MULTIPLE FUNCTIONS IN EQUIVALENCE CLASSES

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Four experiments examined the effects of training a “drawing” response to each of three stimuli in a 5-member equivalence class. In Experiment 1 the stimuli were an arbitrary word, a shape, or a mathematical symbol. Subjects then were trained to draw a separate component of a stickman at each of the 3 stimuli. Subsequent tests for function transfer revealed a variety of novel drawings along with the original drawings. Experiment 2 modified the sequential nature of the general training and testing procedures and produced similar findings. Variability in responses decreased when Experiment 3 standardized the topographies of all the stimuli in each class. In Experiment 4 the procedure from Experiment 1 was replicated with the stimuli from Experiment 3. The finding showed that the drawings recorded in the presence of all stimuli consisted of the originally trained responses. Results from all experiments are discussed in the context of functional equivalence classes.

In recent years a variety of procedures has been employed to generate stimulus equivalence classes (e.g., Sidman & Tailby, 1982; Saunders & Green, 1999; Leader, Smeets, & Barnes, 2000). In a typical matching-to-sample procedure, for example, baseline relations are established initially between stimuli A and B and between stimuli B and C. Subsequent tests are then employed to determine the nature of untrained relations that emerge between these stimuli. These derived relations are AA, BB, and CC (reflexivity), BA and CB (symmetry), AC (transitivity), and CA (equivalence). Together these derived relations constitute the defining features of a stimulus equivalence class (Sidman & Tailby, 1982). Once established, equivalence classes can be expanded with further conditional discrimination training to produce larger classes (Saunders, Wachter, & Spradlin, 1988; Sidman, Kirk, & Wilson-Morris, 1985; Sidman & Tailby, 1982).

The wealth of research generated by this line of enquiry into complex relational responding has parallels with an earlier explosion of research...
into schedules of reinforcement (Zeiler, 1977; Keenan & Kerr, 2002). In both cases the development of sophisticated procedures to generate behaviors outpaced the development of an agreed conceptual framework for handling the findings (Tonneau, 2001). Recently, however, research into functional equivalence classes has moved beyond the practice of devising ever more variations in basic procedures by adding additional functions to standardized preparations. Typically a psychological function is trained to one member of an equivalence class to examine the effects on other members of that class (Dougher & Markham, 1996). The basic finding is that other stimuli in the equivalence class come to control the same response without direct training. Examples of functions that have been studied include rate of responding (Barnes & Keenan, 1993), discriminative stimulus control (Lazar & Kotlarchyk, 1986), instructional control (McGuigan & Keenan, 2002), conditional discriminative control (Wulfert & Hayes, 1988), contextual control (Kohlenberg, Hayes, & Hayes, 1991), and eliciting functions (Dougher, Auguston, Markham, Greenway, & Wulfert, 1994).

Generally the procedures used to date have examined the effects of adding only one function at a time, though there are some exceptions (Fields, Landon-Jimenez, Buffington, & Adams, 1995; Bones et al., 2001). However, as Bones et al. (2001) noted there is a general tendency for these studies to use the same responses to establish an equivalence class and a functional equivalence class.

The fact that the same response topography is used for the selection response in establishing equivalence relations and in the study of transfer of a psychological function may be problematic in that differentiation between equivalence classes and functional equivalence classes may be unclear (cf. Sidman, 1994; p. 91).

Barnes, Browne, Smeets, and Roche (1995) addressed this issue by using two separate behaviors, clapping and waving. In their study 3- to 6-year-old children were initially trained to establish two three-member equivalence classes (A1, B1, C1, and A2, B2, C2). A clapping response was then reinforced in the presence of B1, and a waving response was reinforced in the presence of B2. Subsequent tests for transfer of function revealed that subjects clapped in the presence of C1 and waved in the presence of C2. Next the procedure was modified so that clapping was reinforced at B1 in the presence of the spoken word “yellow,” while waving was reinforced at B1 in the presence of the spoken word “blue.” Conversely, in the presence of B2, waving was reinforced in the presence of the spoken word “yellow,” and clapping was reinforced in the presence of the spoken word “blue.” In a subsequent test for transfer of functions, during which a visual representation of the contextual stimuli were presented, the results showed that some subjects' responses in the presence of C1 and C2 were conditional on the color of the background on which each stimulus was presented (YELLOW/C1–Clapping, BLUE/C1–Waving, YELLOW/C2–Waving, BLUE/C2–Clapping).

