1996) has shown that such pairing may be sufficient to allow human participants to match these stimuli in ways that resemble the emergent behavior shown on stimulus equivalence tests. For example, if stimulus A is paired with stimulus B, and stimulus A is also subsequently paired with stimulus C, it has been reported that participants may spontaneously match B and C on matching-to-sample tests. As yet, however, no one has examined the potential of go/no-go procedures of the type reported by Zentall and Hogan (1975) to promote emergent discriminative stimulus control involving related and nonrelated stimulus components in a compound. On its face, procedures of this type may have certain benefits. For example, the stimuli to be observed are closely spaced and thus can be scanned with little or no change in the direction of gaze.

In the ''separable compound'' analysis offered by Stromer, McIlvane, and Serna (1993), compound stimuli were defined in a manner somewhat different from that typical of previous work (cf. Cumming & Berryman, 1965; Sidman, 1986). These authors suggested that the definition of compound stimuli could be expanded to include stimulus elements joined temporally or spatially – components that could be separated and recombined without loss of discriminative control. Stromer et al. focused on matching-to-sample procedures, but their suggestion extends logically to any procedure that presents potentially separable components. Along these lines, the present research tested whether emergent control could be produced using a go/no-go procedure.

METHOD

Participants

The participants were 6 undergraduate students (2 females and 4 males, between 20 and 26 years of age). None had prior familiarity with the experimental analysis of behavior. They were told that they would receive a voucher for their participation at the end of the study. The voucher could later be exchanged for books or CDs. After finishing the tasks, participants were fully debriefed.

Apparatus

All sessions were conducted individually in a 3-m × 3-m room. An IBM computer with 14'' color monitor was used. Each participant was seated facing the monitor and could respond directly to a compound stimulus by positioning the mouse's cursor anywhere on the compound and depressing the button. A program developed in Visual Basic controlled all stimulus presentations and recorded participants' button presses.

Components of the compound stimuli were nine abstract forms (after Markham & Dougher, 1993). They were designated as A1, B1, C1, A2, B2, C2, A3, B3 and C3 for purposes of identification only; the designations were not displayed on the computer screen (see Figure 1). Pairs of these stimuli (i.e., the compounds) were presented one at a time in the center of the monitor's screen (see Figure 2). The experimental stimuli were judged physically dissimilar with respect to

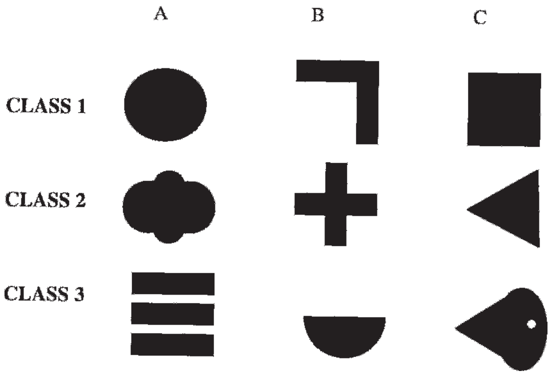

Fig. 1. Abstract stimuli developed by Markham and Dougher (1993) and their designations in the present study (A1, B1, C1, A2, B2, C2, A3, B3, C3).

form; stimulus–stimulus relations were arbitrarily defined by the contingencies programmed by the experimenter.

Procedure

The experiment had three phases. In each phase, all trials started with a 4-s presentation of a stimulus compound. The order of presentation of compounds with to-be-related and not-to-be-related components (henceforth ''related'' and ''not-related'') varied randomly across trials. The order was restricted such that neither type of trial could be presented more than three times successively. During each trial, participants could click one or many times with the mouse. In order to count as a valid response, the mouse cursor had to be positioned on the stimulus.

