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CONTEXTUAL CONTROL OF EQUIVALENCE-BASED TRANSFORMATION OF FUNCTIONS

MICHAEL DOUGHER, DAVID R. PERKINS, DAVID GREENWAY, ASHTON KOONS, AND CARMENNE CHIASSON

UNIVERSITY OF NEW MEXICO

The transformation of functions refers to the untrained acquisition of stimulus functions among members of stimulus equivalence classes or relational frames. Although it is widely assumed that contextual control over the transformation of functions must exist, this has not yet been conclusively demonstrated in laboratory studies. Four experiments are reported in which (a) stimulus equivalence classes were established, (b) a conditional stimulus function was trained for one member of each of the classes, and (c) multiple-exemplar procedures were used to train and test for contextual control over the transformation of the stimulus function within the classes and to assess whether it generalized to new equivalence classes. Although a significant amount of training was required, the procedures ultimately resulted in the contextual control of function transformation for 9 of 10 participants and generalized contextual control for 4 of 5 participants.

Key words: transformation of function, transfer of function, contextual control, stimulus equivalence

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The phenomenon that is often called the *transfer* or *transformation of stimulus functions* is one of the most interesting findings to emerge from the rapidly growing body of research on stimulus equivalence and derived stimulus relations. By transfer of functions, we are referring to the untrained acquisition or emergence of stimulus functions among members of stimulus classes (for further discussion, see Barnes, 1994; Dougher & Markham, 1996; Hayes, 1991; Sidman, 1994). Because stimulus equivalence or derived stimulus classes are defined in part by the transfer of certain conditional discriminative functions (e.g., Hayes, 1994; Sidman & Tailby, 1982), it may appear somewhat redundant to talk about stimulus classes and transfer of function separately. However, the functions to be discussed here are not those that define stimulus equivalence classes but those that accrue to the members of a class after the classes are established and a novel function is subsequently trained for a subset of the class.

The typical procedures used in such studies are as follows. First, some number of equivalence classes are established using match-to-sample or other training procedures. Then, one or more members of one of the classes are selected and given some new behavioral function. Following this, the remaining members of all of the classes are tested to see if they also have acquired the novel function. If the other members of the class from which the subset was selected acquire the new function but the members of the other classes do not, the novel function is said to have transferred within the equivalence class. Using these procedures, investigators have documented the transfer of virtually every stimulus function, including simple discriminative control (de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988), ordinal functions (Green, Sigurdardottir, & Saunders, 1991; Lazar, 1977; Lazar & Kotlarchyk, 1986; Wulfert & Hayes, 1988), conditional stimulus control (Wulfert & Hayes, 1988), contextual control (Gatch & Osborne, 1989; Hayes, Kohlenberg, & Hayes, 1991), and conditioned reinforcement and punishment (Greenway, Dougher, & Wulfert, 1996; Hayes et al., 1991). In addition to these operant functions, respondent or classically conditioned functions have also been shown to transfer within stimulus equivalence classes (Dougher, Augustson, Markham, Greenway, & Wulfert, 1994; Roche & Barnes, 1997).

As it is used in the stimulus equivalence literature, the term *transfer* refers to the indirect acquisition of similar or even identical functions that exist or are trained for equivalent

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Reprint requests and correspondence should be sent to Michael J. Dougher, Department of Psychology, Logan Hall, University of New Mexico, Albuquerque, New Mexico 87131 (e-mail: dougher@unm.edu).

stimuli. It should be noted, however, that this is somewhat different from the meaning of the term in other literatures (e.g., Ellis, 1965), in which most generally it refers to the effects of one task on the learning of another. Stimulus equivalence studies concerned with the transfer of function generally report the transfer of identical functions, but it remains to be seen whether this is necessarily or even generally the case. It is possible, for example, that partial or even novel functions can be created for equivalent stimuli through the transfer of function.

Although the phenomenon referred to as the transfer of function is robust, the term itself has not been universally endorsed. Sidman (1992) has argued that the term *transfer* implies an unnecessary hypothetical process that is more parsimoniously accounted for in mathematical set theory terms. In particular, he suggested that the observed phenomenon to which the term refers is more usefully understood as the union of two or more stimulus sets or classes. Hayes, Barnes, and others (e.g., Hayes, 1994; Hayes & Barnes, 1997; Hayes, Barnes-Holmes, & Roche, 2001; Hayes, Gifford, & Wilson, 1996; Roche & Barnes, 1997) have also argued against the term *transfer of function.* These researchers share Sidman's concern about the implications of the term *transfer,* but their more fundamental objection is that transfer fails to adequately describe the changes in functions that accrue in stimulus relations other than equivalence. For example, Dymond and Barnes (1995) showed that when the relations of ''sameness,'' ''less than,'' and ''more than'' are established among a set of stimuli and then a novel function is given to a subset of those stimuli, the functions acquired by the other stimuli are determined by the previously established relations. That is, the functions of the related stimuli were transformed in accord with the previously established relations. For this reason, Hayes and Barnes prefer the term *transformation* rather than *transfer* of functions. In our view, although the term *transformation* has some problems of its own, Hayes' and Barnes' arguments have merit, and, for that reason, we use the term *transformation of functions* in the present paper. In order to specify the basis for the transformation of functions we report, however, we refer to equivalence-based function transformations.

The transformation of functions associated with stimulus classes or relational frames is advantageous in that it allows organisms to adapt and respond appropriately in the absence of direct training. It is equally obvious that not all of the members of stimulus classes acquire all of the functions of the other members in all situations. As Sidman (1992) noted,

> The words ''Route 128'' on the map and the road on which we are driving are equivalent when we are trying to find our way to an unfamiliar place, but we do not try to drive our car onto the words, or to illuminate the road with a reading lamp. We do not try to eat the word, ''bread,'' or to swat the word, ''fly.'' (p. 22)

Some sort of contextual control over the transformation of functions must exist, or, as Sidman (1986, 1992) and Hayes and Hayes (1992) point out, all stimuli would eventually acquire the functions of all other stimuli.

Despite the assumption that there must be some type of contextual control over equivalence-based transformation of functions, to our knowledge there have been no published studies in which it has been conclusively demonstrated. Wulfert and Hayes (1988) reported the most relevant study in this regard by demonstrating higher order conditional (contextual) control over both stimulus class membership and the set of stimuli that acquired control over a conditional ordering response. It has yet to be demonstrated, however, that equivalence-based transformation of function within established equivalence classes can be brought under contextual control.

At this point it is useful to define the term *contextual control.* According to Cumming and Berryman (1965), Lawrence (1963), and Osgood (1953), contextual stimuli determine or influence the discriminative functions of other stimuli. However, Sidman (1986) and others (e.g., Lashley, 1938; Wulfert & Hayes, 1988) describe this kind of control as conditional stimulus control. Actually, the distinction between conditional and contextual control has been somewhat blurred in the literature. For example, in his seminal paper on behavioral units of analysis, Sidman

(1986) stated, ''Another name for conditional control might very well be contextual control'' (p. 16). Later in that same paper he seemed to equate contextual control with second-order conditional control, which is defined as conditional control over conditional discriminations (p. 25). Although Sidman used contextual control as a general term to describe both conditional control and higher order conditional control, the term has increasingly been used to refer specifically to the latter. This is particularly true of those studies that have attempted to demonstrate contextual control over stimulus equivalence classes (Bush, Sidman, & de Rose, 1989; Gatch & Osborne, 1989; Hayes, 1991; Kennedy & Laitinen, 1988; Kohlenberg, Hayes, & Hayes, 1991; Lynch & Green, 1991; Meehan & Fields, 1995; Steele & Hayes, 1991). In keeping with this trend, we will use the term *contextual control* to refer to higher order conditional stimulus control. In Sidman's (1986) terminology, contextual stimuli are the fifth element in the five-term contingency.

Another issue that arises concerning the term *contextual control* is that of the functional independence of putative contextual stimuli. As several researchers (e.g., Lynch & Green, 1991; Meehan & Fields, 1995; Sidman, 1986; Stromer, McIlvane, & Serna, 1993) have pointed out, what appears to be contextual control of stimulus equivalence classes may be joint or compound conditional or discriminative control by the putative contextual stimulus and specific members of equivalence classes. To demonstrate contextual control unambiguously, contextual control by Stimulus A must be demonstrated over stimuli that were not used to train contextual control. Only then can the possibility of compound-stimulus control be ruled out. Examples of this kind of demonstration of contextual control can be found in Barnes, Brown, Smeets, and Roche (1995) and Roche, Barnes-Holmes, Smeets, Barnes-Holmes, and McGeady (2000).

Contextual control over the transformation of functions has both theoretical and applied significance. Because stimulus classes, relational frames, or both are defined in part by the transformation of functions (Dougher & Markham, 1996; Goldiamond, 1962, 1966; Hayes, 1994; Sidman, 1992), understanding the variables that influence function transformation would enhance our theoretical understanding of stimulus classes. Moreover, appropriate contextual control over function transformation is necessary for adaptive and appropriate behavior. Function transformation in inappropriate contexts and the absence of function transformation in appropriate contexts could be problematic. As examples, consider the unattended child who responds to strangers at a shopping mall the same way she has been encouraged to interact with strangers in her home, or the snake-phobic college student who cannot open a biology textbook for fear of encountering pictures or descriptions of snakes.

The purpose of the present set of experiments was to determine whether contextual control over equivalence-based transformation of function could be demonstrated in a laboratory setting. In particular, we attempted to bring the transformation of conditional stimulus control on a series of computer tasks under the contextual control of the background color of the computer monitor.

EXPERIMENT 1

METHOD

Participants

Two female (MD and RW) and 5 male (PJ, TR, JR, RC, and RG) introductory psychology students, recruited through in-class and bulletin-board announcements, served as participants. They received course credit for up to 4 hr of participation and monetary compensation at the rate of $5 per hour for additional time. Experimental sessions lasted between 1.5 and 3 hr, and total participation time ranged from 2.5 to 4.5 hr. All participants read and signed a statement of informed consent before beginning the experiment, and all were fully debriefed at the end.

Setting, Apparatus, and Stimuli

The experiment was conducted in an experimental room (2 m by 2 m) equipped with a table, chair, a two-way mirror for observation, and a personal computer with a standard keyboard and 25-cm color monitor. The computer was programmed to present all stimuli and record responses. Stimuli consisted of the 15 ambiguous figures shown in Fig-

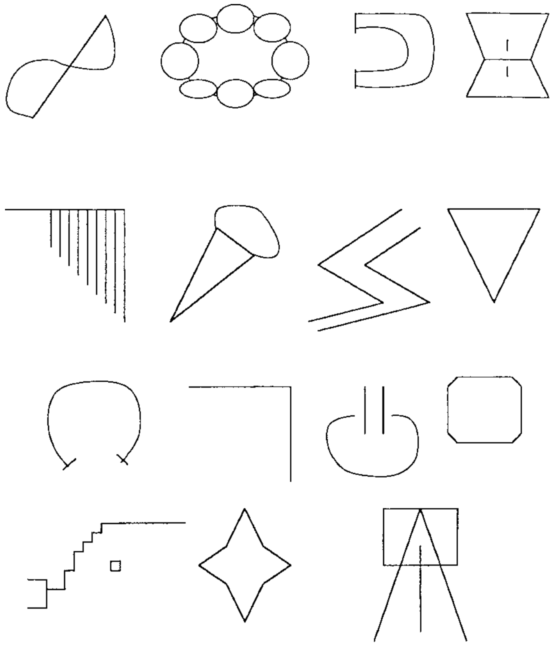

Fig. 1. Stimuli used to establish equivalence classes.

ure 1. The stimuli were white and were presented on a black, red, or blue background.

Procedure

Table 1 provides a general overview of the basic procedures used in Experiment 1. Details of the procedures are reported below. The basic strategy was first to establish three five-member (A through E) equivalence classes. Then, the three arbitrarily designated B stimuli were used to train a sequencing task. Following this, an attempt was made to use multiple-exemplar training to establish contextual stimulus control by the background colors of the computer monitor over sequencing responses to the C and D stimuli. Specifically, the sequencing task was repeatedly presented in either a red or a blue background. When the background color was red, responses to the C and D stimuli that were consistent with equivalence-based transformation of function were reinforced. When the background color was blue, such responses were punished, and other responses were reinforced. Once the participants demonstrated control by the background colors over their sequencing responses to the C and D stimuli, the B stimuli were then used to train a key-choice task, and the multiple-exemplar procedures used to establish contextual control over sequencing the C and D stimuli were repeated with the key-choice task. The B stimuli were then used to train a sorting task. Immediately following this training, differential control by the background colors over sorting responses was tested with the E stimuli. A positive test result would demonstrate contextual control by the background colors over equivalence-based transformation of function. A final stimulus equivalence test was presented in both color backgrounds to determine whether the originally trained classes had changed as the result of the differential training in the color backgrounds. It is important to note that, although the three tasks (i.e., sequencing, key choice, and sorting) were topographically distinct, they were functionally similar. Each task entailed conditional discriminations, and in each task, the B, C, and D stimuli functioned as conditional stimuli. Accordingly, if participants did show evidence of contextual control over function transformation, the function would be conditional stimulus control.

