

TRANSFER OF OPERANT DISCRIMINATION AND RESPONDENT
ELICITATION VIA EMERGENT RELATIONS OF COMPOUND STIMULIMICHAEL R. MARKHAM
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Two experiments investigated transfer of stimulus functions via emergent relations of compound stimuli. In Experiment 1, 4 college students were taught nine conditional relations of compound stimuli and unitary stimuli (A1B1-C1, A1B2-C3, A1B3-C2, A2B1-C3, A2B2-C2, A2B3-C1, A3B1-C2, A3B2-C1, and A3B3-C3), then tested for 18 untrained stimulus relations derived from the trained relations (e.g., A1C1-B1; B1C1-A1). Participants were then taught to sequence the A stimuli (A1→A2→A3), and tested for transfer of this sequencing response to BC compounds. Two participants demonstrated transfer of the sequencing response. Two participants demonstrated transfer of the sequencing response after additional experimental phases. In Experiment 2, 5 college students were taught nine AB-C relations and then tested for 18 AC-B and BC-A relations as in Experiment 1. A skin conductance response was conditioned to A1 by pairing this stimulus with mild electric shock. Participants were then tested for transfer of this skin conductance response to B1C1 and B3C2. Three participants showed the transfer of conditioning. One participant did not demonstrate conditioning of the skin conductance response. One participant showed transfer of the skin conductance response after a supplemental conditioning phase. Initial failures to show transfer for some participants suggest that transfer of function sometimes depends upon a history of differential responding to compound stimuli. These results suggest that emergent relations involving compound stimuli and stimulus equivalence are related phenomena.

Numerous recent studies of stimulus equivalence have included complex (multielement) sample stimuli in the match-to-sample training and testing procedures used to investigate stimulus equivalence. In some experiments, the multielement samples functioned as *complex stimuli* wherein each element of the complex sample could independently control selection of a particular comparison (e.g., Schenck, 1993; Smeets, Schenk,

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& Barnes, 1994, 1995; Smeets & Streifel, 1994; Stromer, McIlvane, & Serna, 1993; Stromer & Stromer, 1990a, 1990b). In other cases, the multielement stimuli functioned as *compound stimuli*, meaning that all elements of the compound had to be present to control comparison selection (e.g., Augustson, Dougher, & Markham, 2000; Carpentier, Smeets, & Barnes-Holmes, 2000; Markham & Dougher, 1993; Serna, 1991).

Collectively, these studies have raised important questions about the stimulus control exerted by multielement stimuli and the individual elements comprising them (Carpentier et al., 2000). These experiments also have produced the suggestion that analysis of control by complex or compound stimuli may be necessary for a complete account of the emergence of equivalence relations from stimulus-stimulus relations (Stromer et al., 1993). In particular, Stromer and colleagues (1993) argued that stimulus equivalence may, at least in some cases, result from discrimination of multielement complex stimuli with separable and substitutable elements (see also Augustson et al., 2000; Carpentier et al., 2000; Dougher & Markham, 1994).

Additionally, some of the experiments that used *compound stimuli* have shown the emergence of matching performances that are difficult to conceptualize in terms of equivalence relations (Markham & Dougher, 1993; Perez-Gonzalez, 1994; Serna 1991). For example, Markham and Dougher (1993) taught college students to match unitary stimuli to compound samples (AB-C relations - see Figure 1, left panel). In subsequent tests for emergent matching performances, participants readily demonstrated symmetrical responding (i.e., C-AB matching). Following training of C-D matching, participants also demonstrated transitive responding (i.e., AB-D matching).

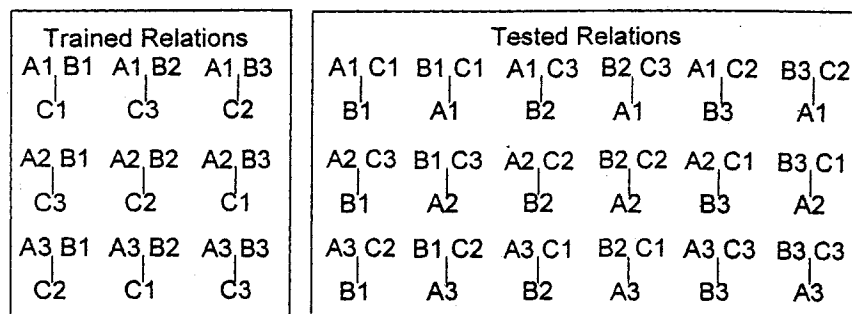


Figure 1. Stimulus relations trained (left panel) and tested (right panel) in Markham and Dougher (1993; Experiment 1).

In another of Markham and Dougher's 1993 experiments, they taught 11 participants nine AB-C relations (Figure 1, left panel). All 11 participants subsequently matched elements of the compound samples to novel

compound samples at high levels of accuracy (AC-B and BC-A matching - see Figure 1, right panel). This emergent matching is similar to emergent symmetry and transitivity, two of the properties that define equivalence relations (Saunders & Green, 1992; Sidman, 1986, 1994, 2000; Sidman & Tailby, 1982). However, the emergent AC-B and BC-A matching observed by Markham and Dougher is not reducible to symmetrical responding (i.e., C-AB matching) and/or transitive responding (i.e., AB-D responding). Thus, a critical issue raised by these experiments is whether the emergent AC-B and BC-A matching is a property of an equivalence relation among the stimuli or a property of some other emergent relation among the stimuli.

One way to address this issue would be to extend Markham and Dougher's 1993 findings by first replicating their procedures then performing tests for transfer of function. Transfer of function among stimuli may, in fact, be a better measure of their substitutability (thereby equivalence) than emergent matching performances alone (Fields, Adams, Verhave, & Newman, 1993; Spencer & Chase, 1996). Accordingly, successful tests for transfer of function would suggest that Markham and Dougher's findings are a result of establishing equivalence relations, whereas failure to demonstrate transfer of function would suggest that the emergent AC-B and BC-A matching was not under the control of an equivalence relation.

In one such study (Augustson et al., 2000) we established the nine AB-C baseline relations shown in Figure 1, then tested for emergent compound-compound matching (e.g., AC-AC, BC-BC). Following positive tests for the compound-compound relations, we demonstrated that a classically conditioned respondent function established for one compound stimulus transferred to related compound stimuli. These experiments thus verified the functional substitutability of the emergent compounds, suggesting equivalence of the compounds. These experiments, however, did not address the functional substitutability of stimuli in the AC-B and BC-A relations shown by Markham and Dougher (1993).

The present experiments attempted to extend our earlier (Augustson et al., 2000) findings by establishing the same emergent relations as in the Markham and Dougher (1993) study, then investigating whether a stimulus function established for a single-element stimulus would transfer to related compound stimuli. The experiments described here also extended our earlier findings by testing for transfer of both operant and respondent stimulus functions.

Experiment 1 was designed to test for the transfer of an operant sequencing response via emergent relations of compound stimuli, and Experiment 2 was designed to test for the transfer of a classically conditioned skin conductance response. In both experiments, we first taught participants the 9 AB-C relations shown in the left panel of Figure 1, then tested for the 18 AC-B and BC-A relations shown in the right panel of Figure 1. Subsequently, in Experiment 1, participants were taught to sequence the A stimuli (A1→A2→A3) then tested for transfer of appropriate sequencing of BC compounds. In Experiment 2, participants

completed a respondent conditioning phase wherein A1 served as CS+ while A2 and A3 served as CS-. We then tested for respondent elicitation by the B1C1 and B3C2 compounds.

Experiment 1

Method

Participants

Participants were 4 undergraduates (3 female and 1 male) recruited from introductory psychology courses and remunerated with course credit. At the beginning of the experiment, the general procedures were explained, and all participants read and signed a statement of informed consent. Upon completion of the study, all participants were thoroughly debriefed.

Apparatus and Stimuli

An IBM Personal Computer with a 33-cm (diagonal) monochrome display presented stimuli and recorded data during the experiment. Participants were seated before the personal computer in a small experiment room (2 m x 3 m) with a two-way mirror for participant observation.