During Phase I, stimulus components were always presented in the same spatial location (e.g., always A1B1 and never B1A1). Reinforcers for button presses to compounds with related components consisted of the sound of tokens falling and of the addition of 10 points on a counter positioned in the upper-left corner of the screen. 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 and no programmed consequences for responding during the intertrial interval. During Phases II and III, no point counter was shown. Phase I ended when participants had made no errors in a given session, that is, they had responded to each compound with related components and made no response to compounds with not-related components. Phases II and III were test sessions, and were conducted for one session only, regardless of performance.

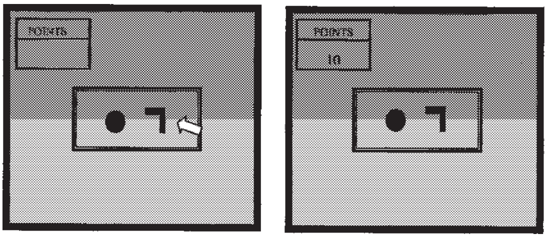

Fig. 2. Illustration of the monitor screen during a trial. The drawing on the left shows the monitor screen after a participant clicked the ''OK'' button. The drawing on the right shows the screen after a participant's correct response to the compound stimulus. The point counter is shown at the upper-left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

Phase I: Training of Baseline Relations. In this phase, a differential reinforcement procedure was used to establish button-pressing to related components and not pressing to not-related components. At the beginning of this phase, each participant sat facing the monitor that showed 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. Thus, pay attention even when the task seems very simple. Please, repeat to me the instructions you just read.

When participants stated that they understood the procedures, they received the following 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 compound stimulus was presented in

Table 1

Compound abstract stimuli presented in each of the experimental phases.

PHASE I		PHASE II		PHASE III			
TRAINING		TEST I Symmetry		TEST II Transitivity		TEST III Equivalence	
Related	Not Related	Related	Not Related	Related	Not Related	Related	Not Related
A1B1	A1B2	B1A1	B2A1	A1C1	A1C2	C1A1	C1A2
A2B2	A1B3	B2A2	B3A1	A2C2	A1C3	C2A2	C1A3
A3B3	A2B1	B3A3	B1A2	A3C3	A2C1	C3A3	C2A1
B1C1	A2B3	C1B1	B3A2		A2C3		C2A3
B2C2	A3B2	C2B2	B2A3		A3C1		C3A1
B3C3	A3B1	C3B3	B1A3		A3C2		C3A2
	B1C2		C2B1				
	B1C3		C3B1				
	B2C1		C1B2				
	B2C3		C3B2				
	B3C1		C1B3				
	B3C2		C2B3				

the center of the screen, and the counter (initially set at zero) was displayed in the left upper corner (see Figure 2).

During the first 36 trials, button presses to related compound 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 compound stimuli and 2.5 s, on average, had elapsed). The conjunctive schedule was used in order to prevent very rapid responding that might interfere with the development of stimulus control by the compound stimuli (i.e., responding solely under the discriminative control of the consequences). When not-related components were displayed, behavior was never followed by points (thus following the procedure used in previous work with nonhumans).

Each compound stimulus with related and not-related components was presented for 4 s regardless of participant behavior.

Eighteen different compound stimuli resulted from the combinations of the nine abstract forms used (see Table 1). Each compound with related components was presented twice in a block of trials, while each of the not-related components was presented once. Via this balancing procedure, related and not-related compounds appeared equally often in a block. Sessions consisted of 12 blocks of 24 4-s trials each and lasted for about 30 min.

Phase II: Symmetry Tests. This phase tested for symmetry under extinction conditions. On such tests, the spatial position of the components of the compound stimuli in Phase I were reversed (see Table 1, Phase II). At first blush, such spatial rearrangement may not appear to

Table 2

Percentage of correct performances for each participant during training and testing.