Several procedures were common to all of the steps of this and, unless otherwise noted,

Table 1

Overview of procedure of Experiment 1.

Step	Procedure
1	Establish three five-member (A–E) equivalence classes.
2	Train sequencing task with B stimuli.
3	Establish contextual control by background colors over sequencing of C and D stimuli.
4	Train key-choice task with B stimuli.
5	Establish contextual control over key-choice responses to C and D stimuli.
6	Train color-sorting task with B stimuli.
7	Test for contextual control over transformation of function of E stimuli on color-sorting task.
8	Retest equivalence classes in both background colors.

subsequent experiments. All instructions were written and presented to participants on the computer screen. To demonstrate their understanding of the instructions, participants were asked to read the instructions and then explain them to the experimenter before beginning any task. Unless specifically indicated, there were no breaks or instructions between or within the steps of the experiment.

All training and testing trials were presented in a quasirandom order within trial blocks. Also, within each trial block, each stimulus with the same alpha designation (e.g., B1, B2, and B3) (a) appeared equally often, (b) appeared in quasirandom order, (c) appeared equally often in each serial position (where appropriate), and (d) appeared equally often in the red and blue backgrounds (where appropriate). For all training trials on which feedback was provided, a response immediately cleared the screen and was then followed by the written word ''correct'' or ''wrong'' for 1.5 s. The screen then cleared again for an intertrial interval of 2 s before a new trial began. On those trials on which no feedback was given, a response simply cleared the screen for 3.5 s. Even on no-feedback trials, responses were defined and recorded as correct or wrong as they were on trials conducted with feedback.

On training trials designed to establish contextual control by the background colors over responding to the C and D stimuli, responding in line with equivalence-based transformation of function produced the written feedback ''correct'' in the red background and ''wrong'' in the blue background. Any other response to the C or D stimuli produced ''wrong'' in the red background and ''correct'' in the blue background. Responding consistent with equivalence-based function transformation was defined as responding to the C and D stimuli as participants had been trained to respond to the related B stimuli.

After participants met the training criterion with the C or D stimuli, they were presented with two blocks of mixed B, C, and D trials without feedback (nfdbk). They were required to respond 100% correctly on either of those blocks in order to move on to the next step. If they did not, the mixed B, C, and D trials were repeated with feedback until the participants responded 100% correctly over one full block of trials. Participants were again presented with two blocks of mixed trials without feedback and were required to perform at 100% accuracy on either block before moving on to the next step. The number and types of trials in each trial block, as well as the performance criterion for each step, are presented in Table 2.

Step 1: Establishing and testing equivalence classes. To establish three five-member equivalence classes, 12 stimulus relations were trained using one-to-many (Spradlin & Saunders, 1986) match-to-sample procedures. These relations are presented in the top of Table 3. The actual stimuli presented were the ambiguous forms presented in Figure 1. The alphanumeric designations of the stimuli in Table 3 are presented to facilitate description of the procedures and were not available to the participants. Numbers refer to class membership, and letters refer to the specific members of each class. The 15 ambiguous figures in Figure 1 were randomly assigned an alphanumeric designation for each participant.

For all training and testing trials, a sample stimulus appeared at the top center of the monitor on a black background. After a 1-s delay, three comparison stimuli appeared at the bottom left, middle, and right of the screen. Sample and comparison stimuli were white and were presented on a black background. Participants selected the left, middle, or right comparison by pressing 1, 2, or 3 on the number pad of the keyboard, respectively. The specific instructions were as follows:

> When the experiment begins, symbols will appear on the computer screen. One symbol will appear at the upper middle of the screen and three additional symbols will appear at the lower left, middle, and right of the screen. Your task is to choose the correct symbol from among those in lower portion of the screen. In this task you will choose just one symbol on each trial. To do this, press the number 1, 2, or 3 on the keyboard number pad located on the right hand portion of the keyboard. Pressing these numbers will select the lower left, middle, or right symbol, respectively. During the first part of the experiment, you will receive feedback telling you whether your choices are correct or wrong. Later in the experiment, you won't receive feedback. However,

Table 2

Type and number of trials per block with and without feedback and performance criteria in Steps 1 through 8.

Step	Trials with feedback	Criterion	Trials without feedback	Criterion
1	12: one for each trained relation in Table 3	100% over six consecutive blocks		
			96: 24 symmetry and 72 equivalence probes	97% over entire block
2	6: two with each B stimulus	100% over six consecutive blocks		
3	18: 6 B and 12 C	100% over three consecutive blocks		
	18: 6 B and 12 D	100% over three consecutive blocks		
			36: 12 B, 12 C, and 12 D	100% of either of two blocks
4	6: 2 for each B stimulus	100% over six consecutive blocks		
5	18: 6 B and 12 C	100% over six consecutive blocks		
	18: 6 B and 12 D	100% over six consecutive blocks		
			36: 12 B, 12 C, and 12 D	100% on either of two blocks
6	18: each B stimulus with each possible serial arrangement of boxes	100% over two consecutive blocks		
7			12: 6 B and 6 E	
8			96: 24 symmetry and 72 equivalence probes	

Table 3

Trained and tested relations in Steps 1 and 8.

12 trained relations			
A1-B1	A2-B2		A3-B3
A1-C1	A2-C2		A3-C3
A1-D1	A2-D2		A3-D3
A1-E1	A2-E2		A3-E3
12 tested symmetrical relations			
B1-A1	C1-A1	D1-A1	E1-A1
B2-A2	C2-A2	D2-A2	E2-A2
B3-A3	C3-A3	D3-A3	E3-A3
36 tested equivalence relations			
B1-C1	B2-C2		B3-C3
B1-D1	B2-D2		B3-D3
B1-E1	B2-E2		B3-E3
C1-D1	C2-D2		C3-D3
C1-E1	C2-E2		C3-E3
D1-E1	D2-E2		D3-E3
C1-B1	C2-B2		C3-B3
D1-B1	D2-B2		D3-B3
D1-C1	D2-C2		D3-C3
E1-B1	E2-B2		E3-B3
E1-C1	E2-C2		E3-C3

there is always a correct answer. Please try to do your best. Do you have any questions?

On both training and testing trials, comparison arrays always consisted of stimuli with the same alpha designation. Each presentation of a sample and comparison array comprised a trial type. Training trials were presented in blocks of 12 trial types, one for each of the 12 trained relations depicted in Table 3. Thus, all conditional discriminations were trained simultaneously. Once participants reached the training criterion (see Table 2), tests for the 12 symmetrical and 36 equivalence relations presented in the middle and lower portions of Table 3 were introduced without feedback. Because one-to-many training procedures were used, there were no tests for transitivity that did not also involve symmetry. Accordingly, all tests other than those for symmetry are called equivalence tests (Sidman, 1986, 1990; Sidman, Wynne, McGuire, & Barnes, 1989). Test trials were presented in blocks of 96 trials consisting of two test trials for each symmetrical and equivalence relation. If participants did not meet the testing criterion within five blocks of test trials (480 trials), the training phase was reinitiated. Participants who failed to meet the testing criterion after three repetitions of training and testing were excused from the study.

Step 2: Training the sequencing task with the B stimuli. The B stimuli were used to train participants to perform a sequencing task. The three B stimuli were presented across the middle of the computer screen on either a red or a blue background. Participants were instructed to press the 1, 2, or 3 keys on the number pad to select the left, middle, or right symbol, respectively. The task was to select the stimuli in the order B1, B2, and B3, regardless of background color. For example, if, on a given trial, the three B stimuli were presented in the order B3, B1, B2, the keypress sequence 2, 3, 1 would be correct. The specific instructions were as follows:

> You will see three symbols located at the left, right, and middle of the screen. Your task is to choose the symbols in the proper order, i.e., first, second, and third. Press 1 to select the left symbol, press 2 to select the middle symbol, and press 3 to select the right symbol. The keys can be pressed in any order (e.g., 1, 2, 3 or 2, 3, 1, or 3, 1, 2, etc.). The order in which you press the keys orders the symbols. For example, if the symbol on the right should be first, the symbol in the middle second, and the symbol on the left third, then you should press 3 first, 2 second, and 1 third. If the symbol in the middle should be first, the symbol on the right second, and the symbol on the left third, then you should press 2 first, 3 second, and 1 third. You will have to discover the correct order by pressing the keys. In the beginning, you will receive feedback telling you whether the order you selected was correct or wrong. Later in the experiment, you will not receive feedback. However, there is always a correct answer. Do you have any questions?

Step 3: Multiple-exemplar training to establish contextual control by background color over sequencing responses to the C and D stimuli. After reaching the training criterion with the B stimuli, participants were trained to differentially select a sequence for the C stimuli depending on the background color of the computer screen. To begin this step, the C stimuli were presented exactly as the B stimuli were presented in Step 2. As described above, there were differential contingencies in place for sequencing the C stimuli depending on background color. B stimuli trials were interspersed among C stimuli trials on the average of every third trial. On B stimuli trials, however, there were no differential contingencies for sequencing the B stimuli in the two background colors; the sequence B1, B2, B3 was correct regardless of background color. The purpose of presenting B trials in the same colored backgrounds as the C (and later, D) trials was to prevent the unintended generalization of contextual control by the background colors over the sequencing of the B stimuli. The intent was for the background colors to control equivalence-based function transformation, not responding to the B stimuli.

Once participants satisfied the training criterion with the C stimuli, the D stimuli were introduced for differential sequence training. Training with the D stimuli was identical to that for the C stimuli, including the interspersed B stimuli trials and performance criterion. When this criterion was met, two blocks of mixed B, C, and D stimuli trials were introduced without feedback.

Step 4: Training the key-choice task with the B stimuli. Once there was clear evidence of contextual control by the background colors over sequencing of the C and D stimuli, the B stimuli were used to train the key-choice task. On each trial, one of the three B stimuli was presented alone on the computer screen on either the red or the blue background. The task was to discover which key on the computer keyboard to press in the presence of each of the B stimuli. Possible key choices were restricted to the top row of letters on the keyboard. The arbitrarily designated correct choices were Q, Y, and P for B1, B2, and B3, respectively. The actual instructions were as follows:

> For this task, your job is to choose the correct letter, either Q, Y, or P, for each symbol that appears at the top of the screen. You will have to figure out which letter goes with which symbol. Always restrict your letter choices to Q, Y, or P. In the beginning, you will receive feedback telling you whether your choices are correct or wrong. Later in the experiment, you will not receive feedback. Remember that even when there is no feedback, there is always a correct choice. Do you have any questions?

Step 5: Multiple-exemplar training to establish contextual control by color background over key choices to the C and D stimuli. As in Step 3, after participants reached the training criterion in Step 4, the C stimuli were presented in the same manner as the B stimuli. Again, B stimuli trials were interspersed on the average of every third trial. Once the training criterion was reached with the C stimuli, D stimuli trials were introduced in the same manner. When the training criterion was met with the D stimuli, two blocks of mixed B, C, and D stimuli trials were introduced without feedback.

Step 6: Training the sorting task with the B stimuli. At the beginning of each trial in this task, one of the B stimuli appeared at the top of the computer screen and three different colored boxes (purple, green, and yellow) appeared along the bottom. Using the arrow keys on the keyboard, participants were instructed to move the B stimuli and place them in one of the three boxes. Participants were trained to place B1 in the purple box, B2 in the green box, and B3 in the yellow box. Each trial consisted of a different combination of one of the three B stimuli, one of the two background colors, and one of three serial arrangements of the colored boxes at the bottom of the screen. The three serial arrangements were such that none of the colored boxes appeared more than once in any serial position per color background in a trial block. The specific instructions were as follows:

> In this task, one symbol will appear at the top of the screen with three colored boxes at the bottom of the screen. Use the arrow keys to place the symbol in the correct box. You will have to discover which box each of the symbols goes in. In the beginning you will receive feedback telling you whether your choices are correct or wrong. Later in the experiment you will not receive feedback, but remember there is always a correct choice. Do you have any questions?

Step 7: Testing for contextual control by the background colors over transformation of the function of the E stimuli. Once criterion was reached with the B stimuli in the sorting task, the E stimuli were presented exactly as the B stimuli, except that no feedback was provided. If the color backgrounds had achieved differential contextual control over the transformation of function, then participants should have sorted the E and B stimuli similarly in the red background but differently in the blue background.

Table 4

Number of trial blocks to reach conditional discrimination training criterion and percentage correct on initial and final equivalence tests for all participants in Experiment 1.

Participant	Trial blocks to training criterion	% correct initial test	% correct final test
PJ	7	100	100
TR	14	100	100
JR	12	100	100
MD	13	100	100
RW	14	100	100
RC	23	100	100
RG	119[a]		

[a] Failed to reach criterion and excused from study.

Step 8: Final equivalence test in both color backgrounds. To determine whether the background colors had acquired control over the composition of the originally trained equivalence classes, a final stimulus equivalence test was given without feedback in both background colors. The instructions preceding this step were as follows:

> In this final part of the experiment, you will see one symbol at the top of the computer screen and three symbols across the bottom, just like the very first part of the experiment. When you see the symbol at the top of the screen, use the 1, 2, or 3 keys on the number pad to choose the correct symbol from the bottom of the screen. You will not receive any feedback about your choices. Do you have any questions?