Stimuli were nine abstract forms identified as A1, B1, C1, A2, B2, C2, A3, B3, and C3 (see Figure 2). Each stimulus occupied a 4-cm by 5-cm

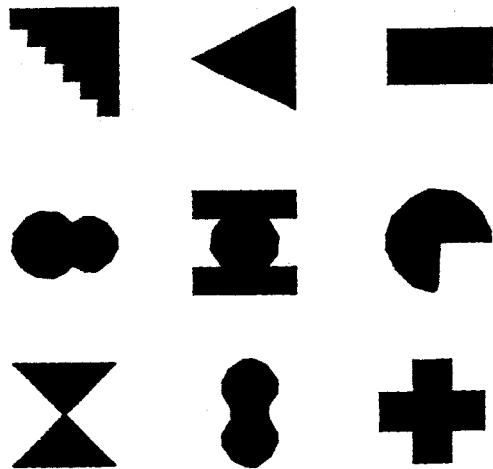


Figure 2. Stimuli used in Experiments 1 and 2.

space on the display. Compound stimuli were pairs of stimuli (e.g., A1 and C2) presented side by side on the screen (see Figure 3). Elements comprising compound stimuli were randomly assigned to the left and right positions for each trial. Thus, left or right position of compound elements was not systematically related to other experimental events.

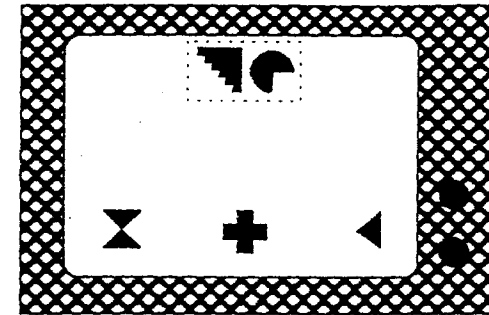


Figure 3. Compound samples and unitary comparisons as they would appear on the participant's monitor.

Procedure

The experiment consisted of five phases. In Phase 1, participants were taught nine AB-C relations. During Phase 2 participants were tested for 18 AC-B and BC-A relations derived from the initially trained AB-C relations. In Phase 3, participants were taught to sequence the three A stimuli in the order A1→A2→A3. Phase 4 tested participants for transfer of the sequencing response to BC compounds. In Phase 5, participants were retested for the 18 AC-B and BC-A relations presented in Phase 2.

Phase 1 - Train nine AB-C relations. Phase 1 trained nine conditional relations among compound samples and unitary comparisons. Phases 1, 2, and 5 used arbitrary match-to-sample procedures. For each trial, the compound sample appeared at the top center of the screen, followed 2 s later by the three comparisons at the bottom left, bottom center, and bottom right of the screen. The comparisons were randomly assigned to the left, middle, or right position at the bottom of the screen. Participants selected one of the comparisons by pressing the "1," "2," or "3" key on the computer keyboard to select the left, middle, or right comparison, respectively. After a key was pressed, the screen cleared and, during training, responses to the correct comparison produced the word "Correct" on the monitor, while other choices produced the word "Wrong." The screen cleared again after a 5-s delay. After a 2-s intertrial interval, a new trial began. During testing trials (Phases 2 and 5), no feedback appeared after participants' choices. Participants were given the following instructions to read:

When the experiment begins, you will see sets of symbols appear on the screen. They will appear at the top of the screen, and at the bottom of the screen on the left, middle and right. Your task is to choose the correct symbol at the bottom of the screen by pressing the "1," "2," or "3" key on the keyboard to select the left middle or right symbol. During the experiment you will get feedback on every choice. Later in the experiment you will not get feedback every time. However, there is always a correct answer. During the first part of the experiment the task will be easy and it is tempting not to pay attention. However, the experiment will increase in difficulty

and choosing the correct symbols in the latter parts of the experiment will depend on the knowledge you gain during the early parts of the experiment. To prevent impulsive responding, the computer will not accept choices for one second after the symbols appear. Do you have any questions?

After reading the instructions participants were asked to explain the instructions to the experimenter. If unable to do so, the experimenter explained the instructions and the participant was required to read the instructions again. After mastering the instructions, participants began the experiment.

Nine AB-C relations were trained using the nine trial types shown in the left panel of Figure 1 until participants reached a training criterion of 70 correct out of 72 consecutive trials. The comparison array for each trial type consisted of C1, C2, and C3. These nine baseline AB-C relations were designed such that no stimulus was associated exclusively with any other stimulus. Thus, this design prevented participants from responding based upon only one element of the compound samples. For example, if a participant were to correctly select C1 in the trial type A1B1-C1 based only upon the presence of B1, then his or her response to the trial type A2B1-C3 would necessarily be incorrect, as B1 would in this case control choices of C1.

Baseline relations were presented in blocks of nine trial types. Each trial type consisted of one compound sample and its designated comparison array. Within each block of training trials, trial types were presented in a random order.

Phase 2 - Test for 18 AC-B and BC-A relations. Once baseline AB-C relations were established in Phase 1, participants were tested for nine AC-B and nine BC-A relations. The trial types for these tests are shown in Table 1. During testing, 20 blocks of these 18 trial types were presented. Within each block, trial types were presented in a random order. As was the case in training, responding only to elements of the stimulus compounds would necessarily lead to a majority of incorrect responses. For example, if a participant's choice of B1 in the presence of A1C1 was controlled by C1 alone, then the participant would also select B1 in the presence of A2C1 which is an incorrect selection (see Table 1). Thus, reliable correct responding during testing must be controlled by both elements of the sample in conjunction with the correct comparison.

Phase 2 ended when participants completed 360 test trials. After completing Phase 2, participants were allowed a 5-min break before beginning Phase 3.

Phase 3 - Train sequencing of A stimuli. Participants were given the following instructions before beginning Phase 3:

During this part of the experiment, there will be three symbols at the bottom of the screen on the left, middle, and right. Your task is to choose the symbols in the correct order by pressing the "1", "2", and "3" keys on the keyboard. The "1" key chooses the left symbol, the "2" key chooses the middle symbol, and the "3" key chooses the right symbol. A marker will appear above each symbol as you choose it. Press the keys in the order you think the symbols should

Table 1

Trial Types Presented During Phases 2 and 5 of Experiments 1 and 2

Sample	Comparisons		
	Correct	Incorrect	Incorrect
A1C1	B1	B2	B3
B1C1	A1	A2	A3
A1C3	B2	B1	B3
B2C3	A1	A2	A3
A1C2	B3	B1	B2
B3C2	A1	A2	A3
A2C3	B1	B2	B3
B1C3	A2	A1	A3
A2C2	B2	B1	B3
B2C2	A2	A1	A3
A2C1	B3	B1	B2
B3C1	A2	A1	A3
A3C2	B1	B2	B3
B1C2	A3	A1	A2
A3C1	B2	B1	B3
B2C1	A3	A1	A2
A3C3	B3	B1	B2
B3C3	A3	A1	A2

be in. During the first part of the task you will get feedback after every sequence choice. Later, you will not get feedback. However, there is always a correct answer. When this part of the experiment ends, the computer will instruct you to find the experimenter for further instructions.

During Phase 3, participants were taught to select the A stimuli in the order A1→A2→A3. On each trial, the three A stimuli appeared at the bottom left, middle, and right of the screen. The stimuli were randomly assigned to the left, middle, and right positions for each trial. Participants selected one of the stimuli by pressing the "1," "2," or "3" key on the computer keyboard to select the left, middle, or right comparison, respectively. When the participant selected a stimulus, a box appeared around the selected stimulus. After participants selected all three stimuli, the screen cleared and written feedback appeared on the screen. During training, if participants selected stimuli in the order A1→A2→A3, the screen cleared and the word "Correct" appeared on the monitor, while other sequences produced the word "Wrong." The screen cleared again after a 5-s delay. After a 2-s intertrial interval, a new trial began. Training continued until participants reached a criterion of 28 trials correct out of 30 consecutive trials.