Participant		A	N
Training	Session 1	60.0 (173/288)	70.1 (202/288)
	Session 2	93.4 (269/288)	90.6 (261/288)
	Session 3	100.0 (288/288)	90.6 (261/288)
	Session 4	—	96.8 (279/288)
	Session 5	—	99.6 (287/288)
	Session 6	—	100.0 (288/288)
Symmetry Test	Session 1	100.0 (144/144)	100.0 (144/144)
Transitivity and Equivalence Tests	Block 1	58.3 (14/24)	75.0 (18/24)
	Block 2	100.0 (24/24)	95.8 (23/24)
	Block 3	95.8 (23/24)	95.8 (23/24)
	Block 4	100.0 (24/24)	95.8 (23/24)
	Block 5	100.0 (24/24)	100.0 (24/24)
	Block 6	100.0 (24/24)	100.0 (24/24)

constitute a true test of symmetry. From a logical perspective, however, it is in fact a test of symmetric stimulus–stimulus relations. The separable compound account of Stromer et al. (1993) makes this relationship explicit.

Sessions were composed of six blocks of 24 trials each. 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.

Phase III: Transitivity and Equivalence Tests. This phase tested for transitive relations (compounds of the form AC) and equivalence relations (compounds of the form CA) under extinction conditions. These specifications follow the logical definition of these terms as per Stromer et al. (1993). Such relations would be shown if participants responded appropriately to recombinations of related (A1C1, A2C2, A3C3, C1A1, C2A2, and C3A3) and unrelated (A1C2, A1C3, A2C1, A2C3, A3C1, A3C2, C1A2, C1A3, C2A1, C2A3, C3A1, and C3A2) component stimuli (see Table 1). Six blocks of 24 trials were presented. Twelve trials of Transitivity and twelve of Equivalence were intermixed randomly within the same block. Instructions were the same as those presented during Phase II.

RESULTS

Table 2 shows the percentage of correct performances during training and testing for each participant. The number of compounds with related components to which there was at least one button press was added to the number of compounds with not-related components to which there were no such responses and divided by the total number of trials.

Training was completed within three to six sessions. All participants showed the emergence of symmetric relations from the start of the first session of Phase II. Four participants (A, N, S, and Y) showed emergence of transitive and equivalence relations within two to five blocks of the first test session in Phase III. Participant D exhibited scores that were between 75% and 91.6% consistent with transitivity and equivalence. Thus, for all but one participant, the results demonstrated that components of a compound stimulus could be separated and recombined in a manner consistent with stimulus–stimulus relations established in training.

Table 3 presents a finer-grain analysis of the emergence of transitive and equivalence relations for Participants A, N, S, and Y during Phase III. It shows that accuracy was generally higher during Block 1 for the compounds with not-related component stimuli; thus, there was a pervasively low rate of responding initially. This pattern may be due in part to the brief duration of each trial. Given that the participants were exposed to new stimulus compounds, it is perhaps not surprising that they showed an initial tendency towards slower responding. The result, of course, was initially high percentages of correct performance for compounds with not-related components and low percentages for compounds with related components. That pattern changed quickly,

Table 2

(*Extended*)

S	Y	D	J
63.5 (183/288)	69.0 (199/288)	52.4 (151/288)	64.2 (185/288)
81.2 (234/288)	82.6 (238/288)	57.9 (167/288)	80.5 (232/288)
91.6 (264/288)	99.3 (286/288)	83.6 (241/288)	93.4 (269/288)
97.5 (281/288)	100.0 (288/288)	94.0 (271/288)	100.0 (288/288)
100.0 (288/288)	—	94.4 (272/288)	—
—	—	100.0 (288/288)	—
100.0 (144/144)	100.0 (144/144)	100.0 (144/144)	100.0 (144/144)
54.1 (13/24)	45.8 (11/24)	75.0 (18/24)	62.5 (15/24)
100.0 (24/24)	75.0 (18/24)	83.3 (20/24)	62.5 (15/24)
100.0 (24/24)	91.6 (22/24)	91.6 (22/24)	66.6 (16/24)
100.0 (24/24)	100.0 (24/24)	87.5 (21/24)	75.0 (18/24)
100.0 (24/24)	100.0 (24/24)	91.6 (22/24)	66.6 (16/24)
100.0 (24/24)	100.0 (24/24)	87.5 (21/24)	66.6 (16/24)

Table 3

Percentage of correct performances for Participants A, N, S and Y in each block during Transitivity and Equivalence Test in Phase III.