Results and Discussion

Establishing and Testing Equivalence Classes

Because the formation of stimulus equivalence classes among college students is a common finding and was not the specific focus of the study, individual acquisition curves are not reported. Table 4 shows the numbers of trial blocks needed to reach the training criterion and percentage of correct responses in the initial and final equivalence tests for all participants. In this and all subsequent tables and figures, participants are listed in the order in which they participated in the study.

Participant RG failed to reach the training criterion, even after 119 trial blocks, and was excused from the experiment. All other participants satisfied the training criterion within 23 training blocks (*M* = 13.8, range, 7 to 23) and scored at 100% accuracy on the first and final equivalence tests. Except for RG, all participants demonstrated the formation and maintenance of the intended (i.e., A1-E1; A2-E2; A3-E3) three five-member equivalence classes in both background colors.

Task Training, Contextual Control Training, and Contextual Control Testing

Table 5 shows the numbers of training-trial blocks necessary to reach criterion during the task training and contextual control training components of the experiment and the percentage of correct responses on the various tests. After 36 blocks of training trials, TR failed to reach criterion during contextual control training over sequencing with the B and D stimuli and dropped out of the study. Participant RW failed to meet criterion on the first set of mixed B, C, and D no-feedback trials (BCD nfdbk) and, after six blocks of retraining, dropped out of the study.

The remaining 4 participants met criterion in all of the training components of the experiment. Except for PJ, who met the training criterion for sequencing the B stimuli after only six trial blocks, there was remarkable consistency among the remaining participants in the number of trial blocks required to reach the training criteria when the B stimuli were used to train the sequencing and key-choice tasks (12 for each participant). The number of blocks required before the participants reliably sequenced the C and D stimuli correctly in the two background colors varied between four and eight. Three of the participants, PJ, MD, and RC, scored 100% on the first set of mixed BCD nfdbk sequencing trials. JR scored 97% on the first set of BCD nfdbk trials and, after two trial blocks of retraining, scored 100% on the second set. Interestingly, however, even after the background colors came to exert reliable differential control over sequencing the B, C, and D stimuli, all participants initially responded to the C and D stimuli in the key-choice tasks as they had to the respective B stimuli, regardless of background color. Participants PJ and MD required four blocks and JR and RC required six blocks of training trials before their key-choice responses to the C stimuli came under control of the background colors. Moreover, PJ, MD, and RC required four blocks and JR required six blocks of training trials before their key-choice responses to the D stimuli came under control of the background colors. In other words, despite the contextual control training with the C and D stimuli on the sequencing task, and the fact that all 4 participants met criterion on the BCD nfdbk trials, none of the participants showed evidence of contextual control by the background colors over function transformation on the key-choice task. Instead, they continued to show evidence of function transformation in both background colors until they were directly trained to do otherwise.

After being directly trained to respond differentially to the C and D stimuli in the two background colors, 3 participants demonstrated background-color control over their key choices on the first set of BCD nfdbk key-choice trials. Participant JR failed to meet criterion on the first set of BCD nfdbk trials, but after four blocks of retraining, he met criterion on the second set of BCD nfdbk trials. Despite this, none of the participants showed any evidence of contextual control by the background colors over function transformation on the sorting task in Step 7. All 4 participants responded to the E stimuli in both background colors as they had to the respective B stimuli. Thus, each participant obtained a correct response rate of 75%.

The present data demonstrate that equivalence-based transformation of function is robust. Until directly trained to do otherwise, all of the participants responded to the C, D, and E stimuli exactly as they had to the respective B stimuli. In other words, given the opportunity, all of the participants showed evidence of function transformation, and considerable training was required to get them to respond differently.

It is not clear why the sorting responses to the E stimuli failed to come under contextual control of the background colors. One possibility is simply that there was insufficient differential training with the C and D stimuli in the two background colors to produce generalized contextual control. Participants were directly trained to respond similarly to the B

Table 5

Number of trial blocks to reach criterion on each trial type during task and contextual control training and percentage of correct responses on no-feedback trials for all participants in Experiment 1.

	Task					
	Sequencing					
Participant	B	BC	BD	BCD/nfdbk	Retraining	BCD/nfdbk
PJ	6	4	4	100		
TR	12	28	36[a]			
JR	12	4	8	97	2	100
MD	12	4	4	100		
RW	12	18	12	84	6[a]	
RC	12	6	4	100		

[a] Failed to reach criterion at this point and dropped out of study.

stimuli in the two background colors, and that training likely competed with the differential training they received with the C and D stimuli. In addition, the differential training with the C and D stimuli was presented on only two tasks, and, subsequent to that training, there were no tests to determine whether the background colors would control responding to the C and D stimuli on novel forms of the tasks. Moreover, the tasks used in the experiment were topographically distinct, and these formal differences may have precluded the generalization of control by the background colors from one task to another. To examine whether more extended multiple-exemplar training would produce generalized contextual control by the background colors over responding on a novel task we conducted a second experiment.

EXPERIMENT 2

Method

Participants, Setting, Apparatus, and Stimuli

One male (DC) and 3 female (KD, KL, and MS) introductory psychology students served as participants. They were recruited, compensated, and debriefed exactly as in Experiment 1. Experimental sessions lasted between 1.5 and 4 hr, and all participants completed the study within a single session. The experimental setting, apparatus, and stimuli were the same as those in Experiment 1, except that only the first 9 of the 15 stimuli depicted in Figure 1 were used.

Procedure

The general strategy for Experiment 2 is outlined in Table 6. Unless otherwise noted, the presentation of instructions and feedback, the quasirandomization of trials within blocks, and definition of ''correct'' and ''wrong'' responses were the same as Experiment 1.

Step 1: Establishing and testing equivalence classes. Using procedures similar to those in Step 1 of Experiment 1, three three-member (A through C) stimulus equivalence classes were trained. The six conditional relations depicted in the top two rows of Table 3 comprised the training trials. As in Experiment 1, blocks of training trials consisted of all six conditional relations. Training continued until participants reached a criterion of 96% correct responses over eight consecutive trial blocks. Test trials were presented without feedback in blocks of 24 trials. Two test trials for each of the six possible symmetrical relations and six possible equivalence relations were presented in each block. Participants met the criterion of 96% correct over a single block of trials before moving on to Step 2.

Step 2: Training the key-choice tasks with the B stimuli. Instead of using different tasks to train functions for the B stimuli, as was done in Experiment 1, only key-choice tasks were used in Experiment 2. The procedures and instructions were identical to those in Experiment 1, except that the row on the keyboard from which participants could select keys and the specific keys that were designated as correct changed with repeated presentations of the task. Also, participants were not told to

Table 5

(*Extended*)

Task							
Key choice						Color sort	
B	BC	BD	BCD/nfdbk	Retraining	BCD/nfdbk	B	BE/nfdbk
12	4	4	100			3	75
12	6	6	86	4	100	3	75
12	4	4	100			3	75
12	6	4	100			4	75

limit their selections to specific keys within a row. On the first key-choice task, participants were instructed to select keys from the top row of letters on the keyboard. The letters that were arbitrarily designated as correct in the presence of B1, B2, and B3, respectively, varied randomly across participants. Thus, T, E, and I, respectively, were correct for 1 participant, whereas W, P, and Y were correct for another. The specific instructions were as follows:

> For this task, your job is to choose the correct key on the keyboard for each symbol that appears at the top of the screen. You will have to figure out which key goes with which symbol. To start, we want you to use just the top row of letters on the keyboard. Later, you will use the other rows, but we will always tell you which row to use. In the beginning, you will receive feedback telling you whether your choices are correct or wrong. Later in the experiment you will not receive feedback, but there is always a correct choice. Do you have any questions?

Training trials were presented in blocks of six, two trials with each of the B stimuli. Training continued until participants reached a performance criterion of 96% over four consecutive trial blocks.

Step 3: Testing for contextual control by the background colors over responding to the B and C stimuli. Once participants met the training criterion with the B stimuli, mixed BC trials were introduced without feedback. These trials were presented in blocks of 30, consisting of the six previously trained B trials and 24 C trials. The purpose of these trials was to determine whether the background colors had acquired differential contextual control over responding to the B and C stimuli. Of course, participants who had not yet gone through Step 4 were not expected to respond differentially to the C stimuli in the two background colors. Implementing this step at this point was done simply to be consistent with subsequent training and testing procedures. Participants then moved on to Step 4, which was intended to bring responding to the C stimuli under differential control of the background colors.

Step 4: Multiple-exemplar training to establish control by the background colors over responding to the B and C stimuli. This differential training

Table 6

Overview of procedure of Experiment 2.

Step	Procedure
1	Established three three-member (A–C) equivalence classes.
2	Train new key-choice task with B stimuli.
3	Test whether background colors have acquired contextual control over responding to C stimuli on key-choice task. If no, go to Step 4. If yes, terminate experiment.
4	Differentially train responding to the C stimuli on key-choice task in two background colors.
5	Repeat Steps 2 through 4 until participant passes test in Step 3.

was similar to that described in Step 5 of Experiment 1. Blocks of 30 mixed B and C trials were presented exactly as in Step 3 except that participants received feedback for their responses. This training continued until participants reached a performance criterion of 97% correct over a complete block of 30 trials. Once participants met this training criterion, they moved on to the next key-choice task.

Step 5: Repeating Steps 2 through 4 with new key choices. For the second key-choice task, participants were told to restrict their choices to the second row of letters on the keyboard. Again, the arbitrarily designated correct keys in the presence of B1, B2, and B3 varied randomly across participants. Trials were presented as in Step 2, and participants were required to meet the same performance criterion before the mixed BC trials were presented without feedback. The mixed BC trials were presented exactly as described in Step 3, except for the keys that were arbitrarily designated as correct. If participants met the criterion of 97% correct over a complete block of 30 trials, the experiment was terminated. If not, the previously described multiple-exemplar procedures were repeated, except that the specific key choices considered correct and wrong were tied to the keys used to train responding to the B stimuli in the immediately preceding training session. Differential training continued until participants met the 97% correct performance criterion over a complete block of trials. They then moved on to a new key-choice task with the B stimuli. This sequence of training, testing, and training was repeated until participants met the testing criterion on the mixed BC nfdbk trials, which would demonstrate generalized contextual control over responding to the C stimuli on a new key-choice task. Through each iteration of this sequence, the row on the keyboard from which keys could be selected varied unsystematically from the top row to the bottom. Participants were always told which row of keys to use before any set of trials began.

Table 7

Number of trial blocks to reach conditional discrimination training criterion, percentage of correct responses on equivalence test trials, and number of key-choice tasks presented before reaching criterion on BC no-feedback trials for all participants.

Participant	Trial blocks to training criterion	% correct equivalence test trials	Key-choice tasks to reach criterion on BC no-feedback trials
KD	13	100	5
KL	10	100	5
MS	104	100	8
DC	15	100	13

Results and Discussion

Establishing and Testing Equivalence Classes

The second and third columns of Table 7 show the numbers of trial blocks required for each participant to reach the conditional discrimination training criterion and percentage of correct responses on the first block of equivalence test trials, respectively. As these data suggest, MS required substantially more training to reach criterion (104 blocks) than the other participants, who varied between 10 and 15 trial blocks. Despite this variation in the number of trials needed to meet the training criterion, all participants responded correctly on each of the 24 test trials and, thus, demonstrated the formation of three three-member equivalence classes.

Key-Choice Training, Testing, and Differential Control Training

The last column of Table 7 shows the numbers of key-choice tasks presented to each participant before they reached criterion on the BC nfdbk trials. The numbers ranged from a low of 5 (KD and KL) to a high of 13 (DC). Given these data, it is not surprising that contextual control over the transformation of function failed to emerge in Experiment 1, in which only two differential training tasks were presented before participants were tested for contextual control over function transformation.

Although the results of Experiment 2 were encouraging and demonstrated the emergence of control by the background colors over responding to the C stimuli, they did not unambiguously demonstrate the emergence of contextual control over equivalence-based transformation of functions. As stated previously, because the B and C stimuli had been used both to train and test differential control by the background colors, it cannot be determined whether the background colors functioned as contextual stimuli or whether they combined with the B and C stimuli to function as compound conditional stimuli. For the same reason, it cannot be determined whether the functions of the C stimuli were acquired via equivalence or through direct training. Because the B and C stimuli were used in the differential training procedures, participants could have learned simply to respond to the B and C stimuli similarly in the red background and differently in the blue background. Of course, the fact that all of the participants initially responded to the C stimuli exactly as they had to the B stimuli and that a considerable amount of training was required to get the participants to respond differentially to the C stimuli in the two background colors certainly suggests that the functions of the C stimuli were acquired via equivalence. Nevertheless, an unambiguous demonstration of contextual control over equivalence-based transformation of function requires differential control by the background colors over responding to equivalent stimuli that have not been used in the differential training. That was the purpose of Experiment 3.

EXPERIMENT 3

Method

Participants, Setting, Apparatus, and Stimuli

One female (SR) and 4 male (RR, TH, WR, and DW) introductory psychology students served as participants. They were recruited, compensated, and debriefed as in Experiment 1. The numbers of sessions required to complete the experiment were one for RR and DW, two for TH and WR, and three for SR. Session 1 lasted 4 hr for all participants. Session 2 lasted 1.5 hr for WR and 2 hr for SR and TH. Session 3 lasted 1 hr for SR. One session was scheduled per day, and subsequent sessions were scheduled as close together as the participants' schedules allowed. All participants completed the experiment within 5 days. The setting, apparatus, and stimuli were identical to those in Experiment 1.