Phase 4 - Test for transfer of sequencing response to BC compounds. During Phase 4, participants were tested for the transfer of the trained sequencing function to the BC compounds. Twenty blocks of three different trial types were presented. Testing trials followed the same format as training trials in Phase 3 with two exceptions: (a) Trials consisted of three BC

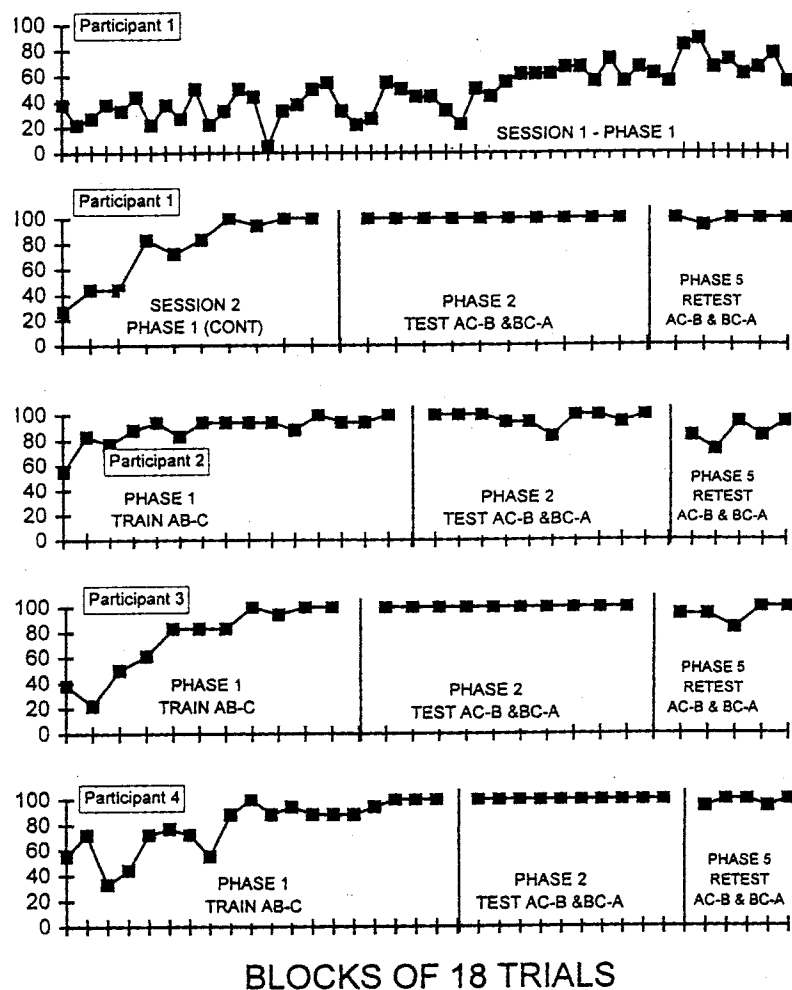


Figure 4. Data for all participants in Experiment 1, Phases 1, 2, and 5.

compounds presented at the bottom left, middle, and right of the screen and (b) no feedback appeared on the screen after the participant's response. Correct sequence choices for the trial types presented in this phase were B1C1→B2C2→B3C3, B2C3→B3C1→B1C2, and B3C2→B1C3→B2C1. Phase 4 ended after participants completed all 60 trials.

Phase 5 - Retest AC-B and BC-A relations. In Phase 5, participants were retested for the 18 AC-B and BC-A relations initially tested in Phase 2. Phase 5 proceeded exactly as Phase 2 except that only five 18-trial blocks were presented. The experiment ended when participants completed Phase 5.

Results

Phases 1, 2, and 5

Data for all participants in Phases 1, 2, and 5 of Experiment 1 are shown in Figure 4. This figure presents the percentage of trials correct over 18-trial blocks. All participants acquired the baseline AB-C relations in Phase 1 and demonstrated the emergence of AC-B and BC-A relations in Phase 2. Participant 1 required two sessions to complete the experiment. She did not complete Phase 1 during the first 4-h session, but did complete Phase 1 and all remaining phases in a second session. The other three participants completed the experiment in one session.

Data for all participants in Phase 5 are shown in Figure 4. These data indicate that all participants maintained the emergent AC-B and BC-A relations initially tested in Phase 2 throughout the experiment.

Phases 3 and 4

Data for all participants in Phases 3 and 4, graphed as percentage of trials correct over 12-trial blocks are shown in Figure 5. All participants rapidly met the criterion for sequencing of the A stimuli in Phase 3. Participants 1 and 4 performed at high levels of accuracy during Phase 4, thus demonstrating transfer of the sequencing response to the BC stimuli. Participants 2 and 3, however, performed near chance-level accuracy during the test for transfer in Phase 4. Both participants demonstrated maintenance of the emergent AC-B and BC-A relations during Phase 5. Therefore, failure to maintain the derived AC-B and BC-A relations demonstrated in Phase 2 was not the reason for the failure to demonstrate transfer in Phase 4. Both participants were asked by the experimenter how they chose their sequences in Phase 4. The experimenter asked Participant 2, "During the part of the experiment where you were putting the pairs of shapes in order, how did you choose the order?" Participant 2 stated, "I didn't know what the pairs at the bottom meant. They were from the first part [Phases 1 and 2], but I couldn't figure out how to pick them, so I tried different orders." Participant 3 stated "I wasn't sure how to pick the pairs at the bottom. I knew which ones [stimuli] the pairs went with, but you didn't tell me if I had to put the pairs in the right order, or the parts of them, or what."

Based on these reports, we hypothesized that one possible reason why the BC compounds presented during Phase 4 did not control participants' sequence responses as expected was that participants had no previous history of responding differentially to compound stimuli in the experiment. That is, at no other time during the experiment had more than one compound appeared on the screen at the same time, and participants had not previously been required to select from an array of compound stimuli. To test this possibility, four additional experimental phases (A1, A2, A3, and A4) were conducted with Participants 2 and 3. In Phase A1, which was identical to Phase 5, participants were retested for AC-B and BC-A relations. We then introduced Phase A2, wherein

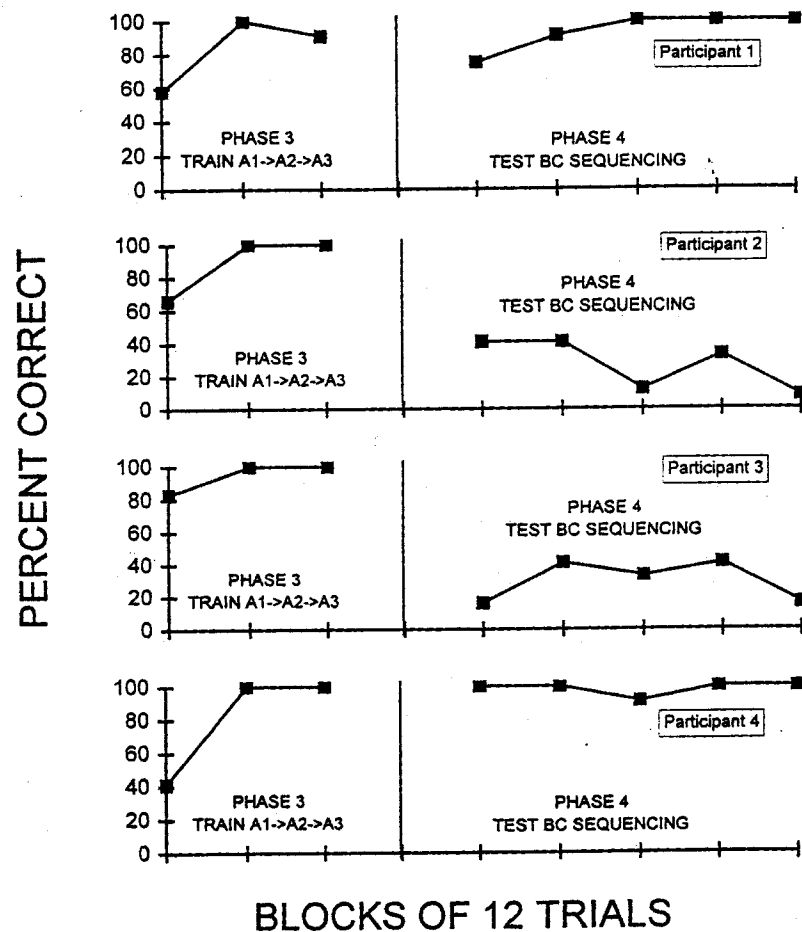


Figure 5. Data for all participants in Phases 3 and 4.