These results demonstrate that stimuli within equivalence classes can evoke different topographical responses conditional on context. Bones et al. (2001), however, argued that these findings may have been influenced by the use of incompatible behaviors and by the fact that both behaviors were trained in the presence of the same stimulus (B1). In the study by Bones et al. functional equivalence classes were established using “clapping hands” and “stamping feet.” Thus, in one experiment after adult subjects were trained
to clap their hands in the presence of A1, two three-member equivalence classes (A1, B1, C1, and A2, B2, C2) were established. As expected, subsequent tests for transfer of function revealed clapping at both B1 and C1. In the next part of the study, a new response (stamping feet) was trained at C1. All adult subjects now stamped their feet at A1, B1, and C1. When retrained to clap their hands at A1 all adult subjects again clapped in the presence of A1, B1, and C1. This study showed that although the responses of clapping and stamping were not incompatible and thus could have occurred together, there was no evidence of these separate responses merging in the presence of any of the stimuli. In a second similar experiment using children, Bones et al. (2001) found limited evidence that separate repertoires, such as clapping hands and stamping feet, would merge in a functional equivalence class so that subjects would perform both behaviors at the same time in the presence of certain stimuli. It was unclear whether this latter finding was something specific to children or whether specific aspects of the procedure were responsible. Compared with the study by Barnes et al. (1995), though, the findings do raise the possibility that differential findings across studies are traceable, at least in part, to the ways in which the functional equivalence classes are established (see also Fields et al., 1995) and that the compatibility of different response topographies also has an effect.

Taking these issues into consideration it would be worthwhile extending the analysis of functional equivalence classes by further examining whether the manner in which multiple responses are trained influences the way in which they interact. More specifically, can we devise procedures that facilitate the merging of repertoires and would these procedures help us identify rules determining how they merge? To this end we decided to use a drawing response, as it would be relatively easy to train, it was sufficiently different from the selection response, and it was assumed that any merging of repertoires, such as that found in Bones et al. (2001), would be traceable to identifiable components. However, once we decided on this response and on the methodology, we were unable to draw on previous literature to help us anticipate the expected outcomes. Quite simply, there was nothing in the literature that had addressed the questions we decided to address. For example, there was nothing to help us determine the effects of adding one function at a time compared with adding three functions at the same time. If three separate functions were added to A1, C1, and E1, respectively, from the equivalence class A1, B1, C1, D1, and E1, what then would happen at B1 and D1? Would all the responses appear at B1 and D1, or would something else occur? Might the behaviors trained at A1 and C1 control responding at B1, while behaviors trained at C1 and E1 control responding at D1? In the following experiments, then, two five-member equivalence classes were established by using a linear series matching-to-sample format (A1, B1, C1, D1, E1 and A2, B2, C2, D2, E2). The stimuli used, similar to the variations in stimuli employed by Bones et al. (1995), consisted of an arbitrary word, a shape, or a mathematical symbol. Distinct “drawing” responses that were trained to each of three stimuli within one class were the separate components of a stickman at A1 (head), C1 (torso and arms), and E1 (legs; see Figure 1). The members of each class were then examined in relation to the stability of the trained functions, the transfer of functions to the other members of the class, and the possible blending of these trained functions so that a completed stickman might appear at B1 and D1.
Subjects

Five adult college students (4 male and 1 female) volunteered to take part in the study. All subjects were aged between 18 and 25 years old, and all were native English speakers with no prior knowledge of the subject area of research. Participation was voluntary, and subjects were informed that their names would be entered into a raffle for a prize of £20 on completion of the research. Subjects were free to terminate their participation at any time.

Apparatus and Setting

Experimental sessions were conducted in two separate experimental rooms situated in the School of Psychology at the University of Ulster, Coleraine. In the first laboratory, subjects were seated in front of two PowerMac 4400/160 computers with 14-inch monitors. Equivalence classes were established using software specifically designed for equivalence research that trained all the relevant stimulus relations. Each on-screen stimulus, consisting of an arbitrary word, a shape, or a mathematical symbol, was 7.5 cm × 7.5 cm in size and was labeled alphanumerically in relation to the equivalence class in which it was attributed and its position within that class. These labels were used by the experimenter only and were not available to the subjects. The classes and their alphanumerical labels were as follows: Class 1—A1-ZID, B1-FAP, C1-WOL, D1-E, E1-E; Class 2—A2-VEK, B2-YIM, C2-GOC, D2-E, E2-E. A specially

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Figure 1. Responses obtained during tests for transfer of function for Subject 4 during test for function transfer with stimuli from Class 1 (left panel) and Class 2 (right panel).
designed paper A4 (21.0 cm × 29.7 cm) folder that consisted of presentations of all possible matching-to-sample stimulus combinations for symmetry and equivalence in two five-member classes (100 presentations in all) was used to test for equivalence class formation. A modified A4 sheet of paper was also used for recording the responses in the symmetry and equivalence tests. A 1.5 m × 1 m table was also situated at the far end of the room with a chair placed at each narrow end.