Procedure

The specific steps of the experiment are listed in Table 8 and described in detail below. Because of the complexity of this experiment and the need to refer to its numerous steps when describing the results, the steps are identified by descriptive shorthand. The present experiment was similar to Experiment 1 in that five-member equivalence classes were used, and demonstration of the transformation of function depended on participants responding differentially to the E stimuli in the two background colors, but it was similar to Experiment 2 in its overall strategy. That is, participants were repeatedly given multiple-exemplar training with new key-choice tasks with the B and C stimuli until there was evidence that the color backgrounds had acquired differential control over responses to the C stimuli on a new key-choice task. The present experiment differed from both Experiments 1 and 2, however, in that participants were required to demonstrate differential control by the background colors over responding on a new key-choice task with the C stimuli before the D stimuli were introduced, and they then had to demonstrate background-color control over responding to the D stimuli on a new key-choice task before the E stimuli were introduced. If, without direct training, participants responded differentially to the D and E stimuli in the two background colors, then it could be argued convincingly that the background colors had acquired contextual control over equivalence-based transformation of function.

Establishing and testing stimulus equivalence classes. Three five-member equivalence classes were established and tested exactly as in Experiment 1 with two exceptions. First, all stimuli were black instead of white. Second, in an attempt to reduce differences in context between the stimulus equivalence and key-choice phases, all training and testing, including stimulus equivalence, occurred in both the red and blue background colors. Training trials were presented in blocks of 24, consisting of two presentations of each of the 12 trained relations in Table 2. A training criterion of 100% over three consecutive trial blocks was required before test trials were introduced. Test trials were presented as in Ex-

Table 8

Overview of procedure of Experiment 3.

Step	Procedure
Establish and test equivalence classes	Establish and test three five-member (A–E) equivalence classes in red (rd) and blue (bl) backgrounds.
KC1/B/rd	Train first key-choice task (KC1) with B stimuli (B) sequentially in red (rd),
KC1/B/bl	blue (bl), and
KC1/B	mixed backgrounds.
KC1/B/nfdbk	First key-choice task with B stimuli in mixed backgrounds, no feedback (nfdbk).
KC1/C/rd	Differentially train first key-choice task with C stimuli (C) sequentially in red,
KC1/C/bl	blue, and
KC1/C	mixed backgrounds.
KC1/BC	Mixed BC training on first key-choice task in mixed (alternating) backgrounds.
KC1/BC/nfdbk	Mixed BC no-feedback trials on first key-choice task in mixed backgrounds.
KC2/B	Train second key-choice task with B stimuli in mixed backgrounds.
KC2/C	Differentially train second key-choice task with C stimuli in mixed backgrounds.
KC2/BC	Mixed BC training on second key-choice task in mixed backgrounds.
KC2/BC/nfdbk	Mixed BC no-feedback trials on second key-choice task in mixed backgrounds.
KC3(N)/B	Train third (or new) key-choice task with B stimuli in mixed backgrounds.
KC3(N)/C probes	Two probe trials with C stimuli, no feedback. If pass, skip next step. If fail, go to next step.
KC3(N)/BC	Mixed BC training on third (or new) key-choice task in mixed backgrounds.
KC3(N)BC/nfdbk	Mixed BC no-feedback trials on third (or new) key-choice task in mixed backgrounds. If pass step and previous probes, go to next step. If pass step but fail probes, repeat from KC3(N)/B with new key-choice task.
KC4(N)/B	Train fourth (or new) key-choice with B stimuli in mixed backgrounds.
KC4(N)/BD/nfdbk	Mixed BD no-feedback trials with key-choice task from previous step in mixed backgrounds. If pass on first try, skip next step. If fail, go to next step. If pass after first try, repeat from KC3(N) with new key choice, but skip C probes and KC3(N)/BC.
KC4(N)/BD	Mixed BD training with key-choice task from previous step in mixed background. Go back to previous step.
KC5(N)/B	Train new key-choice task with B stimuli in mixed backgrounds.
KC5(N)/BE/nfdbk	Mixed BE no-feedback trials in mixed backgrounds.
Fin equiv tst	Final equivalence test in mixed backgrounds.

periment 1. Participants were required to meet a 96% correct performance criterion over an entire block of test trials before moving to the next step. Participants who failed to meet the 96% correct criterion repeated the equivalence training and testing procedures. The testing procedures were repeated in the final equivalence test at the end of the experiment.

Multiple-exemplar training with the key-choice tasks and testing for contextual control by color backgrounds. The key-choice tasks, including instructions and feedback for correct and incorrect responses, were presented exactly as in Experiment 2 with two exceptions. First, in an attempt to facilitate contextual control by the background colors, we altered the way we trained the first key-choice task with both the B and C stimuli. In particular, rather than present training trials in quasirandomly alternating background colors, the background colors were introduced sequentially. That is, the key-choice tasks were trained first in the red background, then in the blue background, and then in quasirandomly alternating (mixed) backgrounds. This change pertained only to the first key-choice task; subsequent key-choice tasks were trained in mixed backgrounds.

Second, once participants met criterion in all of the steps that involved training the various key-choice tasks, a final block of training trials was presented in which feedback was gradually faded. This was an attempt to reduce discriminability between the training and testing phases. Feedback was faded over the trial block by successively removing the last letter from the written feedback presented on preceding trials (e.g., correct, correc, corre, corr, etc.). Performance on this final block of trials is not presented in the results.

After meeting criterion on the stimulus

equivalence test, participants were trained on the first key-choice task (KC1) with the B stimuli (B) in the red background (rd). Trials were presented in blocks of 24, consisting of eight presentations of each of the B stimuli in the red background only. In this and all subsequent steps, participants were required to meet a performance criterion of 96% correct over a complete block of trials in order to move on to the next step. Once participants met the performance criterion, the screen background changed to blue (bl), and similarly comprised blocks of training trials were presented until participants met criterion. Following this, blocks of 24 mixed-background (KC1/B; note that there is no background designation for trial blocks in mixed-background colors) training trials were presented. Once participants met criterion, they moved on to KC1/B/nfdbk in which up to two blocks of similarly comprised trials were presented without feedback. Participants were required to meet criterion on either of these blocks before moving on to the next step.

In the next step, the C stimuli were presented in the first key-choice task. As with the B stimuli in the previous step, blocks of training trials were introduced first in the red background (KC1/C/rd), then in the blue background (KC1/C/bl), then in mixed backgrounds (KC1/C). Trial blocks were comprised and presented exactly as described for the B stimuli, except that differential feedback, as described in Experiment 1, was given for responses to the C stimuli depending upon background color.

Once participants met criterion with the C stimuli in mixed-background training (note that there were no blocks of C trials without feedback), they moved on to KC1/BC, which consisted of the presentation of blocks of 24 mixed BC training trials in mixed backgrounds. This step was identical to the BC training in Experiment 2, except that there were equal numbers (12) of B and C stimuli trials in each block. This was also true of all subsequent steps involving BC and BD training trials. After meeting criterion, participants moved on to KC1/BC/nfdbk, which entailed the presentation of up to two blocks of trials comprised exactly as in the previous step but with no feedback. Participants were required to meet criterion on either block of trials to move on to the next step.

In KC2/B, participants were trained on the second key-choice task with the B stimuli. In this and all subsequent steps in which key-choice tasks were trained, the procedures were identical to those in Step 2 of Experiment 2, except that participants were required to meet criterion on only one block of trials before moving on.

In KC2/C, the C stimuli were introduced in the second key-choice task. Blocks of trials were comprised exactly as with the B stimuli in KC2/B, but, again, differential feedback was provided depending upon color background. Once participants met criterion, they moved on to KC2/BC, which entailed mixed BC training on the second key-choice task. Meeting criterion moved the participants to KC2/BC/nfdbk, which consisted of up to two blocks of trials comprised similarly to those in the previous step, but without feedback. When participants met criterion on either of these two blocks of trials, they moved to the next step.

In KC3(N)/B, the third key-choice task was trained with the B stimuli exactly as in KC2/B. After participants met criterion, they moved to KC3(N)/C probes. The purpose of these probe trials was to test for evidence of differential control by the background colors over responses to the C stimuli. On the probe trials, one of the three C stimuli was randomly selected and presented once on both background colors. Participants passed the probe trials if they selected the same key for the C stimulus in the red background as they did for the respective B stimulus in KC3(N)/B, but selected a different key for the C stimulus in the blue background. If participants passed the probe trials, they skipped KC3(N)/BC and moved to KC3(N)/BC/nfdbk. If participants failed the probe trials, they moved to KC3(N)/BC. KC3(N)/BC and the subsequent step, KC3(N)/BC/nfdbk, were identical to KC2/BC and KC2/BC/nfdbk, except for the row on the keyboard on which participants could respond. If participants responded correctly on both trials in KC3(N)/C probes and met criterion in KC3(N)/BC/nfdbk, they moved on to KC4(N)/B. If not, they repeated KC3(N)/B through KC3(N)/BC/nfdbk with new (N) key-choice tasks until they did so.

In KC4(N)/B, participants were again trained on a new key-choice task with the B stimuli. Once they met criterion, they moved to KC4(N)/BD/nfdbk, which entailed the presentation of up to two blocks of mixed BD trials without feedback. These BD trials were comprised exactly as the previous BC nfdbk trials described above. If participants met criterion on either trial block, they skipped KC4(N)/BD and moved to KC5(N)/B. If participants failed to meet criterion in KC4(N)/BD/nfdbk, they moved to KC4(N)/BD, in which they received blocks of mixed BD training trials on the fourth or new key-choice task. After meeting criterion in KC4(N)/BD, participants returned to KC4(N)/BD/nfdbk for another block of BD nfdbk trials. After meeting criterion on these no-feedback trials, participants returned to KC3(N)/B with a new (N) key-choice task and repeated the procedure just described, with the exception of KC3(N)/C probes and KC3(N)/BC, until they met criterion on the first presentation of a block of BD nfdbk trials [KC4(N)/BD/nfdbk] on the key-choice task trained for the B stimuli in the immediately preceding step [KC4(N)/B].

Once participants met criterion on either block of the KC4(N)/BD/nfdbk trials, they moved to KC5(N)/B, in which they were trained on another new key-choice task with the B stimuli. Following this, participants moved to KC5(N)/BE/nfdbk, in which they received a block of 24 mixed BE trials without feedback. These BE trials were comprised and presented exactly as previous BC and BD nfdbk trials. Regardless of how they performed on the BE trials, participants moved to the final equivalence test in which, except for SR (see below), they received a final block of 96 equivalence test trials.

Results and Discussion

Establishing and Testing Equivalence Classes

Table 9 shows the number of trial blocks to reach the conditional discrimination training criterion and the percentage of correct responses on the first and, if necessary, second and third equivalence tests. (Data for the final equivalence test are presented in Tables 11 and 12, along with the data for the tests for contextual control.) All 5 participants met the training and testing criteria. The number of training-trial blocks required to meet criterion ranged from a low of 6 for TH to a high of 15 for WR. Participants SR and RR failed to meet the 96% testing criterion on the first block of test trials, but after retraining, they performed at 100% accuracy on the second test. As described below, SR received a second round of stimulus equivalence training and testing trials. On the second round, she required two trial blocks to reach the training criterion and performed at 100% accuracy on the first block of test trials.

Table 9

Number of trial blocks to reach conditional discrimination training criterion and percentage correct on initial equivalence tests for all participants in Experiment 3.

Participant	Trial blocks to criterion		% correct Test 1	% correct Test 2	% correct Test 3
SR	12	2[a]	86	100	100[a]
RR	9		91	100	
TH	6		96		
WR	15		98		
DW	9		99		

[a] See text.

Key-Choice Training and Tests for Contextual Control of Function Transformation

Table 10 presents each participant's percentage of correct responses on each trial block up to the first set of C stimuli probes (KC3/C probes). These steps involved basic training on the key-choice tasks, and the data are not considered critical to the central question of the experiment. The data in Table 10 show that (a) all participants learned the various key-choice tasks with both the B and C stimuli, (b) participants tended to respond to the C stimuli in both background colors as they had to the respective B stimuli until directly trained to do otherwise, and (c) the training procedures produced differential control by the background colors over all participants' responses to the C stimuli. The number of trial blocks necessary to train key-choice responding with the B stimuli ranged from two to four, and the number of training blocks necessary to train differential responding to the C stimuli (in blue or mixed backgrounds) ranged from two to four.

Table 11 presents percentage of correct responses from the first set of C stimuli probes

Table 10

Percentage of correct responses for all participants on each block of trials up to the first set of C stimuli probes.