participants were tested for the 18 A-BC and B-AC relations shown in Table 2. Phase A2 was designed to evoke differential responding to BC and AC compounds presented as comparisons by requiring participants to select one of the three compounds presented in the comparison array for each trial. Phase A2 proceeded exactly as Phase A1 except that the comparison arrays at the bottom of the screen consisted of three AC compounds or three BC compounds (see Figure 6) and trial blocks consisted of the 18 trial types shown in Table 2. Five blocks of 18 trials each were presented. Phases A3 and A4 were identical to Phases 3 and 4. In Phase A3, participants were again taught to sequence the three A stimuli in the order A1→A2→A3. In Phase A4 participants were again tested for transfer of sequencing to BC compounds.

Data for Participants 2 and 3 in Phases A1 through A4, graphed as percentage correct over blocks of 18 trials (Phases A1-A2) or 12 trials (Phases A3-A4), are shown in Figure 7. Consistent with their performance in Phase 5, both participants performed at high levels of accuracy in Phase A1. Participant 3 performed at near perfect accuracy throughout Phase A2. Participant 2 performed at 44% and 66% correct on the first

Table 2

Trial Types Presented During Phase A2 of Experiment 1

Sample	Comparisons		
	Correct	Incorrect	Incorrect
A1	B1C1	B2C2	B3C3
A1	B2C3	B3C1	B1C2
A1	B3C2	B1C3	B2C1
B1	A1C1	A2C2	A3C3
B1	A2C3	A3C1	A1C2
B1	A3C2	A1C3	A2C1
A2	B1C3	B3C2	B2C1
A2	B2C2	B1C1	B3C3
A2	B3C1	B2C3	B1C2
B2	A1C3	A3C2	A2C1
B2	A2C2	A1C1	A3C3
B2	A3C1	A2C3	A1C2
A3	B1C2	B2C3	B3C1
A3	B2C1	B3C2	B1C3
A3	B3C3	B1C1	B2C2
B3	A1C2	A2C3	A3C1
B3	A2C1	A3C2	A1C3
B3	A3C3	A1C1	A2C2

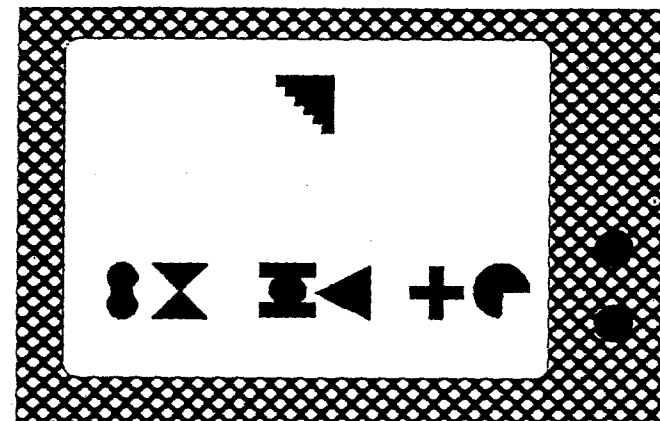


Figure 6. Sample display with compound stimuli as comparisons.

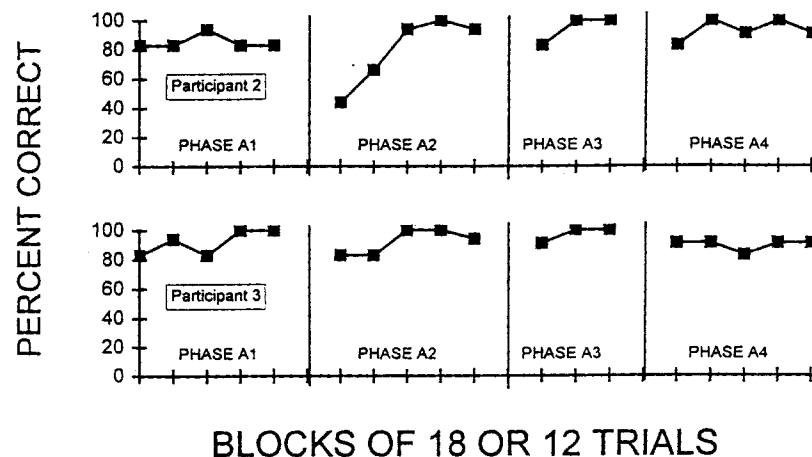


Figure 7. Percentage of trials correct over trial blocks for Participants 2 and 3 in Phases A1-A4. Data for Phases A1 and A2 are graphed over 18-trial blocks. Data for Phases A3-A4 are graphed over 12-trial blocks.

two trial blocks of Phase A2, then performed at near perfect accuracy on the remaining three trial blocks. Both participants quickly met the performance criterion of Phase A3. Finally, during Phase A4, which was the retest for transfer of sequencing to the BC compounds, both participants responded at high levels of accuracy.

Discussion

The results of this experiment show the transfer of a sequencing response via emergent relations of compound stimuli. After learning nine AB-C relations, participants were tested for 18 derived AC-B and BC-A relations. Participants were taught to select the A stimuli in the order A1→A2→A3. During the test for transfer of sequencing, two participants (1 and 4) reliably sequenced arrays of three BC compounds as predicted. The other two participants did not respond systematically during this initial test for transfer of sequencing. These participants' verbal reports suggested that the absence of an experimental history of responding differentially to compound stimuli prevented demonstration of transfer of sequencing when they were required to sequence compound stimuli. To test this possibility, Participants 2 and 3 completed four additional experimental phases during which they were first retested for the 18 AC-B and BC-A relations, then tested for 18 A-BC and B-AC relations in Phase A2, wherein they were required to select compound stimuli from an array of compound comparisons. After retraining sequencing of the A stimuli, both participants demonstrated transfer of sequencing to BC compounds in Phase A4. Thus, results from these additional experiment phases showed that, after these participants were required to respond

differentially to compound stimuli in Phase A2, tests for transfer of sequencing in Phase A4 were positive for both participants.

The results of this experiment show that a sequencing response will transfer via emergent relations that include compound stimuli. However, the initial failure to show transfer of sequencing in Participants 2 and 3, followed by successful demonstration of transfer in these participants in Phases A1-A4 suggests that, for some participants, a history of differential responding to compound stimuli may be necessary for transfer of a sequencing response to occur to compound stimuli.

Experiment 2

Experiment 2 was designed to test for the transfer of respondent elicitation via emergent relations of compound stimuli. This experiment was analogous to Experiment 1 except we tested for transfer of respondent elicitation of skin conductance responses. Skin conductance was chosen as the measure of respondent conditioning because respondent conditioning in humans has been reliably demonstrated using skin conductance measures and it has been effectively used in recent experiments demonstrating transfer of respondent elicitation via emergent stimulus relations (Dougher, Auguston, Markham, Greenway, & Wulfert, 1994; Roche & Barnes, 1997). When skin conductance is used as a measure of conditioning, phasic skin conductance change (skin conductance response; SCR) is a widely used and accepted measure of electrodermal activity (Fowles, 1981). Therefore, SCR was used as the measure of conditioning in this experiment.