In an adjoining experimental room a 1.5 m × 1 m table was situated in the middle of the room with a chair at each narrow end of the table. On the middle of this table, visually partitioning one side from the other was a 0.7 m × 0.7 m cardboard partition that was held in place by two customized wooden stands that allowed a 5 cm gap between it and the table. On one side of this partition were placed six 7.5 cm × 7.5 cm stimulus cards (each representing printed versions of stimuli A1, C1, E1 (Class 1) and A2, C2, E2 (Class 2), three 7.5 cm × 7.5 cm “function” cards containing pictures of the three separate components of a stickman, three separate stacks of drawing sheets (two containing 60 sheets and one containing 100), and a pen. Parallel to the right-hand side of the partition was a 0.5 m × 0.3 m cardboard box with a 20 cm × 10 cm hole cut into one side. Subjects were required to post all responses in this box.

Procedure

An overview of the procedure for Experiment 1 can be seen in Table 1. All subjects were trained and tested on an individual basis with each experiment ranging from 1 to 2 hours in duration. During this time all instructions appeared on a computer screen or on a sheet provided by the experimenter. During each procedure the experimenter was present at all times.

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<th>Procedure</th>
<th>Establishment of two five-member equivalence classes</th>
<th>Training of functions</th>
<th>Test 1 for transfer of functions</th>
<th>Test 2 for constancy of original functions</th>
<th>Retest for the establishment of two five-member equivalence classes</th>
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Training and testing of A1-A2 and B1-B2. Prior to each subject entering the room, two computers were set up to train two separate three-member equivalence classes. Once each subject arrived they were seated in front of one of the computers and were asked to familiarize themselves with the instructions that were displayed on the computer’s monitor. The written instructions were as follows:

Thank you for taking part in this experiment. Your instructions are very simple. In a moment you will see three squares (with either a word, a shape, or a symbol, in each square). One of these squares will be at the top of the screen and two will be at the bottom of the screen. Your task is to look at the square at the top of the screen and then choose one of the squares at the bottom of the screen. You choose by moving the “hand” to that square and clicking ONCE. You will be told if your selection is correct or incorrect. Click once on “Start” when you are ready to begin.
Subjects then were asked if they understood the instructions. If they did, then the experiment proceeded. Once a subject pressed the start button, the instructional message was replaced with three stimuli situated in an isosceles triangle formation. In each trial the sample stimulus (Sa) and correct comparison stimulus (Co+) from one class was presented along with a comparison (Co−) from the other class. The sample stimulus was situated at the top-middle of the screen, and the two comparison stimuli were located at the corners of the base of the screen. Once a selection was made by clicking the mouse button on one of the stimuli, either “CORRECT” or “INCORRECT” appeared on the screen, accompanied by either a “joyous” tune or “raspberry” sound, respectively.

All responses involving the selection of comparison stimulus B1 in the presence of sample stimulus A1 produced the message “CORRECT” on the computer screen, as did choosing comparison stimulus B2 in the presence of sample stimulus A2. This training was segmented into presentations of two different trial blocks of Sa, Co+, and Co− stimuli, with each trial being presented 20 times semirandomly throughout each block. Each trial block consisted of equal presentations involving the appropriate selection of comparison stimulus B1 in the presence of sample stimulus A1, and comparison stimulus B2 in the presence of sample stimulus A2. The positions of both B1 and B2 were counterbalanced throughout each block to eliminate any position bias. The next stage was initiated if 100% correct responding was achieved over a period of 8 trials at any stage after the 32nd trial and before the 80th trial. If 100% mastery was not achieved before the 80th trial, then this stage was repeated until all trials occasioned 100% correct responding. If mastery was not reached after five attempts, the session was terminated and the subject was asked to return on another day.

Training and testing of B1-C1 and B2-C2. Training relations between B1-C1 and B2-C2 involved a match-to-sample procedure identical to that for A1-B1 and A2-B2. The initial instructions that were presented in the training and testing of A1-B1 and A2-B2 were not presented here.