	A		N		S		Y	
	Related	Not Related	Related	Not Related	Related	Not Related	Related	Not Related
Block 1	25.0 (3/12)	91.6 (11/12)	50.0 (6/12)	100.0 (12/12)	25.0 (3/12)	83.3 (10/12)	0 (0/12)	91.6 (11/12)
Block 2	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	91.6 (11/12)	100.0 (12/12)	100.0 (12/12)	58.3 (7/12)	91.6 (11/12)
Block 3	100.0 (12/12)	91.6 (11/12)	100.0 (12/12)	91.6 (11/12)	100.0 (12/12)	100.0 (12/12)	91.6 (11/12)	91.6 (11/12)
Block 4	100.0 (12/12)	100.0 (12/12)	91.6 (11/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)
Block 5	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)
Block 6	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)	100.0 (12/12)

however, as participants were further exposed to the new combinations.

Remaining for consideration are the performances of Participants D and J; neither achieved 100% performance during Phase III. Table 4 presents a summary of the performance of Participant D. It shows that performance was characterized throughout by occasional errors, especially on trials involving compounds with related components, but these were unsystematic in the sense that they were distributed across all trial types. Indeed, the overall pattern was largely consistent with the emergent relations that one might predict given the prior training with compounds with related and unrelated components.

Another way to examine the performance of participant D is by comparing it to chance (which would be 50% in the present design). In each block of transitivity and equivalence test, participant D exhibited more than 75% correct performance and reached more than 90% in some blocks. Scores at the latter level reach statistical significance via exact-probability statistics (p = .03, binomial test, see Deutsch, Lauer, Patel, & Mehta, 2001, for a discussion of the use of such metrics in behavior analysis). Thus, one could argue that participant D also showed emergence of transitive and equivalence relations.

By contrast, Table 5 indicates that Participant J showed a definitive pattern of behavior. He did not respond whenever A1 or C1 was present but did respond when they were absent. This is evidence of simple discriminative stimulus control. There was no evidence of emergent relations consistent with transitivity or equivalence.

Unfortunately neither Participants D nor J could be tested further after the initial test session in Phase III. Although further testing was scheduled, they did not return to the laboratory at the appointed time.

DISCUSSION

All 6 participants exhibited emergent relations consistent with symmetry, and 4 (arguably 5) participants exhibited emergent relations consistent with transitivity and equiva-

Table 4

Percentage of correct performances and of the compound stimuli to which Participant D produced errors during Phase III.

	Related	Not Related	Errors in related	Errors in not related
Block 1	66.6 (8/12)	83.3 (10/12)	A1C1, A1C1, A2C2, C1A1,	A3C2, C3A2
Block 2	83.3 (10/12)	83.3 (10/12)	A1C1, C3A3	A2C3, C3A2
Block 3	83.3 (10/12)	100.0 (12/12)	A3C3, C3A3	—
Block 4	83.3 (10/12)	91.6 (11/12)	A3C3, C1A1	A2C3
Block 5	83.3 (10/12)	100.0 (12/12)	A3C3, C3A3	—
Block 6	75.0 (9/12)	100.0 (12/12)	A1C1, C1A1, C2A2	—

Table 5

Percentage of compound stimuli to which Participant J responded in Phase 3.