	Participant																
	SR block				RR block			TH block			WR block				DW block		
Step	1	2	3	4	1	2	3	1	2	3	1	2	3	4	1	2	3
KC1/B/rd	38	67	100		54	96		42	100		46	96			33	96	
KC1/B/bl	100				100			100			100				100		
KC1/B	96				100			100			100				100		
KC1/C/rd	96				100			100			100				100		
KC1/C/bl	83	100			50	79	100	88	100		88	100			92	100	
KC1/C	79	100			100			92	100		59	100			96		
KC1/BC	75	67	75	96	79	92	100	100			100				100		
KC1/BC/nfdbk	100				100			100			100				100		
KC2/B	33	71	100		38	88	100	21	79	100	38	100			54	96	
KC2/C	88	100			79	100		88	96		96				88	100	
KC2/BC	100				100			100			100				100		
KC2/BC/nfdbk	100				100			100			100				100		
KC3/B	46	63	79	100	50	92	100	54	100		13	71	88	100	50	88	100

(KC3/C probes) through the final equivalence test for SR, RR, and TH. The data for WR and DW are presented in Table 12. Those steps critical to the demonstration of emergent control by the background colors over responding are presented in boldface. Due to the volume of data and variability in the number of training and testing conditions across participants, each participant's data are described separately.

Table 11

Percentage of correct responses for Participants SR, RR, and TH on each block of trials from the first set of C stimuli probes through the final equivalence test. Critical steps are in boldface.

SR				RR				TH			
	Block				Block				Block		
Step	1	2	3	Step	1	2	3	Step	1	2	3
KC3/C probes	0			**KC3/C probes**	100			**KC3/C probes**	50		
KC3/BC	79	96		**KC3/BC/nfdbk**	100			KC3/BC	100		
KC3/BC/nfdbk	100			KC4/B	33	79	100	KC3/BC/nfdbk	100		
KC4/B	17	100		**KC4/BD/nfdbk**	54	54		KC4/B	42	100	
KC4/C probes	50			KC4/BD	71	71	100	**KC4/C probes**	50		
KC4/BC	97			KC4/BD/nfdbk 2	100			KC4/BC	92	100	
KC4/BC/nfdbk	100			KC5/B	75	100		KC4/BC/nfdbk	100		
KC5/B	25	67	100	**KC5/BC/nfdbk**	100			KC5/B	4	88	100
KC5/C probes	100			KC6/B	21	67	100	**KC5/C probes**	50		
KC5/BC/nfdbk	100			**KC6/BD/nfdbk**	100			KC5/BC	79	100	
KC6/B	25	88	100	KC7/B	13	100		KC5/BC/nfdbk	100		
KC6/BD/nfdbk	100			**KC7/BE/nfdbk**	100			KC6/B	42	100	
KC7/B	42	92	100	**Fin equiv tst**	100			**KC6/C probes**	100		
KC7/BE/nfdbk	79							**KC6/BC/nfdbk**	100		
Fin equiv tst	86							KC7/B	13	92	100
KC8/B	67	100						**KC7/BD/nfdbk**	96		
KC8/BC/nfdbk	100							KC8/B	29	88	100
KC9/B	67	100						**KC8/BE/nfdbk**	96		
KC9/BD/nfdbk	100							**Fin equiv tst**	96		
KC10/B	50	92	100								
KC10/BE/nfdbk	100										
Fin equiv tst	100										

Table 12

Percentage of correct responses for Participants WR and DW on each block of trials from the first set of C stimuli probes through the final equivalence tests. Critical steps are in boldface.

WR						DW				
	Block						Block			
Step	1	2	3	4	5	Step	1	2	3	4
KC3/C probes	50					**KC3/C probes**	100			
KC3/BC	100					**KC3/BC/nfdbk**	100			
KC3/BC/nfdbk	100					KC4/B	46	100		
KC4/B	54	96				**KC4/BD/nfdbk**	75	75		
KC4/C probes	100					KC4/BD	83	100		
KC4/BC/nfdbk	96					KC4/BD/nfdbk 2	100			
KC5/B	0	8	29	71	100	KC5/B	54	100		
KC5/BD/nfdbk	83	83				**KC5/BC/nfdbk**	88	100		
KC5/BD	88	96				KC6/B	25	79	88	100
KC5/BD/nfdbk 2	100					**KC6/BD/nfdbk**	100			
KC6/B	75	100				KC7/B	42	96		
KC6/BC/nfdbk	100					**KC7/BE/nfdbk**	75	75		
KC7/B	46	100				**Fin equiv tst**	100			
KC7/BD/nfdbk	100									
KC8/B	33	92	100							
KC8/BE/nfdbk	100									
Fin equiv tst	96									

Participant SR. This participant performed at 0% accuracy on KC3/C probes, the first set of C stimuli probes. Her responses on the probe trials were opposite to what was trained in the previous steps (i.e., she showed evidence of function transformation in the blue background but not in the red background). She quickly met criterion in KC3/BC and KC3/BC/nfdbk, required just two blocks of trials to meet criterion in KC4/B, but failed the second set of C stimuli probes (KC4/C probes). This time she responded in line with function transformation in both backgrounds. She again quickly met criterion in KC4/BC and KC4/BC/nfdbk and took three blocks to meet criterion in KC5/B. She then passed the third set of C stimuli probes (KC5/C probes) and the first block of KC5/BC/nfdbk. This was the first evidence of control by the background colors over SR's responses to the C stimuli on a new key-choice task.

Participant SR took three blocks to pass KC6/B and then met criterion on the first block of KC6/BD/nfdbk. This was the first evidence of control by the background colors over the transformation of function. She then took three blocks to pass KC7/B but failed the subsequent BE nfdbk trials (KC7/BE/nfdbk). She also failed the final equivalence test.

An inspection of the final equivalence-test data indicated that SR had swapped the class membership of two of the E stimuli. Because this may have accounted for her failing the BE nfdbk trials, we decided to repeat equivalence training and testing and then present SR with another sequence of key-choice training and contextual control testing procedures.

After quickly meeting the equivalence training and testing criterion, SR took two blocks to meet criterion in KC8/B and met criterion on the first block in KC8/BC/nfdbk. She passed KC9/B in two blocks and met criterion on the first block in KC9/BD/nfdbk. She took three blocks to pass KC10/B and then passed KC10/BE/nfdbk on the first block of trials. She also scored 100% on the final equivalence test. As these data indicate, SR demonstrated contextual control over the transformation of function, but only after several repetitions of the key-choice and contextual control training and testing phases.

Participant RR. This participant passed KC3/C probes and met criterion in KC3/BC/nfdbk on the first block of trials. He took three blocks to meet criterion in KC4/B but failed to meet criterion on either block of trials in KC4/BD/nfdbk. He took three blocks to pass KC4/BD and passed the second set of BD nfdbk trials with the fourth key-choice task (KC4/BD/nfdbk 2) on the first trial block. He took two blocks to meet criterion in KC5/B, met criterion on the first block in KC5/BC/nfdbk, took three blocks to pass KC6/B, and then passed KC6/BD/nfdbk on the first block. Because he had been directly trained to respond differentially to the D stimuli, meeting criterion in KC6/BD/nfdbk could not be considered evidence for contextual control over function transformation. He met criterion in KC7/B in two blocks and performed at 100% accuracy in KC7/BE/nfdbk. He also performed at 100% accuracy on the final equivalence test. Based on RR's performance in KC7/BE/nfdbk, the background colors appeared to have acquired contextual control over the transformation of function.

Participant TH. This participant showed evidence of function transformation with the C stimuli in both background colors and, thus, failed the KC3/C probes. He quickly met criterion in KC3/BC and KC3/BC/nfdbk, passed KC4/B in two trial blocks, and then failed the second set of C stimuli probes (KC4/C probes). He met criterion in KC4/BC and KC4/BC/nfdbk, took three trials to pass KC5/B, but failed the KC5/C probes. After meeting criteria in KC5/BC, KC5/BC/nfdbk, and KC6/B, he passed the fourth set of C stimuli probes (KC6/C probes) and scored perfectly in the subsequent KC6/BC/nfdbk. He took three blocks to meet criterion in KC7/B and then passed KC7/BD/nfdbk on the first trial block. He met criterion in KC8/B in three blocks, passed KC8/BE/nfdbk, and passed the final equivalence test. His performance in KC7/BD/nfdbk and KC8/BE/nfdbk was indicative of contextual control over the transformation of function with both the D and E stimuli.

Participant WR. This participant responded consistent with function transformation on both probe trials and failed KC3/C probes. After meeting criterion in KC3/BC, KC3/BC/nfdbk, and KC4/B, he passed the KC4/C probes and met criterion in KC4/BC/nfdbk. He took five blocks to pass KC5/B and then, because he responded in line with function transformation in both background colors, he failed KC5/BD/nfdbk. WR met criterion in KC5/BD and KC5/BD/nfdbk 2, took two blocks to pass KC6/B, met criterion in KC6/BC/nfdbk, passed KC7/B in two blocks, and then passed KC7/BD/nfdbk. He took three blocks to pass KC8/B and then evidenced contextual control of function transformation by passing KC8/BE/nfdbk. He also met criterion on the final equivalence test.

Participant DW. This participant passed the KC3/C probes and met criterion on the first block of KC3/BC/nfdbk. He took two trial blocks to pass KC4/B and then failed to meet criterion in KC4/BD/nfdbk. As with the other participants who failed this step, DW showed evidence of function transformation in both background colors. He met criterion in KC4/BD and KC4/BD/nfdbk 2, took two blocks to meet criterion in KC5/B, met criterion in KC5/BC/nfdbk, passed KC6/B in four blocks, and met criterion on the first block in KC6/BD/nfdbk. He passed KC7/B in two trial blocks but then failed KC7/BE/nfdbk. Again, he responded to the E stimuli as he had to the respective B stimuli in both background colors. Unlike SR, DW scored perfectly on the final equivalence test, so his performance in KC7/BE/nfdbk could not be attributed to a failure of the stimulus equivalence classes to be maintained. He was the only participant who did not demonstrate contextual control over function transformation.

Four of the 5 participants in this experiment demonstrated contextual control over equivalence-based transformation of function. Two (SR and TH) demonstrated contextual control on both the BD/nfdbk and BE/nfdbk trials, whereas RR and WR showed evidence of contextual control only on the BE/nfdbk trials.

The failure of the background colors to exert differential control over RR's and WR's responses to the D stimuli and DW's responses to both the D and E stimuli suggests that, for these participants, the training procedures up to that point were insufficient to establish a contextual function for the background colors. Although the color backgrounds did exert differential control on the C stimuli probes and BC nfdbk trials, because the C stimuli had been used in the differential training, the background colors may simply have joined with the B and C stimuli to exert compound discriminative control over these participants' responses. In the absence of direct training, the D stimuli and the background colors could not have acquired compound discriminative control over these participants' responses, and they failed to meet criterion on the first set of BD/nfdbk trials. Evidently, the subsequent differential training with the D stimuli (KCN/BD) was sufficient to produce a contextual function for the background colors on the BE/nfdbk trials for RR and WR but not for DW.

Although these results demonstrate that differential reinforcement procedures can produce contextual control over equivalence-based transformation of function, the control exerted by the background colors was restricted to a single set of equivalence classes. As Meehan and Fields (1995) point out, in order to demonstrate generalized contextual control it is necessary to show that this function generalizes to a novel set of equivalence classes. That was the purpose of Experiment 4.

EXPERIMENT 4

Method

Participants, Setting, Apparatus, and Stimuli

Two male (JS and SM) and 3 female (AM, JL, and PT) introductory psychology students participated. They were recruited, compensated, and debriefed as in Experiment 3. The number of sessions required to complete the experiment was two for JS and JL and three for AM, PT, and SM. Session 1 lasted 4 hr for all participants. Session 2 lasted 3 hr for AM and 2 hr for the other 4 participants. Session 3 lasted 2 hr for SM and 3 hr for AM and PT. Experimental sessions were scheduled as close together as the participants' schedules allowed, with the restriction that only one session was scheduled per day. All participants completed the experiment within 6 days. The setting, apparatus, and stimuli were the same as those in Experiment 3.

Procedure

Phase 1: Initial training. The first phase consisted of the steps described in Experiment 3 with two exceptions. First, the specific keys that were designated as correct in the various key-choice tasks were the same for all participants. Second, it seemed likely that key-choice training with the B stimuli in red and blue backgrounds may have led participants to ignore the background colors and, thus, interfered with the development of stimulus control by the color backgrounds. Accordingly, in Experiment 4, all key-choice task training with the B stimuli was presented in a white rather than colored background, and training with the other stimuli occurred in colored backgrounds. Specifically, B stimuli training trials were presented in blocks of 24, with each of the B stimuli presented quasirandomly a total of eight times in the white background. The same 96% correct performance criterion was required before participants moved on to the next step. Subsequent to training in the white background, participants received a block of mixed-color no-feedback trials with the B stimuli, exactly as they had in Experiment 3. This was done to reduce the possibility of the background colors gaining control over responses to the B stimuli. All other training and testing steps in Phase 1 were presented exactly as in Experiment 3.

Phase 2: Establishing and testing equivalence classes. Once the participants completed the final equivalence test in Phase 1, they entered the second phase. The general strategy of Phase 2 was to (a) establish three new four-member (A through D) equivalence classes, (b) train a new key-choice task with the B stimuli, and (c) test whether the background colors would exert control over key-choice responses to the C and D stimuli. Phase 2 consisted of the seven steps presented in Table 13 and described below.