Method

Participants

Participants were 5 undergraduates (3 female and 2 male) recruited and compensated as in Experiment 1. At the beginning of the experiment, the general procedures were explained, and all participants read and signed a statement of informed consent. Upon completion of the study, all participants were thoroughly debriefed.

Experimental Setting, Apparatus, and Stimuli

Participants were seated in a 2-m x 1.6-m experiment room equipped with a two-way mirror for observation. They were seated facing a table upon which was a personal computer monitor. Three red pushbutton switches, spaced 1.5 cm apart were located across the right armrest of the chair. The computer was used to present stimuli and record data during all phases of the experiment. The red pushbutton switches were used to select stimuli in the conditional discrimination training and testing phases of the experiment. Skin conductance response measures were recorded on a multi-channel polygraph (Dynograph #R511) using a Beckman 9844 skin conductance coupler. SensorMedics skin conductance electrodes were prepared with a Unibase (Parke Davis) and 0.5% NaCl paste (Lykken & Venables, 1971).

Shock was delivered by a Lafayette (Model #82404) variable amperage shock generator. The shock electrode consisted of two 1-cm nickel-plated electrodes fastened 1 cm apart to a 3-cm wide x 2-cm piece of 5-mm Plexiglas. The Plexiglas was strapped to the participant's right forearm with a velcro strip. Stimuli for this experiment were the same as those used in Experiment 1.

Procedure

This experiment consisted of five phases. Phases 1 and 2 were identical to Phases 1 and 2 of Experiment 1; participants were taught nine AB-C relations and then tested for the emergence of 18 AC-B and BC-A relations. Phase 3 was a classical conditioning procedure with one of the A stimuli serving as a CS+ and the other A stimuli serving as CS-. Electric shock was the US. The fourth phase tested for transfer of respondent elicitation to BC compounds. Finally, in Phase 5, participants were retested for the 18 AC-B and BC-A relations tested in Phase 2.

Shock level selection. Shocks were 200 ms in duration and between 1.0 and 2.0 mA in strength. Before beginning the experiment, each participant set his or her own shock level. Participants were instructed to choose a level of shock that was "uncomfortable, but not painful." Allowing participants to select an uncomfortable shock level was specifically required by the university's Institutional Review Board. The shock electrode was attached to participants' exterior right forearms, and the participants were first given a sample shock of 2.0 mA. If this level was too uncomfortable, the level was decreased by .5 mA and another sample shock was given. Shock level was increased or decreased in response to participants' reports until an uncomfortable but not painful level was found. Participants who found even the 1.0 mA shock too uncomfortable were excused from the experiment. Only 1 participant was excused for this reason. After selection of the shock level, the shock electrode was removed from participants' arms.

Phases 1 and 2. Phases 1 and 2 were the same as Phases 1 and 2 of Experiment 1 except that participants selected the comparison stimuli by pressing one of the three red buttons located on the right armrest of the chair. The left, middle, and right buttons selected the left, middle, and right comparisons, respectively. After completing Phase 2, participants were allowed a 5-min break.

Phase 3 - Classical conditioning. Before beginning Phase 3, participants were given the following instructions:

During this part of the experiment, symbols will occasionally appear on the screen one at a time. We want you to watch the symbols carefully. It is important that you pay close attention to the screen. At times you may receive a shock. The shock level is the one that you set when you received the test shocks. Again, pay attention to what happens on the screen. It is also important that you try to remain as still as you can because, if you move, it can disrupt the readings from the sensors on your arm. Before the symbols begin appearing on the screen there will be a five-minute period when nothing appears on the screen. Use this time to get comfortable so that you can avoid moving later on.

Remember, you can discontinue the experiment at any time by knocking on the window or telling me over the intercom. Do you have any questions about what you will be doing?"

To start this phase, the SC sensors were attached with self-adhesive collars to the thenar and hypothenar eminences of the palm of the participants' left hands. The shock electrode was then attached to participants' exterior right forearms. Participants were asked to sit quietly for a 5-min period. After the 5-min baseline period, the conditioning procedure began.

For classical conditioning, A1 served as the CS+ and A2 and A3 served as CS-. Stimulus duration varied randomly between 8 and 10 s to minimize temporal conditioning (Sachs & May, 1969). A delayed conditioning procedure (Kamin, 1965) was used where A1 terminated with the onset of the shock. The interstimulus interval varied between 20 and 30 s to minimize temporal conditioning effects. Eight blocks of three trials each, consisting of one presentation of A1, A2, and A3, were presented. The stimuli were presented in a fixed order derived from extensive pilot research (Augustson, Markham, & Dougher, 1994). The

Table 3

Order of Stimulus Presentations in Each Trial Block During Phase 3 of Experiment 2

Trial Block	Stimulus Order		
	1	2	3
1	A2	A1-S	A3
2	A3	A2	A1-S
3	A1-S	A3	A2
4	A2	A1-NS	A3
5	A3	A2	A1-S
6	A1-NS	A3	A2
7	A2	A1-S	A3
8	A3	A2	A1-S

Note. Conditioning was assessed during Trial Blocks 6 and 8. S = stimulus was followed by shock; NS = stimulus was not followed by shock.

order of stimulus presentation during Phase 3 is shown in Table 3. A2 and A3 were never followed by shock. A1 was followed by shock six times, and presented without shock twice. The second shock-absent presentation of A1 (Trial Block 6) allowed the assessment of SCR at the point where shock would normally follow A1. Conditioning was assessed during Trial Blocks 6 and 8 by comparing the SCRs elicited by A1, A2, and A3. The criterion for conditioning was that, in both test blocks, participants' SCR to A1 had to be higher than their SCR to either A2 or A3.

Phase 4 - Test for transfer of respondent elicitation to BC compounds. Phase 4 began immediately after Phase 3 ended without interruption in the experiment, and without participants' knowledge. Phase 4 tested for transfer of the SCR conditioned to A1 during Phase 3

to the B1C1 and B3C2 compounds while B3C1 and B1C2 served as controls. Procedures for Phase 4 were identical to Phase 3 except that blocks of four BC compounds were presented and no shock was delivered. The BC compounds were presented in the following order: B3C1, B1C1, B3C2, B1C2. This sequence of trials was presented twice in succession.

We selected this particular combination of BC compounds for two reasons. First, each stimulus element (B1, C1, B3, and C2) appeared as part of a compound that should have elicited a high SCR and as part of a compound that should not have elicited a high SCR. Second, to reduce the effect of respondent extinction resulting from repeated stimulus presentations in the absence of the US, only four of the nine BC compounds were presented during Phase 4.

Presentations of novel stimuli often elicit orienting responses and accompanying SCRs. Because of the possibility of such orienting responses during the initial presentations of compound stimuli in the first trial block, participants' SCRs during the second trial block served as the measure of transfer to BC compounds. The criterion for transfer of the conditioned SCR was that participants' largest SCR during presentation of B1C1 and B3C2 had to be greater than the largest SCR to B3C1 and greater than the largest SCR to B1C2.

An important point concerning Phase 4 is that the criterion for successful demonstration of transfer required that participants' SCRs were elicited by the B1C1 and B3C2 compounds, and not by any one stimulus element. The criterion for transfer was that SCRs be elicited by the B1C1 and B3C2 compounds while the same stimulus elements (B1, C1, B3, and C2) did *not* elicit SCRs when presented as different compounds (B3C1 and B1C2).

Phase 4 ended after both sequences of BC compounds were presented. At that time, the skin conductance sensors and shock electrode were removed and participants were allowed a 5-min break.

Phase 5 - Retest of emergent AC-B and BC-A relations. Phase 5 proceeded exactly as Phase 5 of Experiment 1. The experiment ended when participants completed Phase 5.