Training and testing of C1-D1, D1-E1, C2-D2, and E1-E2. At this point, each subject was moved to another computer located in the same room. Training relations between stimuli C1-D1, C2-D2, D1-E1, and D2-E2 involved a procedure identical to training and testing A1-B1-C2 and A2-B2-C2. While moving from computer to computer slightly fragmented the procedure, limitations in the computer software, which allowed for the training and testing of only two three-member equivalence classes, prevented these relations being trained on the original computer.

Equivalence testing. After all relations between stimuli had been trained, each subject was then moved to the table at the far end of the room and given the following instructions:

Along with these instructions you will receive a folder containing a number of pages. On each page you will see three squares (with either a word, a shape, or a symbol, in each square), one square at the top of the page and two squares at the bottom of the page. You may respond by looking at the top square and then selecting one of the bottom two squares. This may be achieved by placing a single finger on one of the bottom squares. You will not be told if your selection is correct or incorrect. Once this has been done
you may then proceed to the next page in the book where the same procedure will continue until no pages remain.

Each subject was given a paper folder containing all possible combinations of the relevant stimuli needed to test for symmetry and equivalence in the two prospective five-member classes (100 presentations overall). This was achieved through the presentation of twenty different trial blocks of Sa, Co+, and Co− stimuli, with each trial being presented five times semirandomly throughout each block. Limitations in the computer software, which allowed for the testing of only two three-member equivalence classes, prevented these relations being tested on the original computer. Each combination was presented in a fashion similar to the equivalence training on the computer. The positions of all the comparison stimuli were counterbalanced throughout each block to eliminate any position bias. During this procedure an experimental assistant, who was naive to the appropriate responses, recorded each subject’s responses. This was implemented to eliminate any possible experimenter cueing. If 95% appropriate responding in relation to the establishment of two five-member equivalence classes containing A1, B1, C1, D1, and E1 (Class 1) and A2, B2, C2, D2, and E2 (Class 2) was achieved, then the training of functions was initiated. If this criterion was not met then the original relations presented in the training and testing of the equivalence classes were retrained, using the same computer, until 95% appropriate responding was achieved during testing. During the retraining phase eight different trial blocks of Sa, Co+, and Co− stimuli were presented, with each trial being presented four times semirandomly throughout each block. Subsequent to this retraining, subjects were once again tested for the combined properties of symmetry and equivalence among the two prospective five-member classes. If subjects were not responding 95% accurately in the two prospective five-member classes after repeating the retraining phase five times, then the experiment was terminated and subjects were asked to return on another day.

**Training of functions.** At this point, due to the requirement for each participant to draw in the presence of various stimuli, a pen-and-paper methodology was introduced. Each subject was moved to the adjoining experimental room and given the following instructions:

Along with these instructions you will have been issued with a pen. You may keep this pen with you for the remainder of the experiment. In a moment I’m going to show you six stimuli. Beside three of these stimuli will be a picture. Beside the other three stimuli no picture will be shown. Each stimulus will be passed under the partition alongside either a picture or no picture. After 10 seconds these stimuli will be removed and the next stimulus will be presented to you in the same manner. You have to remember which stimulus is associated with which picture. You must also remember which stimuli have no picture with them. I will test you by presenting pages containing each stimulus a number of times in a random manner. These pages will be individually passed to you under the partition. Please read the instructions carefully on the first page. These instructions will then be repeated on each page in this phase of the study.
Your task is two-fold. In the presence of the stimuli with which a picture was shown your task is to draw the picture that goes with that particular stimulus on one of the pages provided. When you have finished each picture you may place it in the box provided. In the presence of the stimuli with which no picture was shown, your task is to refrain from drawing on one of the pages provided. The blank page may then be placed in the box. Initially you will receive feedback on whether your choice was correct or incorrect, although further on in the procedure this feedback will be removed. The next page will then be presented in the same manner.

Once participants read these instructions, they were passed back under the partition to the experimenter. The experimenter then passed the stimulus A1 under the partition alongside the function card containing the “bust” of the stickman (see the responses drawn in the presence of A1, C1, and E1 in Figure 1, Blocks 1–10, for representations of the trained “bust,” “body and arms,” and “legs,” respectively). On no occasion during the experiment (other than debriefing) were any of the pictures presented to the subject identified as separate components of a stickman. After 10 seconds stimulus A1 and the function card were removed and were then replaced by stimulus A2 with no picture. This procedure was repeated sequentially in the following order for each stimulus: C1, C2, E1, and E2. The function trained with the remaining stimuli is presented in brackets: C1 (body and arms of stickman), C2 (no picture), E1 (legs of stickman), E2 (no picture).