Compound stimuli whose members were A1 or C1		Compound stimuli whose members were not A1 or C1	
A1C1	0 (0/12)	A2C2	100.0 (12/12)
A1C2	0 (0/6)	A2C3	100.0 (6/6)
A1C3	0 (0/6)	A3C2	66.6 (4/6)
A2C1	0 (0/6)	A3C3	83.3 (10/12)
A3C1	0 (0/6)	C2A2	100.0 (12/12)
C1A1	0 (0/12)	C2A3	100.0 (6/6)
C1A2	0 (0/6)	C3A2	100.0 (6/6)
C1A3	0 (0/6)	C3A3	91.6 (11/12)
C2A1	0 (0/6)		
C3A1	0 (0/6)		

lence during tests in extinction. The positive findings are thus strongly in line with the ''separable compound'' account proposed by Stromer et al. (1993); components of compound stimuli can be ''separated'' and ''recombined'' into new compounds without disrupting stimulus control over performance (these are, of course, mere descriptive terms that do not specify underlying processes). The go/no-go approach suggested by Zentall and Hogan (1975) made it possible to observe compound separation and recombination within the framework of a three-term contingency rather than the four- and five-term contingencies used in past studies (e.g., Markham & Dougher, 1993). Thus, these findings are consistent logically with Sidman's (2000) proposition that equivalence relations can arise at the level of the three-term contingency.

The present results suggest also that one might profitably reconsider 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 argued, for example, that it was more parsimonious to think in terms of discriminative stimulus compounds rather than separate conditional and discriminative stimuli with special and different functions in a conditional discrimination (cf. Stromer et al., 1993; Thomas & Schmidt, 1989). In the present study, for example, how would one assign different functional roles to one component or the other of a stimulus compound? Both were presented in the same manner.

Clearly, the go/no-go procedure at the three-term level can succeed as an alternative to matching-to-sample for study of emergent stimulus–stimulus relations. A critical issue for future research is whether procedures of the type reported here will produce similar results when employed with humans who are developmentally limited (e.g., preschool children) or with nonhumans. There is no reason at this point to suspect that the go/no-go procedure employed here would have qualitatively different effects, given that provision is made to discourage so-called ''stimulus overselectivity'' or ''restricted stimulus control'' (Dube & McIlvane, 1999; Schreibman, Charlop, & Koegel, 1982). However, there is a long history of difficulty in producing emergent behavior in these populations regardless of the testing methodology. Past arguments that failures of behavioral emergence reflected failures of behavioral capacity are rapidly losing their force, however, as more complex relational discrimination performances are being reported in nonhumans (e.g., Galvão et al., 2005; Kastak & Schusterman, 2002).

The literature on relational learning in nonhumans offers many clues for the design of procedures that may produce emergent relations. For example, Zentall, Edwards, Moore, and Hogan (1981) introduced a procedure that ''forced'' pigeons' discrimination of all stimuli in generalized identity matching and oddity tasks. These rigorous requirements resulted in perhaps the strongest evidence for emergent identity matching thus far reported in any avian species. A similar approach at the three-term level seems possible with procedures like those in the present study. Even within the context of the present procedures, one can envision improvements in the parameters of testing. For instance, increasing the time of compound-stimulus presentation might lead to more interpretable results during testing. At present, we cannot differentiate between longer latencies due merely to the sudden appearance of new trial types and those reflecting perhaps more interesting discriminative processes (e.g., see Sidman, 1992, for a discussion of how behavior exhibited during testing might encourage the development of equivalence relations). A question for future research is whether procedural variations might encourage more rapid development of discriminative control and emergent behavior (e.g., reinforcement for ''correct rejections,'' use of an explicit ''Yes/No'' procedure, etc.).

In conclusion, the present study provides some of the strongest evidence thus far in support of the ''separable compound'' account of emergent behavior that was implicit in Zentall and Hogan's (1975) analysis and made explicit by Stromer et al. (1993). Stimulus components presented together in a compound can retain discriminative control consistent with training even when recombined in different pairings. Yet to be determined are the circumstances under which compounds will separate and recombine reliably. Advancing knowledge in this area is likely to teach us about behavioral processes underlying emergent behavior specifically and ''attending'' (Dinsmoor, 1985) in general.

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