Results

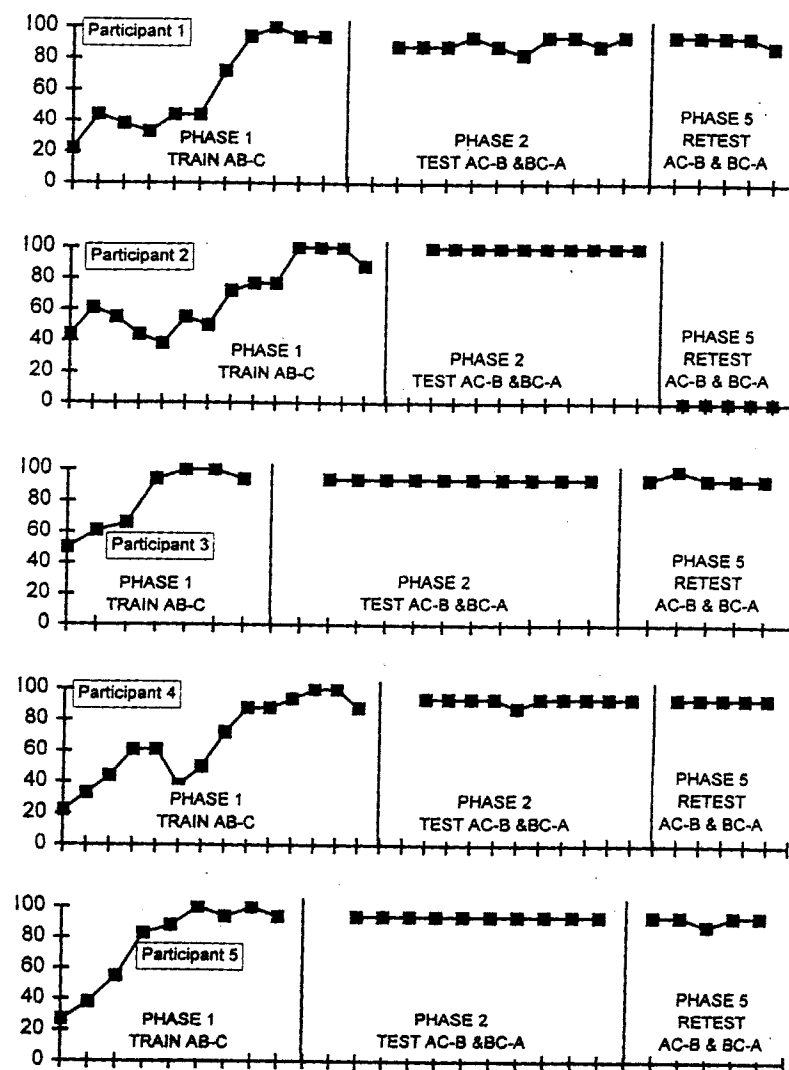
All participants completed the experiment in one session. Participants 1, 2, 3, and 5 completed the experiment in one session lasting between 3 and 4 hr. Participant 4 completed the experiment in one session that lasted 5.5 hr.

Shock Level Selection

Shock levels selected by Participants 1-5, respectively, were 2.0 mA, 1.5 mA, 2.0 mA, 1.0 mA, and 1.0 mA.

Phases 1, 2, and 5

Data for all participants in Phases 1, 2, and 5, graphed as percentage of trials correct over blocks of 18 trials are shown in Figure 8. As can be seen



BLOCKS OF 18 TRIALS

Figure 8. Percentage of trials correct over blocks of 18 trials for all participants in Phases 1, 2, and 5.

from these data, all participants met the training criterion of 70 out of 72 correct responses in Phase 1, and performed at high levels of accuracy during Phase 2. Data for all participants in Phase 5 are shown in Figure 8. These data indicate that all participants maintained the emergent AC-B and BC-A relations initially tested in Phase 2 throughout the experiment.

Phases 3 and 4

For all stimulus presentations in Phases 3 and 4, skin conductance response (SCR) was measured during a predefined assessment interval which began with the onset of the stimulus and ended 10 s after the stimulus offset. For trials where shock was presented, the assessment interval ended when the shock was delivered. Peak SCR was defined as the largest phasic increase during the assessment interval. An increase was defined as a SCR only if it began during the assessment interval and reached a magnitude of at least .2 microsiemens (mS; Levis & Smith, 1987). As mentioned earlier, evidence for conditioning of a SCR to A1 in Phase 3 was assessed during Trial Blocks 6 and 8 by comparing the SCRs elicited by A1, A2, and A3. The criterion for conditioning was that, in both test blocks, participants' SCRs to A1 had to be higher than their SCR to either A2 or A3.

These data are shown in Figure 9. Using this criterion for conditioning, 4 of the 5 participants showed evidence of conditioning. These participants' SCRs were greater to A1 than to A2 and A3 in both Trial Block 6 and Trial Block 8. Only Participant 4 failed to show conditioning according to this criterion. Her peak SCR was greater to A1 than to A2 and A3 in Trial Block 6, but in Trial Block 8 her peak SCR was approximately equal to all three stimuli. This outcome precludes interpretation of data from her transfer tests in Phase 4. This participant refused further participation so extended analysis was not possible. Accordingly, data for Participant 4 will not be discussed further.

The criterion for transfer of the conditioned SCR in Phase 4 was that participants' peak SCRs during presentation of B1C1 and B3C2 had to be greater than the peak SCR to B1C2 and greater than the peak SCR to B3C1. Data from this test for transfer are shown in Figure 9. These data show that 3 of the 4 participants who demonstrated respondent conditioning in Phase 3 met the criterion for demonstration of transfer in Phase 4. Participant 3 failed to show evidence of transfer during these tests. This participant performed at high levels of accuracy during retesting of AC-B and BC-A relations during Phase 5, so the failed transfer tests in Phase 4 could not be explained by failure to maintain the emergent AC-B and BC-A relations during Phases 3 and/or 4.

As part of the postexperiment interview with Participant 3, the experimenter presented a printed paper showing the experimental stimuli and said, "Tell me about what was happening in the different parts of the experiment." Participant 3 stated:

I did fine when I was making choices [Phases 1 and 2], and during the shock part, when one shape was coming on [Phase 3], I learned that the upside down stairs [A1] meant shock. But, when the pairs were on the screen [Phase 4] I didn't get the connection to when there was only one. I mean - I still knew which ones went together in the very last part [Phase 5], but maybe two shapes, pairs of them, meant something would change in the part where I was getting shocked [Phase 4].

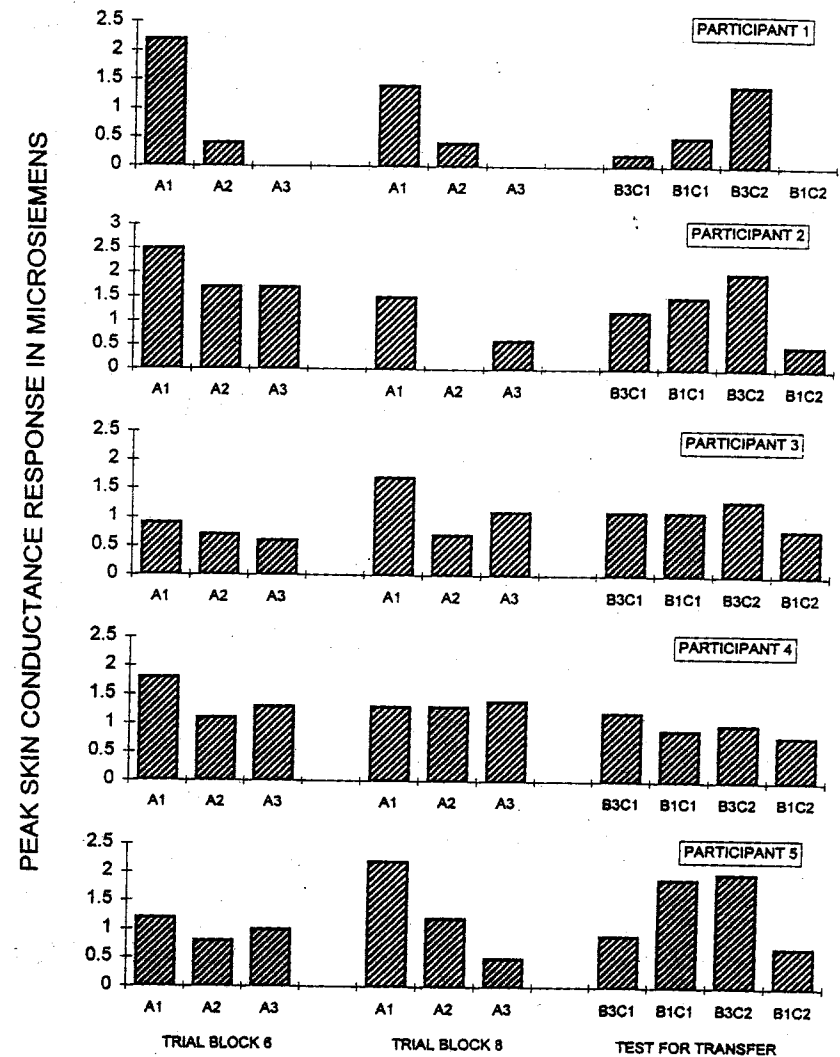


Figure 9. Skin conductance response (SCR) data for all participants in Phases 3 and 4 of Experiment 2.