Following these presentations, a single sheet of paper was passed under the partition toward the subject. At the top of this sheet was a replication of either stimulus A1, A2, C1, C2, E1, or E2. Under this stimulus was a sectioned area called the “Drawing area” in which there was space for each subject to respond. On the right-hand side of the sheet were the following instructions:

Look at the stimulus situated above the drawing area and then respond. To respond you can either draw in the space provided OR you can respond by not drawing in the space provided. When you have made your response then place the sheet in the box provided.

A total of 60 sheets were presented in this phase. Each trial block consisted of all stimuli being presented once. Overall, ten trial blocks were carried out and all stimuli were presented in a semirandom order across trials.

The experimenter, who had visual access to the sheets through the hole at the back of the box, assessed each subject’s responses. Verbal feedback consisting of either “correct” for an appropriate response or “incorrect” for an inappropriate response was given initially. After 48 correct responses in a row, this feedback was removed. If 100% appropriate responding in relation to the correct picture being drawn in the space under stimuli A1, C1, and E1, and no picture being drawn in the space under A2, C2, and E2, was achieved in both reinforcement and extinction conditions (60 correct responses in total), then the test for function transfer was initiated. If this 100% criterion was not achieved, then a replication of the training of the functions was repeated until responding was 100% correct. If subjects were not responding 100% accurately in the two prospective five-member classes after repeating
the retraining phase five times, then the experiment was terminated and
subjects were asked to return on another day.

*Test for function transfer.* The following instructions were given to each
subject.

After you have finished reading these instructions a single
page will be passed under the partition towards you. Please
read the instructions carefully on page 1. These instructions
will then be repeated on each page in this phase of the study.
Once you have responded you may then place the page in the
box provided. The next page will then be presented to you in
the same manner.

At this point a systematic replication of the sheets used in the training
of the “draw” and “no draw” functions was administered individually to each
subject (with the addition of extra sheets containing stimuli B1, D1, B2, and
D2). A total of 100 sheets were presented in this phase across 10 trial blocks.
Each trial block consisted of all stimuli being presented once. Once all the
sheets had been presented, the next stage was initiated.

*Test for original functions.* The following instructions were presented to
each subject:

Next you will be shown the six cards in the presence of which you
were originally trained to either draw, or refrain from drawing.
Your task in the presence of each stimulus is to respond in the
way that you were *originally trained*. After each response please
place the sheet in the box provided.

At this point the sheets used in the training and testing of the
functions were administered individually to each subject (excluding
stimuli B1, D1, B2, and D2). A total of 60 sheets was presented in this
phase. Each trial consisted of all stimuli being presented once. The order
in which the stimuli were presented varied on each trial. Overall 10 trials
were carried out.

*Equivalence retest.* Finally a replication of the equivalence testing was
carried out. Once all the relations for symmetry and equivalence had
been tested, each subject was informed that the experiment was now
officially finished and that any queries that they may have could now be
answered.

**Results**

Prior to the training and testing of the functions, all five subjects met the 95%
testing criterion for the establishment of two five-member equivalence classes.

**Results for Functions Test**

Only S4 continued to emit the responses trained to occur in the
presence of the A1, C1, and E1 stimuli during all test trials. S4 was also
the only subject that drew in the presence of all the stimuli in Class
1 while refraining from drawing in the presence of all the stimuli in
Class 2. At B1 and D1 there were a number of response variations that
sometimes included all (at B1) or one of the originally trained functions
(at D1). The completed drawing of a stickman was also recorded at B1 in
Trials 9 and 10 (see Figure 1). This figure and all subsequent figures are provided to acquaint the reader with the range of behavioral topographies that were produced in each study. In terms of the original functions S2 responded similarly but refrained from drawing in the presence of some of the stimuli in Class 1 and actually drew in the presence of some of the stimuli in Class 2. Responses at B1 and D1 also evidenced function transfer in that they consisted mainly of the originally trained function at C1, although in the presence of D1 in Trials 7–10 this was replaced by the trained function at E1 (Figure 2). For 3 of the 5 subjects (S1, S3, and S5), either one or all of the originally trained functions were replaced by novel responses in both Classes 1 and 2 during the function transfer test (Figures 3 and 4). These responses consisted of representations of the actual stimuli comprising the equivalence classes. On some occasions for S5, responses included a mixture of representations of stimuli from both Classes 1 and 2.