Three four-member stimulus equivalence classes were established and tested using the same match-to-sample procedures as in Experiment 3. The stimuli were ambiguous forms similar to those used in the previous experiments. Conditional discrimination training trials were quasirandomly presented in blocks of 18. Each of the nine trained A-B, A-C, and A-D relations depicted in Table 2 was presented once in a red background and once in a blue background. A training criterion of 100% over three consecutive trial blocks was required before test trials were introduced. Test trials were quasirandomly pre-

Table 13

Overview of Phase 2 procedure of Experiment 4.

Step	Procedure
Establish and test equivalence classes	Establish and test three new four-member (A–D) equivalence classes.
KC1(N)/B/w	Train first or new key-choice task with B stimuli in white (w) background
KC1(N)/BC/nfdbk	Mixed BC no-feedback trials on first or new key-choice task in mixed backgrounds. If pass on first try, skip next step. If pass after first try, repeat previous step with new key-choice task. If fail, go to next step.
KC1(N)/BC	Mixed BC training on first new key-choice task in mixed background. Repeat previous step.
KC2(N)/B/w	Train second or new key-choice task with B stimuli in white background.
KC2(N)/BD/nfdbk	Mixed BD no-feedback trials on second or new key-choice task in mixed backgrounds. If pass, go to final equivalence test. If fail, go to next step.
KC2(N)/BD	Mixed BD training on second or new key-choice task in mixed backgrounds. Repeat previous step.
Fin equiv tst	Final equivalence test.

sented in blocks of 54. Each of the nine possible symmetrical and 18 possible equivalence relations were presented once in each of the two background colors. The test criterion and retraining procedures were the same as in Phase 1. These testing procedures were repeated in the final equivalence test.

Phase 3: Training the key-choice tasks and testing for contextual control by the background colors. The composition of trial blocks and performance criteria used to train the key-choice tasks and test for contextual control by the background colors in Phase 2 were identical to those used in Phase 1. As indicated in Table 13, participants were trained on the first or new key-choice task with the B stimuli in a white background [KC1(N)/B/w]. Once they met criterion, they moved to KC1(N)/BC/nfdbk, which consisted of up to two blocks of mixed BC nfdbk mixed-background trials on the first or new key-choice task. Participants who failed to meet criterion moved to the next step, KC1(N)/BC, which consisted of mixed BC mixed-background training trials on the first or new key-choice task. Once participants met criterion, they repeated the previous step. If they met the testing criterion in KC1(N)/BC/nfdbk after the first try, they repeated KC1(N)/B/w with a new key-choice task. Participants who met criterion in KC1(N)/BC/nfdbk on the first try with a new key-choice task skipped the BC training trials (KC1(N)/BC) and moved to KC2(N)/B/w, in which they were trained on the second or new key-choice task with the B stimuli in a white background. From there, they moved to KC2(N)/BD/nfdbk, which consisted of up to two blocks of mixed BD nfdbk trials on the second or new key-choice task. Participants who met criterion moved to the final equivalence test. Participants who failed to meet criterion moved to KC2(N)/BD, which consisted of blocks of mixed BD mixed-background training trials on the most recently trained key-choice task. Meeting criterion in KC2(N)/BD sent the participants back to KC2(N)/BD/nfdbk. When they met criterion in that step, they received the final equivalence test. Participants who met the testing criterion in KC1(N)/BC nfdbk and KC2(N)/BD/nfdbk on the first try could be said to have demonstrated generalized contextual control of equivalence-based transformation of function.

Results and Discussion

Establishing and Testing Equivalence Classes

Table 14 presents the numbers of trial blocks to reach the training criterion and the percentage of correct responses on the initial equivalence tests in both phases. (Performances on the final equivalence tests are presented in Tables 16 and 17, along with data for key-choice training and tests for contextual control.)

As Table 14 indicates, all 5 participants met the training and testing criterion in both phases. The number of training-trial blocks required to meet the training criterion with the five-member classes in the first phase was six for AM, JS, and PT, seven for JL, and eight

Table 14

Number of trial blocks to meet the conditional discrimination training criteria and percentage correct on initial equivalence tests in Phases 1 and 2 for all participants in Experiment 4.

	Phase 1		Phase 2			
Participant	Trial blocks to training criterion	% correct on equivalence test	Trial blocks to training criterion		% correct on equivalence test	
AM	6	96	6	7[a]	98	96[a]
JS	6	100	5		98	
JL	7	100	6		100	
PT	6	98	5		98	
SM	8	100	6		98	

[a] These data are for the third set of training and testing procedures. See text.

for SM. All 5 participants met the testing criterion for the five-member classes on the first block of test trials. The number of training-trial blocks necessary to meet the training criterion with the four-member classes in Phase 2 was five for JS and PT and six for AM, JL, and SM. Again, all 5 participants met the testing criterion on the first block of trials. For reasons presented below, AM went through a third set of conditional discrimination training and equivalence-testing procedures.

Key-Choice Training and Tests for the Contextual Control of Transfer

Table 15 presents percentage of correct responses for each participant in each step of Phase 1 up to the first set of C stimuli probes (KC3/C probes). As was the case in Experiment 3, all of the participants learned the various key-choice tasks with both the B and C stimuli. Participants showed evidence of transformation of function with the C stimuli until directly trained to do otherwise; the training procedures successfully produced differential control by the background colors over responses to the C stimuli. The number of training-trial blocks necessary to train key-choice responding with the B stimuli varied from two to four, and the number of trial blocks necessary to train differential responding to the C stimuli (in blue or mixed backgrounds) ranged from two to three.

Table 16 shows AM's and JS's percentage of correct responses from the first set of C stimuli probes in Phase 1 (KC3/C probes) through the final equivalence test in Phase 2 (Phase 3 for AM, see below). The data for JL, PT, and SM are presented in Table 17. As in

Table 15

Percentage of correct responses for all participants on each block of trials up to the first set of C stimuli probes in Phase 1.

	Participant															
	AM block			JS block				JL block			PT block			SM block		
Step	1	2	3	1	2	3	4	1	2	3	1	2	3	1	2	3
KC1/B/w	25	88	100	8	46	79	100	33	96		50	100		38	96	
KC1/B/nfdbk	100			100				100			100			100		
KC1/C/rd	96			100				100			96			96		
KC1/C/bl	88	100	90	92	100			75	100		79	100		83	100	
KC1/C	59	96		100				88	100		100			50	100	
KC1/BC	88	100		100				100	100		100			100		
KC1/BC/nfdbk	100			100				100			100			100		
KC2/B/w	42	71	100	46	92	100		46	70	100	17	38	100	67	100	
KC2/C	63	83	100	96				100			82	96		96		
KC2/BC	96			100				100			100			100		
KC/BC/nfdbk	100			96				100			100			100		
KC3/B/w	8	96		58	96			33	79	96	54	96	100	21	38	100

Table 16

Percentage of correct responses for Participants AM and JS on each block of trials from the first set of C stimuli probes in Phases 1 through 3 for AM and Phases 1 and 2 for JS. Critical steps are in boldface.

AM				JS			
	Block				Block		
Step	1	2	3	Step	1	2	3
Phase 1							
KC3/C probes	50			**KC3/C probes**	50		
KC3/BC	75	96		KC3/BC	96		
KC3/BC/nfdbk	96			KC3/BC/nfdbk	100		
KC4/B/W	33	100		KC4/B/W	21	100	
KC4/C probes	100			**KC4/C probes**	100		
KC4/BC/nfdbk	100			**KC4/BC/nfdbk**	100		
KC5/B/W	50	96		KC5/B/W	29	75	100
KC5/BD/nfdbk	92	100		**KC5/BD/nfdbk**	100		
KC6/B/W	33	92	100	KC6/B/W	8	75	100
KC6/BE/nfdbk	96			**KC6/BE/nfdbk**	100		
Fin equiv tst	100			**Fin equiv tst**	100		
Phase 2							
KC1/B/W	42	100		KC1/B/W	13	92	100
KC1/BC/nfdbk	79	79		**KC1/BC/nfdbk**	100		
KC1/BC	88	100		KC2/B/W	50	96	
KC1/BC/nfdbk 2	100			**KC2/BD/nfdbk**	100		
BC2/B/W	42	100		**Fin equiv tst**	100		
KC2/BC/nfdbk	100						
KC3/B/W	33	92	100				
KC3/BD/nfdbk	75	75					
KC3/BD	75	100					
KC3/BD/nfdbk 2	100						
Fin equiv tst	100						
Phase 3							
KC1/B/W	8	79	100				
KC1/BC/nfdbk	75	75					
KC2/B/W	4	96					
KC2/BD/nfdbk	75	75					
Fin equiv tst	100						

Tables 11 and 12, those steps that are critical to the demonstration of emergent control by the background colors are presented in boldface. The data for each participant are described separately.

Participant AM. This participant demonstrated transformation of function in both background colors and, thus, failed KC3/C probes. After meeting criterion in KC3/BC and KC3/BC/nfdbk, she took two trial blocks to pass KC4/B/w and then passed KC4/C probes and the subsequent KC4/BC/nfdbk. She passed KC5/B/w in two blocks and then passed KC4/BD/nfdbk on the second block of trials. She took three blocks to pass KC6/B/w, passed KC6/BE/nfdbk, and then scored perfectly on the final equivalence test. Her performance in both KC5/BD/nfdbk and KC6/BE/nfdbk demonstrates contextual control over the transformation of function.

In Phase 2, AM passed KC1/B/w in two trial blocks but responded in accord with function transformation in both background colors and, thus, failed KC1/BC/nfdbk. She then moved to KC1/BC, in which she met criterion on the second block of training trials and then scored perfectly on KC1/BC/nfdbk 2. She took two trial blocks to pass KC2/B/w, scored perfectly on KC2/BC/nfdbk, and then took three blocks to pass KC3/B/w. Then, because she showed evidence of function transformation in both background colors, she failed both trial blocks in KC3/BD/nfdbk. She met criterion on the second block of the KC3/BD training trials and then scored at 100% accuracy on

Table 17

Percentage of correct responses for Participants JL, SM, and PT on each block of trials from the first set of C stimuli probes in Phases 1 and 2. Critical steps are in boldface.

JL				PT				SM			
	Block				Block				Block		
Step	1	2	3	Step	1	2	3	Step	1	2	3
Phase 1											
KC3/C probes	100			**KC3/C probes**	50			**KC3/C probes**	50		
KC3/BC/nfdbk	100			KC3/BC	92	100		KC3/BC	96		
KC4/B/w	29	46	100	KC3/BC/nfdbk	100			KC3/BC/nfdbk	100		
KC4/BD/nfdbk	100			KC4/B/w	25	100		KC4/B/w	63	92	100
KC5/B/w	54	96		**KC4/C probes**	50			**KC4/C probes**	100		
KC5/BE/nfdbk	100			KC4/BC	96			**KC4/BC/nfdbk**	100		
Fin equiv tst	100			KC4/BC/nfdbk	100			KC5/B/w	8	71	100
				KC5/B/w	50	79	100	**KC5/BD/nfdbk**	100		
				KC5/C probes	100			KC6/B/w	8	71	100
				KC5BC/nfdbk	100			**KC6/BE/nfdbk**	100		
				KC6/B/w	75	100		**Fin equiv tst**	100		
				KC6/BD/nfdbk	100						
				KC7/B/w	13	42	100				
				KC7/BE/nfdbk	96						
				Fin equiv tst	100						
Phase 2											
KC1/B/w	25	100		KC1/B/w	42	100		KC1/B/w	21	79	96
KC1/BC/nfdbk	100			**KC1/BC/nfdbk**	100			**KC1/BC/nfdbk**	100		
KC2/B/w	29	71	100	KC2/B/w	33	67	100	KC2/B/w	25	79	96
KC2/BD/nfdbk	100			**KC2/BD/nfdbk**	100			**KC2/BD/nfdbk**	100		
Fin equiv tst	100			**Fin equiv tst**	100			**Fin equiv tst**	100		

KC3/BD/nfdbk 2. She also performed at 100% accuracy on the final equivalence test.

Despite her performance in Phase 1, AM showed no evidence of generalized contextual control by the background colors over the transformation of function in Phase 2. Based on her performance on KC3/BD/nfdbk 2, however, we repeated Phase 2 with a third set of three four-member equivalence classes and a new set of key-choice training and contextual control testing procedures. These were identical to previous procedures, except that all training trials other than those with the B stimuli in the white background were omitted.

As indicated in the fifth and seventh columns of Table 14, AM met the equivalence training and testing criteria with the third set of stimuli. Her key-choice training and contextual control performance are presented in Table 16 (Phase 3, columns 5 through 8). She continued to show evidence of function transformation to the C and D stimuli in both background colors. Thus, despite showing evidence of contextual control by the background colors over function transformation in Phase 1, AM showed no evidence of generalized contextual control by the background colors in either Phases 2 or 3.

Participant JS. In Phase 1, JS failed KC3/C probes but met criterion on the first trial block in both KC3/BC and KC3/BC/nfdbk. He passed KC4/B/w in two blocks and then passed KC4/C probes and KC4/BC nfdbk on the first trial block. He required three trial blocks to pass KC5/B/w and then scored perfectly on the first block of KC5/BD/nfdbk. He passed KC6/B/w in three blocks and then again scored perfectly on KC6/BE/nfdbk and the final equivalence test. His performance in both KC5/BD/nfdbk and KC6/BE/nfdbk clearly demonstrated contextual control over the transformation of function.