This verbal report suggested that, for Participant 3, the shift in context from presenting only single stimulus elements in Phase 3 to presenting stimulus compounds in Phase 4 interfered with transfer of the SCR conditioned in Phase 3 to B1C1 and B3C2 during Phase 4.

In order to investigate this possibility, two additional experimental phases were conducted with Participant 3. These phases were designed to introduce compound stimuli in the context of respondent conditioning procedures similar to Phase 3, then test again for transfer of conditioned

Table 4

Order of Stimulus Presentations in Each Trial Block During Phase A1 of Experiment 2 for Participant 3

Trial Block	Stimulus Order		
	1	2	3
1	A2	A1-S	A3
2	A3	A2	A1-S
3	B2C3-S	B3C3-NS	B2C2-NS
4	A2	A1-NS	A3
5	A3	A2	A1-S
6	A1-NS	A3	A2
7	B1C3-NS	B2C3-S	B2C1-NS
8	A3	A2	A1-S

Note. Conditioning was assessed during Trial Blocks 6 and 8. S = stimulus was followed by shock; NS = stimulus was not followed by shock.

SCR to BC compounds as in Phase 4. Phase A1 was identical to Phase 3 of Experiment 2 except that blocks of the three BC compounds B2C3, B3C3, and B2C2 were substituted for the third block of A stimuli and the compounds B1C3, B2C3, and B2C1 were substituted for the seventh block of A stimuli. The exact order of stimulus presentations is shown in Table 4. The compound B2C3 was followed by shock in both the third and seventh test block. The other two BC compounds were not followed by shock. Phase A1 was designed to reduce the context change between the conditioning phase and the test for transfer. Phase A2 was identical to Phase 4 of Experiment 2. Two blocks of four BC compounds B3C1, B1C1, B3C2, and B1C2 were presented and the second block of BC compound presentations was the test for transfer. Data for Participant 3 in Phases A1 and A2 are shown in Figure 10. As was the case in Phase 3, conditioning was assessed in the sixth and eighth conditioning blocks of Phase 6. Figure 10 shows that Participant 3's SCR was much higher to A1 than to A2 or A3 in both assessment blocks, thus meeting the criterion for conditioning. Phase A2 data shown in Figure 10 also show that, during the test for transfer, his SCR was higher to B1C1 and B3C2 than to B3C1 and B1C2.

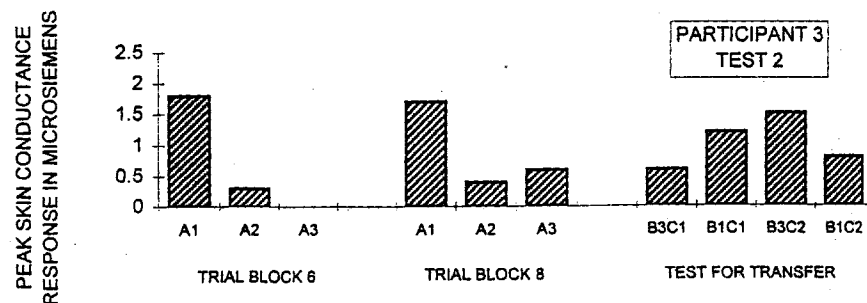


Figure 10. Skin conductance response (SCR) data for Participant 3 in Phases A1 and A2 of Experiment 2.

These results meet the criterion for transfer of the SCR to B1C1 and B3C2. Thus, for Participant 3, additional procedures designed to reduce the shift in testing context from conditioning with stimulus elements to testing with compound stimuli produced orderly data indicating the transfer of the conditioned skin response to BC compounds.

Discussion

Taken together, the results of Experiment 2 show that a classically conditioned skin conductance response will transfer via emergent relations that include compound stimuli. These results are particularly interesting because it was only particular combinations of B and C stimulus elements that elicited SCRs, while the same stimulus elements, when combined in different compounds, did not elicit SCRs.

The results for Participant 3, however, indicate that in some cases transfer of respondent elicitation might be context sensitive—especially to changes in the conditions under which the respondent elicitation is initially conditioned.

General Discussion

The present experiments examined the transfer of operant and respondent functions via emergent relations of compound stimuli. Experiment 1 tested for the transfer of an operant sequencing response and Experiment 2 tested for transfer of respondent SCR elicitation. In Experiment 1, four participants were taught nine AB-C relations and then tested for the emergence of 18 AC-B and BC-A relations. Participants were then taught to select the three A stimuli in the order A1→A2→A3. Finally, participants were tested for sequencing of BC compounds. Of the 4 participants, 2 successfully completed this test for transfer of sequencing. The other 2 participants performed at or near chance level accuracy during these tests for transfer. After completion of further experimental phases which included tasks requiring differential responding to compound stimuli, these 2 participants were again tested for sequencing of BC compounds during which they demonstrated transfer of the initially trained sequencing response.

In Experiment 2, 5 participants were taught the same AB-C relations and tested for the same AC-B and BC-A relations as participants in Experiment 1. A skin conductance response (SCR) was then conditioned to one of the A stimuli and participants were tested for the transfer of the SCR to BC compounds. Of the 4 participants who acquired the initial conditioned response, 3 demonstrated transfer of that conditioned response to the BC compounds. The remaining participant showed conditioning but not transfer of the conditioned SCR. In subsequent tests, this participant demonstrated transfer of the conditioned response.

The results of Experiment 2 merit some caution because only a subset of available BC compounds was used for the transfer tests in Experiment 2.

We tested only four of the nine BC compounds during Phase 4 to avoid extinction of the conditioned response during the tests for transfer. Thus, five of the possible BC compounds were not assessed during transfer tests. A further limitation of both experiments was interparticipant variability observed during transfer tests where additional training procedures were necessary to produce transfer of function for some participants. Such outcomes are not unusual in studies of transfer of function in equivalence classes (e.g., Greenway, Dougher, & Wulfert, 1996) and suggest that caution is in order when appealing to transfer of function as an explanation for commonly occurring behavior outside the laboratory.

The analyses conducted following initial failures to demonstrate transfer in both experiments suggest that transfer of function via emergent relations of compound stimuli may not occur under certain conditions. More specifically, these analyses suggest that for some participants the absence of a history of responding differentially to compound stimuli may have prevented transfer of the function initially trained to unitary stimuli. In both experiments, the test for transfer (Phase 4) was the first time participants were required to respond differentially to compound stimuli. The participants who did not demonstrate transfer in these tests did, however, demonstrate transfer to compound stimuli after additional experimental phases established differential responding (either operant or respondent) to compound stimuli.

The positive transfer tests for these participants could, however, have resulted from other factors. In both experiments, participants who failed the initial transfer tests were asked by the experimenter to describe the procedures and their behavior. These participants also received repeated training and testing procedures. For these participants, the interview and/or the repeated training/testing could have resulted in positive transfer tests. The present data cannot address these possibilities. This issue could be resolved by future experiments that replicate the present experiments but add match-to-sample tests with compound comparisons before the initial tests for transfer of function.

Taken together, the present experiments demonstrate that both operant discrimination and respondent elicitation functions will transfer via emergent relations of compound stimuli such as those described by Markham and Dougher (1993). Both experiments offer systematic replications of our earlier demonstration of transfer of function with compound stimuli (Augustson et al., 2000). The present experiments also extend those findings by demonstrating that both respondent and operant functions established for a *unitary* stimulus will transfer to related *compound* stimuli.

A particularly important outcome in Experiment 2 was that respondent SCR conditioned to a unitary stimulus (A1) resulted in elicitation of SCR by B1C1 and B3C2 compounds while the same stimulus elements (B1, C1, B3, and C2) did *not* elicit SCRs when presented as different compounds (B3C1 and B1C2). These findings thereby suggest a process by which emotional responses (e.g., anxiety)

can be elicited by stimuli only when those stimuli are present in particular combinations, but not when they appear alone or with other stimuli.

In a broader sense, the present experiments and other recent studies support two conclusions about the emergent AC-B and BC-A matching demonstrated by Markham and Dougher (1993; see also Serna, 1991). First, the present experiments and those reported by Augustson et al. (2000) provide sound evidence that transfer of function occurs for emergent relations involving compound stimuli. Second, the class-like emergent AC-B and BC-A matching appears to be a reliable outcome with normal adults (Augustson et al., 2000; Carpentier et al., 2000; Markham & Dougher, 1993; Serna, 1991) and normal children (Carpentier et al., 2000). The reliability of these outcomes highlights the question of whether such emergent relations of compound stimuli and stimulus equivalence result from the same behavioral process.

On one hand, the emergent AC-B and BC-A matching in these experiments is not reflexive, symmetrical, or transitive responding, which suggests that these emergent performances are not the result of equivalence relations among the stimuli. On the other hand, some authors have argued that transfer of function among stimuli may, in fact, be a better measure of their substitutability (thereby equivalence) than emergent matching performances alone (Fields et al., 1993; Spencer & Chase, 1996). Thus, the transfer of function observed in the present experiments and in those of Augustson et al. (2000) could be taken as evidence of equivalence relations among the stimuli. These contradictory interpretations leave unclear the relationship between emergent relations of compound stimuli and equivalence relations.

One possibility is that the emergent AC-B and BC-A performances result from contextually controlled equivalence relations (e.g., Bush, Sidman, & de Rose, 1989) wherein one element of the compound functions as a contextual stimulus for a conditional discrimination controlled by the other element of the compound. This explanation, however, introduces the problem of determining which element functions as the contextual stimulus and which functions as the conditional stimulus for any given trial (Carpentier et al., 2000; Markham & Dougher, 1993). Furthermore, all stimulus elements are functionally substitutable across trials which would mean that the elements functioning as contextual stimuli were members of the equivalence classes under their control, a situation Sidman (1986) has argued must lead to the collapse of all classes into a single equivalence class (cf. Carpentier et al., 2000).

A second possibility, proposed by Stromer et al. (1993; see also Augustson et al., 2000; Carpentier et al., 2000; Dougher & Markham, 1994, 1996; Markham & Dougher, 1993), could account for emergent matching both in equivalence experiments with unitary stimuli and experiments using compound stimuli. They proposed that, in both cases, emergent matching performances could be controlled by compound stimuli with separable and substitutable elements. This separable compound proposal has gained substantial support from the present

experiments and recent empirical work (e.g., Augustson et al., 2000; Carpentier et al., 2000; Markham & Dougher, 1993; Serna, 1991). Furthermore, it offers theoretical advantages and a number of empirical challenges. The separable compound approach offers the parsimony of invoking a single behavioral process to account both for emergent performances in stimulus equivalence and for emergent relations of compound stimuli. This approach also is consistent with Sidman's (1994, 2000) recent theoretical proposals that stimulus equivalence results from reinforcement contingencies, including three-term contingencies (cf. Sidman, 1986).

Importantly, the separable compound account leads to specific empirical questions and experimental predictions. Most notably, it leaves unanswered the question of how the elements of compound stimuli become separable and substitutable. One possibility is that the procedures in the present experiments, and match-to-sample procedures generally, directly train the separability and substitutability of stimulus elements. For example, in the present experiments, the randomization of comparison positions within each comparison array and the randomization of element positions in the compound samples could directly encourage spatial separability of these elements. In addition, the randomization of trial-types across trials during baseline training also could contribute to separability and substitutability of compound elements.

The separable compound approach also leads to an important experimental prediction. Specifically, procedures that establish simple and/or conditional discriminations but restrict the spatial and temporal substitutability of stimuli should interfere with emergence of equivalence relations and other emergent class-like performances such as AC-B and BC-A matching. Doing so would likely require using procedures other than match-to-sample for establishing conditional discriminations, such as those used by Cullinan, Barnes, and Smeets (1998).

Finally, the present experiments and similar recent studies (e.g., Augustson et al., 2000; Carpentier et al., 2000) also raise questions concerning stimulus control by compound stimuli in humans (see also Dougher & Markham, 1994, 1996; Stromer et al., 1993). What is the nature of stimulus control exerted by compound stimuli in these preparations, and what is the functional relation between the elements of these compound stimuli? These and other questions await future investigations which might prove essential to our understanding of stimulus equivalence (Stromer et al. 1993).

To address these questions, future experiments investigating the nature of stimulus control by compound stimuli in humans might benefit by investigating directly trained simple discriminations controlled by compound stimuli rather than the emergent performances resulting from conditional discriminations under compound stimulus control. Informative experiments could include establishing discriminative control over operant responding by multielement compound stimuli, then assessing control over response rate by different combinations and spatial

arrangements of the original compounds' constituent elements. Such procedures might shed light on the functional relations among the elements of compound stimuli and could provide opportunity for investigating the role of spatial and temporal contiguity in compound stimulus control.

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MATCHING FUNCTIONALLY SAME RELATIONS: IMPLICATIONS FOR EQUIVALENCE-EQUIVALENCE AS A MODEL FOR ANALOGICAL REASONING

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Adults, 9-year-old children, and 5-year-old children were trained on multiple A-B and A-C matching tasks. Then they received a series of tests, first symmetry (B-A, C-A), then equivalence (B-C, C-B), and finally equivalence-equivalence tests (BC-BC). The latter tests assessed whether the subjects matched BC compounds with equivalent elements with one another and BC compounds with nonequivalent elements with one another; for example, B1C1-B3C3 (equivalence-equivalence) and B1C2-B2C3 (nonequivalence-nonequivalence). Most adults and 9-year-old children demonstrated equivalence-equivalence and nonequivalence-nonequivalence (Experiments 1 and 2). These performances were not seen with any of the 5-year-old children (Experiments 1 - 3) without first having the opportunity to match compounds with trained correct relations between elements (e.g., A1B1-A3B3) and compounds with trained incorrect relations between elements (e.g., A3C1-A3C2) (baseline-baseline, Experiment 4). Present findings suggest a developmental divide similar to that reported in earlier developmental research on analogical reasoning for which equivalence-equivalence has been used as a model. Yet, they should be taken only as tentative. Although equivalence-equivalence and classical analogies (a:b::c:?) require subjects to match functionally same relations, the procedures for measuring equivalence-equivalence are sufficiently different from those used in classical analogy tests, not to permit any direct comparisons.

After being trained on multiple arbitrary match-to-sample tasks, verbal humans frequently relate all directly and indirectly related stimuli with one another. For example, after learning to relate sample A1 to comparisons B1 and C1 (not to B2 and C2) most humans relate, without further training, B1 to C1 (and vice versa (C1-B1)). This finding is normally accepted as an indication for the formation of a three-term equivalence class (A1-B1-C1) (Barnes, 1994; Saunders & Green, 1992; Sidman,

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