In Phase 2, JS required three trial blocks to pass KC1/B/w and then scored perfectly on KC1/BC/nfdbk. He passed KC2/B/w in two blocks and again scored perfectly in KC2/BD/nfdbk and the final equivalence test. His performance in both KC1/BC/nfdbk and KC2/BD/nfdbk indicates that the background colors acquired generalized contextual control over equivalence-based function transformation.

Participant JL. This participant passed the first set of C stimuli probes in Phase 1 (KC3/C probes) and scored perfectly in the subsequent KC3/BC/nfdbk. She required three blocks to pass KC4 (KC4/B/w) and responded without error in KC4/BD/nfdbk. After learning KC5 (KC5/B/w) in two blocks, she again scored perfectly in KC5/BE/nfdbk and the final equivalence test. She not only demonstrated contextual control over function transformation but also moved through the steps of the experiment faster than any other participant.

In Phase 2, JL took two blocks to pass KC1/B/w, scored perfectly in KC1/BC/nfdbk, took three blocks to pass KC2/B/w, scored perfectly again in KC2/BD/nfdbk, and performed at 100% accuracy on the final equivalence test. Her data demonstrate generalized contextual control over function transformation.

Participant PT. This participant responded in line with function transformation in both background colors and failed the first C stimuli probes in Phase 1 (KC3/C probes). She passed KC3/BC in two blocks and KC3/BC/nfdbk on the first block. She required two blocks to learn KC4 (KC4/B/w) but failed KC4/C probes. She passed KC4/BC and KC4/BC/nfdbk on the first block of trials, took three blocks to pass KC5, and then passed KC5/C probes and KC5/BC/nfdbk on the first block. She passed KC6/B/w on the second block, scored perfectly on the first block of KC6/BD/nfdbk, took three blocks to pass KC7, and met criterion on the first block of KC7/BE/nfdbk. She then performed at 100% accuracy on the final equivalence test. She showed evidence of contextual control over function transformation in both KC6/BD/nfdbk and KC7/BE/nfdbk.

In Phase 2, PT required two blocks to learn KC1, scored perfectly on the first block of KC1/BD/nfdbk, took three blocks to pass KC2, and then scored perfectly on KC2/BE/nfdbk and the final equivalence test. These data demonstrate generalized contextual control over function transformation.

Participant SM. This participant failed the first set of C stimuli probes in Phase 1 (KC3/C probes). He then met criterion in KC3/BC and KC3/BC/nfdbk. He passed KC4 in three blocks and then passed KC4/C probes and KC4/BC/nfdbk. He took three blocks to pass KC5 and then scored perfectly on the first block of KC5/BD/nfdbk. He learned KC6 in three blocks and then scored perfectly on KC6/BE/nfdbk and the final equivalence test. Like all of the other participants in Experiment 4, SM demonstrated contextual control over function transformation in Phase 1 with both the D and E stimuli.

In Phase 2, SM took three blocks to learn both KC1 and KC2 and performed perfectly on KC1/BD/nfdbk, KC2/BE/nfdbk, and the final equivalence test. Along with every participant other than AM, SM demonstrated generalized contextual control over equivalence-based transformation of function.

Key Choices in the Blue Background

The data reported thus far indicate only whether the participants responded ''correctly'' in the red and blue backgrounds; they do not reveal actual responses. We thought it interesting to examine the actual responses, particularly in the blue background, in which any response was reinforced as long as it was different from the response in red. In particular, we asked (a) whether, within a step, participants varied their key choices in the blue background or simply stayed with the same response once it had been reinforced, and (b) whether, across relevant steps, there was a systematic pattern in key choices in the blue background.

The sheer volume of data precluded reporting key choices on every trial, so we focused on selected aspects of the data. To assess the first question, we informally examined responses in the blue background within the various steps. This revealed a very high level of consistency in responding. With few exceptions, once participants made a correct key-choice response to the C, D, or E stimuli in the blue background, they tended to persist with that response when presented with those stimuli on subsequent blue-background trials within the step. Every participant showed this pattern of responding on the vast majority of trials.

To assess whether there was a systematic pattern of responding in the blue background across relevant steps, we examined each participant's actual key choices on the last presentation in both background colors

Table 18

Participants' key choices on the last presentation in both background colors of each of the C, D, and E stimuli in the last set of relevant no-feedback trials.

	Equivalence Class 1			Equivalence Class 2			Equivalence Class 3		
		Key choice			Key choice			Key choice	
Participant	Stimulus	In red	In blue	Stimulus	In red	In blue	Stimulus	In red	In blue
AM	C1	9	4	C1	J	H	C1	Z	Z
	C2	8	3	C2	K	F	C2	B	B
	C3	5	1	C3	D	A	C3	N	N
	D1	,	C	D1	T	Q	D1	D	D
	D2	M	C	D2	E	Q	D2	;	;
	D3	.	Z	D3	Q	T	D3	K	K
	E1	K	F						
	E2	H	F						
	E3	;	F						
JS	C1	/	V	C1	J	K			
	C2	C	/	C2	K	D			
	C3	V	C	C3	D	J			
	D1	D	K	D1	T	E			
	D2	;	D	D2	E	Q			
	D3	K	;	D3	Q	T			
	E1	U	Q						
	E2	Q	O						
	E3	Q	O						
JL	C1	Q	T	C1	.	N			
	C2	T	U	C2	X	N			
	C3	U	T	C3	N	X			
	D1	3	8	D1	A	K			
	D2	8	6	D2	L	K			
	D3	6	8	D3	K	L			
	E1	B	C						
	E2	C	M						
	E3	M	C						
PT	C1	9	8	C1	,	N			
	C2	8	7	C2	N	B			
	C3	5	4	C3	B	V			
	D1	,	M	D1	S	A			
	D2	M	N	D2	J	H			
	D3	.	,	D3	L	K			
	E1	K	J						
	E2	H	G						
	E3	;	L						
SM	C1	Q	T	C1	.	X			
	C2	T	U	C2	X	N			
	C3	U	Q	C3	N	.			
	D1	3	6	D1	A	K			
	D2	8	3	D2	L	A			
	D3	6	8	D3	K	;			
	E1	B	M						
	E2	C	B						
	E3	M	C						

of each of the C, D, and E stimuli in the last set of relevant no-feedback trials in all phases of the experiment. These data are presented in Table 18. With the exception of AM, responses to the stimuli in the blue background appeared to be somewhat systematically related to their responses to the stimuli in the red background. For example, JS, JL, and SM responded to almost all of the stimuli in the blue background as they had to at least one of the stimuli in the red background. In Phase 1, JS responded to the 1, 2, and 3 stimuli of all types (C, D, and E) in the blue background as he had to the corresponding 3, 1, and 2 stimuli, respectively, in the red background. In Phase 2, JS responded to the 1, 2, and 3 stimuli of all types as he had to the corresponding 2, 3, and 1 stimuli, respectively, in the red background. In Phase 1, JL responded to both the 1 and 3 stimuli of all types in the blue background as she had to the corresponding 2 stimuli in the red background. She responded to the 2 stimuli of all types in the blue background as she had to the corresponding 3 stimuli in the red background. In Phase 2, she responded to the 1 and 2 stimuli of all types in the blue background as she had to the corresponding 3 stimuli in the red background. She responded to the 3 stimuli of all types in the blue background as she had to the corresponding 2 stimuli in the red background.

Participant SM's pattern of responding was more complex. In Phase 1, he responded to C1, C2, and C3 in the blue background as he had to C2, C3, and C1, respectively, in the red background. He responded to D1, D2, and D3, and E1, E2, and E3, in the blue background as he had to the corresponding 3, 1, and 2 stimuli, respectively, in the red background. In Phase 2, he responded to C1, C2, and C3 in the blue background as he had to C2, C3, and C1, respectively, in the red background. He responded to D1 and D2 in the blue background as he had to D3 and D1, respectively, in the red background, but his response to D3 in the blue background was novel in the sense that he had not selected that key to any previous stimulus in that step.

The response pattern of PT in the blue background was simple. She selected the key to the immediate left of the key she had selected for the corresponding stimulus in the red background.

All 5 participants in Experiment 4 demonstrated contextual control over equivalence-based transformation of function within a single equivalence class, and 4 of the 5 participants demonstrated evidence of generalized contextual control by the background colors over transformation of function within a novel equivalence class. For these 4 participants, the experimental procedures were sufficient to produce generalized contextual control over equivalence-based transformation of function.

In the blue background, in which responding in line with the transformation of function was punished, once participants made an alternative key choice to the individual stimuli, they almost always stayed with that response on subsequent presentations of those stimuli. The specific alternative key choices selected reflected strategies that varied among the participants. Although AM's selections appeared to be unsystematic, JS, JL, and SM usually responded in the blue background as they had to one of the noncorresponding stimuli in the red background. Participant PT simply selected the key that was just to the left of the key she selected in the red background.

GENERAL DISCUSSION

The data from Experiments 3 and 4 demonstrate that (a) equivalence-based transformation of stimulus functions can be brought under contextual control via multiple-exemplar training procedures, and (b) once established, contextual control can generalize to novel equivalence classes. These results provide empirical evidence for the assumption made by Sidman, Hayes, and others that the transformation of functions or the union of stimulus sets must be under contextual control. It is precisely this control that prevents all stimuli from taking on the functions of all the other stimuli to which they are related. Accordingly, the contextual control over function transformation must play a critically important role in the development and maintenance of behavioral repertoires that are based on stimulus classes and derived relational responding.

Given the importance of contextual control over function transformation for verbal organisms and the obvious verbal competence of the participants in the present study, the amount of training necessary to bring function transformation under the control of the background colors in the present experiments was somewhat surprising. For example, despite the emergence of control by the background colors on the first two tasks in Experiment 1, none of the participants showed evidence of contextual control over function transformation on the color-sorting task. Participants in Experiment 2 required between 5 and 13 repetitions of the differential reinforcement procedures before control by the background colors over responding on a novel key-choice task developed. Moreover, in Experiments 3 and 4, none of the participants (with the exception of JL in Experiment 4) moved through the steps without some retraining, and some participants required substantial retraining before they demonstrated evidence of contextual control. One participant (DW in Experiment 3) never showed evidence of contextual control, and AM (Experiment 4) failed to show evidence of generalized contextual control with a novel stimulus class. On the other hand, none of the participants failed to show evidence of equivalence-based function transformation, and virtually every error that was made in all of the experiments was the result of function transformation. At least with respect to the present procedures, equivalence-based transformation of function was a robust phenomenon, and substantial training was necessary to bring it under the control of the background colors.

The difficulty in bringing transformation of function under the control of the background colors should not be taken to imply that function transformation was not under some sort of contextual control. Matching to sample itself may have served as a powerful context for the direct transformation of function, and it may have taken a good deal of multiple-exemplar training to establish a different type of function transformation in the blue background. Of course, there may also have been a host of other variables imbedded within the present procedures that somehow impeded the development of the intended contextual control. For example, task training with the B stimuli in both background colors in Experiments 1 through 3 and conditional discrimination training in both backgrounds in Experiments 3 and 4 may have led subjects to ignore the background colors and interfered with their acquisition of contextual control. The original rationale for this training was to prevent the unintended control by the background colors over responding to the B stimuli and the formation of the equivalence classes. In hindsight, however, it probably would have been better to conduct both the training with the B stimuli and conditional discrimination training in a neutral background. Although it was beyond the scope of the present set of experiments, given the theoretical and practical importance of contextual control over function transformation, experimental analyses that attempt to identify its determinants and ways to facilitate its development seem worth conducting.

Although the present results demonstrate contextual control over the transformation of function, it is important to note that it was the type of function transformation rather than the occurrence of function transformation that came under contextual control by the background colors. Obviously, responding to the C, D, and, where relevant, E stimuli in both the red and blue backgrounds was dependent on the originally established equivalence relations or frames of coordination, and there had to be some kind of function transformation in both backgrounds or the participants could not have satisfied the contingencies in either background. The function that was indirectly acquired by these stimuli in the red background was simply what had been trained to the related B stimuli. In the blue background, however, the C, D, and E stimuli directly or indirectly occasioned the selection of a different key than was occasioned by the related B stimuli. The data in Table 18 show that these stimuli came to occasion more than simply responding differently from B. All but 1 of the participants developed idiosyncratic response patterns to satisfy the existing contingencies.

The question arises as how best to describe or explain the present results. As stated earlier, there is disagreement in the literature about how the phenomena described as the transfer or transformation of functions should be conceptualized, and this disagreement extends to more basic issues surrounding stimulus classes and stimulus equivalence. Sidman (e.g., 1986, 1990, 1992, 1994, 2000) has argued that stimulus equivalence and related phenomena are best described in mathematical set theory terms (see also Saunders & Green, 1992) and result directly from reinforcement contingencies. Hayes, Barnes, and colleagues (e.g., Barnes, 1994; Barnes & Roche, 1996; Hayes, 1994; Hayes et al., 1996; Hayes & Hayes, 1992; Hayes & Wilson, 1996), on the other hand, have contended that equivalence phenomena are instances of derived relational responding and best explained in terms of relational frame theory. Both of these theoretical positions can account for the present findings as well as most equivalence-related phenomena (Clayton & Hayes, 1999), although they would differ in their terminology, basic units of analysis, and underlying assumptions.

From Sidman's perspective (especially Sidman, 2000), the original conditional discrimination training combined with the key-choice training with the B stimuli can be seen as having created three distinct stimulus classes consisting of the relevant ambiguous figures, the corresponding keys on the computer keyboard, and the corresponding key-choice responses (because the consequences for correct and incorrect key choices were common to all classes, they did not become members of any). The resulting transformation of function was the direct result of the formation of these classes. The multiple-exemplar training served to alter the composition of the classes so that a different set of keys and selection responses replaced those that were trained with the B stimuli.

From a relational frame theory perspective, the conditional discrimination training resulted in a derived relational frame of coordination among the relevant ambiguous figures. The subsequent task training directly altered the functions of the B stimuli and, by virtue of their participation in the respective frames of coordination, the functions of the related stimuli were, thus, indirectly transformed. The multiple-exemplar training procedures established contextual control by the background colors over the specific functions that were transformed or indirectly acquired by the related stimuli. In the red background, the functions of the various stimuli were transformed in accord with the task training involving the related B stimuli, whereas in the blue background they were not. Thus, it was the transformation of functions and not class or relational frame membership that was contextually controlled by the background colors.

One finding of the present study that might weigh in favor of relational frame theory is the success of the multiple-exemplar training in establishing contextual control. As Barnes-Holmes and Barnes-Holmes (2000) describe it, multiple-exemplar training is a key process in the development of relational frames, and Sidman (1994) expressed doubts as to whether multiple-exemplar training with arbitrary stimuli can serve as the basis of equivalence. It is important to note, however, that Sidman was talking about multiple-exemplar training with arbitrary stimuli in linguistically naive individuals, which was obviously not the case in the present studies. The present experiments were not designed to test these alternative conceptual accounts of stimulus equivalence or the transformations of functions, and the results, describable from both perspectives, fail to provide evidence in favor of either one. Which account proves to be the most compelling awaits further research.

Although multiple-exemplar training was sufficient to bring equivalence-based function transformation under contextual control in Experiments 3 and 4, it is likely that additional processes like instructional control, imitation, stimulus generalization, and function transformation itself are involved in the development of contextual control of function transformation in natural contexts. In addition, the present experiments used stimulus equivalence classes that consisted entirely of two-dimensional, ambiguous, visual stimuli. Naturally occurring equivalence classes, such as those containing objects, written words, sounds, pictures, and so on, include stimuli that vary on several dimensions in addition to their visual form. It is possible that these stimulus dimensions themselves, as well as the response classes associated with them, acquire both generalized and specific contextual control over the transformation of functions. For instance, stimuli that are presented on a page in a book or magazine are usually not edible, and most edible stimuli cannot be folded into shapes or strung together with other edible stimuli to create a command or question.

As mentioned earlier, the failure to develop appropriate contextual control over function transformation can be problematic. In particular, it can lead to inappropriate or maladaptive responding to classes of stimuli. The tendency, for example, for some individuals to respond to verbal descriptions of events as they would to the events themselves has been suggested to be a factor contributing to the development of a number of clinical disorders, including anxiety, depression, and substance abuse (Dougher & Hackbert, 1994; Forsyth, 2000; Hayes & Wilson, 1993; Wilson & Blackledge, 2000; Wilson & Hayes, 2000). Given the prevalence and impact of these disorders, an experimental analysis of the relative contribution and interaction of the various processes and stimulus dimensions that play a role in the development of contextual control over the transformation of function seems to be a fruitful avenue of research for both theoretical and applied purposes.

REFERENCES

Barnes, D. (1994). Stimulus equivalence and relational frame theory. *The Psychological Record, 44,* 91–124.

Barnes, D., Brown, M., Smeets, P. M., & Roche, B. (1995). A transfer of functions and a conditional transfer of functions through equivalence relations in three to six year old children. *The Psychological Record, 45,* 405–430.

Barnes, D., & Roche, B. (1996). Stimulus equivalence and relational frame theory are fundamentally different: A reply to Saunders' commentary. *The Psychological Record, 46,* 489–507.

Barnes-Holmes, D., & Barnes-Holmes, Y. (2000). Explaining complex behavior: Two perspectives on the concept of generalized operant classes. *The Psychological Record, 50,* 251–266.

Bush, K. M., Sidman, M., & de Rose, T. (1989). Contextual control of emergent equivalence relations. *Journal of the Experimental Analysis of Behavior, 51,* 29–45.

Clayton, M. C., & Hayes, L. J. (1999). Conceptual differences in the analysis of stimulus equivalence. *The Psychological Record, 49,* 145–161.

Cumming, W. W., & Berryman, R. (1965). The complex discriminated operant: Studies on matching-to-sample and related problems. In D. J. Mostofsky (Ed.), *Stimulus generalization* (pp. 284–330). Stanford, CA: Stanford University Press.

de Rose, J. C., McIlvane, W. J., Dube, W. V., Galpin, V. C., & Stoddard, L. T. (1988). Emergent simple discrimination established by indirect relation to differential consequences. *Journal of the Experimental Analysis of Behavior, 50,* 1–20.

Dougher, M. J., Augustson, E. M., Markham, M. R., Greenway, D. E., & Wulfert, E. (1994). The transfer of respondent eliciting and extinction functions through stimulus equivalence classes. Journal of the Experimental Analysis of Behavior, 62, 331–351.

Dougher, M. J., & Hackbert, L. (1994). A behavior analytic account of depression and a case report using acceptance–based procedures. *The Behavior Analyst, 17,* 321–334.

Dougher, M. J., & Markham, M. R. (1996). Stimulus classes and the untrained acquisition of stimulus function. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 71–90). Amsterdam: North Holland.

Dymond, S., & Barnes, D. (1995). A transformation of self-discrimination response functions in accordance with the arbitrarily applicable relations of sameness, more than, and less than. *Journal of the Experimental Analysis of Behavior, 64,* 163–184.

Ellis, H. C. (1965). *The transfer of learning.* New York: Macmillan.

Forsyth, J. P. (2000). A process-oriented behavioral approach to the etiology, maintenance, and treatment of anxiety-related disorders. In M. J. Dougher (Ed.), *Clinical behavior analysis* (pp. 153–180). Reno, NV: Context Press.

Gatch, M. B., & Osborne, J. G. (1989). Transfer of contextual stimulus function via equivalence class development. *Journal of the Experimental Analysis of Behavior, 51,* 369–378.

Goldiamond, I. (1962). Perception. In A. J. Bachrach (Ed.), *Experimental foundations of clinical psychology* (pp. 280–340). New York: Wiley.

Goldiamond, I. (1966). Perception, language, and conceptualization rules. In G. Kleinmuntz (Ed.), *Problem solving* (pp. 183–224). New York: Wiley.

Green, G., Sigurdardottir, Z. G., & Saunders, R. R. (1991). The role of instructions in the transfer of ordinal functions through equivalence classes. *Journal of the Experimental Analysis of Behavior, 55,* 287–304.

Greenway, D. E., Dougher, M. J., & Wulfert, E. (1996). The transfer of conditioned reinforcement and punishment functions through stimulus equivalence classes. *The Psychological Record, 46,* 131–144.

Hayes, S. C. (1991). A relational control theory of stimulus equivalence. In L. J. Hayes & P. N. Chase (Eds.), *Dialogues on verbal behavior* (pp. 19–40). Reno, NV: Context Press.

Hayes, S. C. (1994). Relational frame theory: A functional approach to verbal behavior. In S. C. Hayes, L. J. Hayes, M. Sato, & K. Ono (Eds.), *Behavior analysis of language and cognition* (pp. 11–30). Reno, NV: Context Press.

Hayes, S. C., & Barnes, D. (1997). Analyzing derived stimulus relations requires more than the concept of stimulus class. *Journal of the Experimental Analysis of Behavior, 68,* 235–244.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (Eds.). (2001). *Relational frame theory: A post-Skinnerian account of human language and cognition.* New York: Plenum.

Hayes, S. C., Gifford, E. V., & Wilson, K. G. (1996). Stimulus classes and stimulus relations: Arbitrarily applicable relational responding as an operant. In T. Zentall & P. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 279–299). Oxford, England: Elsevier.

Hayes, S. C., & Hayes, L. J. (1992). Verbal relations and the evolution of behavior analysis. *American Psychologist, 47,* 1383–1395.

Hayes, S. C., Kohlenberg, B. K., & Hayes, L. J. (1991). The transfer of specific and general consequential functions through simple and conditional equivalence classes. *Journal of the Experimental Analysis of Behavior, 56,* 119–137.

Hayes, S. C., & Wilson, K. G. (1993). Some applied implications of a contemporary behavior analytic account of verbal behavior. *The Behavior Analyst, 16,* 283–301.

Hayes, S. C., & Wilson, K. G. (1996). Criticisms of relational frame theory: Implications for a behavior analytic account of derived stimulus relations. *The Psychological Record, 46,* 221–236.

Kennedy, C. H., & Laitinen, R. (1988). Second-order conditional control of symmetric and transitive stimulus relations: The influence of order effects. *The Psychological Record, 38,* 437–446.

Kohlenberg, B. S., Hayes, S. C., & Hayes, L. J. (1991). The transfer of contextual control over equivalence classes through equivalence classes: A possible model of social stereotyping. *Journal of the Experimental Analysis of Behavior, 56,* 505–518.

Lashley, K. S. (1938). Conditional reactions in the rat. *Journal of Psychology, 6,* 311–324.

Lawrence, D. H. (1963). The nature of a stimulus: Some relationships between learning and perception. In S. Koch (Ed.), *Psychology: A study of a science* (Vol. 5, pp. 179–212). New York: McGraw-Hill.

Lazar, R. (1977). Extending sequence-class membership with matching to sample. *Journal of the Experimental Analysis of Behavior, 27,* 381–392.

Lazar, R. M., & Kotlarchyk, B. J. (1986). Second-order control of sequence-class equivalences in children. *Behavioural Processes, 13,* 205–215.

Lynch, D. C., & Green, G. (1991). Development and crossmodal transfer of contextual control of emergent stimulus relations. *Journal of the Experimental Analysis of Behavior, 56,* 139–154.

Meehan, E. F., & Fields, L. (1995). Contextual control of new equivalence classes. *The Psychological Record, 45,* 165–182.

Osgood, C. E. (1953). *Method and theory in experimental psychology.* New York: Oxford University Press.

Roche, B., & Barnes, D. (1997). A transformation of respondently conditioned stimulus function in accordance with arbitrarily applicable relations. *Journal of the Experimental Analysis of Behavior, 67,* 275–301.

Roche, B., Barnes-Holmes, D., Smeets, P. M., Barnes-Holmes, Y., & McGeady, S. (2000). Contextual control over the derived transformation of discriminative and sexual arousal functions. *The Psychological Record, 50,* 267–291.

Saunders, R. R., & Green, G. (1992). The nonequivalence of behavioral and mathematical equivalence. *Journal of the Experimental Analysis of Behavior, 57,* 227–241.

Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units* (pp. 213–245). Hillsdale, NJ: Erlbaum.

Sidman, M. (1990). Equivalence relations: Where do they come from? In D. E. Blackman & H. Lejeune (Eds.), *Behaviour analysis in theory and practice: Contributions and controversies* (pp. 93–114). Hillsdale, NJ: Erlbaum.

Sidman, M. (1992). Equivalence relations: Some basic considerations. In S. C. Hayes & L. J. Hayes (Eds.), *Understanding verbal relations* (pp. 15–27). Reno, NV: Context Press.

Sidman, M. (1994). *Equivalence relations and behavior: A research story.* Boston: Authors Cooperative.

Sidman, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 74,* 127–146.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37,* 5–22.

Sidman, M., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior, 52,* 261–274.

Spradlin, J. E., & Saunders, R. R. (1986). The development of stimulus classes using match-to-sample procedures: Sample classification vs. comparison classification. *Analysis and Intervention in Developmental Disabilities, 6,* 41–58.

Steele, D., & Hayes, S. C. (1991). Stimulus equivalence and arbitrarily applicable relational responding. *Journal of the Experimental Analysis of Behavior, 56,* 519–555.

Stromer, R., McIlvane, W. J., & Serna, R. W. (1993). Complex stimulus control and equivalence. *The Psychological Record, 43,* 585–598.

Wilson, K. G., & Blackledge, J. T. (2000). Recent developments in the behavioral analysis of language: Making sense of clinical phenomena. In M. J. Dougher (Ed.), *Clinical behavior analysis* (pp. 27–46). Reno, NV: Context Press.

Wilson, K. G., & Hayes, S. C. (2000). Why it is crucial to understand thinking and feeling: An analysis and application to drug abuse. *The Behavior Analyst, 23,* 25–44.

Wulfert, E., & Hayes, S. C. (1988). Transfer of a conditional ordering response through conditional equivalence classes. *Journal of the Experimental Analysis of Behavior, 50,* 125–144.

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The label on the *y* axis of Figures 3 and 4 should read ''Run Rates (Responses per Minute).''