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**Figure 2.** Responses obtained during tests for transfer of function for Subject 2 during test for function transfer with stimuli from Class 1 (left panel) and Class 2 (right panel).

In the test for original functions all subjects responded by drawing the originally trained function in the presence of the stimulus in which it was initially trained. In the equivalence retest, all subjects responded 100% accurately in the tests for symmetry and equivalence among the stimuli in Classes 1 and 2.

**Discussion**

The purpose of Experiment 1 was to establish two five-member equivalence classes (A1, B1, C1, D1, E1 and A2, B2, C2, D2, E2). A distinctly separate drawing function was then trained to three members of Class 1 (A1, C1, and E1), and a no-draw function was trained to three separate members of Class 2 (A2, C2, and E2). The subsequent effect on all members of both classes was examined.
MULTIPLE FUNCTIONS IN EQUIVALENCE CLASSES

Figure 3. Responses obtained during tests for transfer of function for Subject 1 during test for function transfer with stimuli from Class 1 (left panel) and Class 2 (right panel).

The design of the procedure, and the nature of the functions that were trained, were specifically chosen to optimize identification and categorization of any mergence of these functions. The results showed that the completed drawing of a stickman was recorded for 1 subject (S4). Apart from this single instance, however, the results generally were rather surprising in that they consisted of drawings representing the actual stimuli that comprised the stimuli within Class 1 and Class 2 rather than the actual trained functions.
Stability of Trained Functions

Once a single operant function has been explicitly trained to a member of an equivalence class, subsequent tests usually demonstrate that this function is recorded in the presence of other members of that particular class (Barnes & Keenan, 1993; Lazar & Kotlarchyk, 1986; Wulfert & Hayes, 1988; Kohlenberg, Hayes & Hayes, 1991; Dougher, Auguston, Markham, Greenway & Wulfert, 1994). Because this finding has been so consistent it has not been necessary to inquire about the stability of trained functions. The function either appears at other stimuli in the class or doesn’t. For 4 of the 5 subjects during the test for function transfer, either one or all of the originally trained functions were replaced by a novel response (S1, S2, S3, and S5). These responses included either representations of actual stimuli comprising the equivalence classes (S3, S4, and S5) or a replication of a function that was trained to another stimulus (see Figure 2, Trial 2 at A1). Although the original functions disappeared on many trials in the function transfer test, they reappeared intact for all subjects in the test for original functions. This is a remarkable demonstration of the sensitivity of this drawing response to subtle differences in instructions in each condition.

Function Transfer

The demonstration of function transfer has been suggested as being an unequivocal test for functional equivalence (Dougher & Markham, 1994). In the current experiments the procedural variation of adding a different function to three separate stimuli within a single equivalence class (A1, C1, and E1) raises some interesting issues regarding the relativity of functional equivalence to particular functions. First, it is difficult to decide how the class of stimuli is to be described. That drawing was confined to one class but not the other indicates that that class was indeed a functional class. But should it be described as a functional equivalence class? Most studies addressing this issue have worked within a context where the appearance of identical functions in an equivalence class justified the use of the term “functional equivalence class.” Here, however, function transfer undoubtedly occurred, but in many cases the stimuli in that class controlled different topographies of the same function. What’s more, on some occasions the nature of the drawing seems to have been influenced by the nature of the stimuli. This unusual finding highlights both the value and the difficulties of using a response like drawing in this context. Had we used a different response, like clapping, for instance, we would not have uncovered the possibility of the kinds of interactions observed here. Quite simply, you cannot clap a ““ or a “£.”

In conclusion, the results from Experiment 1 raise a number of issues regarding the nature of the stability, mergence, and transfer of multiple functions within equivalence classes. However, the variability in performance across subjects, while interesting in and of itself (cf. Keenan, 1999) is cause for concern. In the next experiments we examined whether it was possible to attain greater control over performance.

Experiment 2

In this experiment the general procedures were modified such that the training and testing of the required responses occurred across sessions in a
sequential manner; the responses to A1 and A2 were trained first, and then all stimuli were tested subsequently; similarly, responses to C1 and C2, and then to E1 and E2, were trained and tested.

Method

Subjects

Five adult college students (1 male and 4 female) volunteered to take part in the study. All subjects were aged between 18 and 45 years old, and all were native English speakers with no prior knowledge of the subject area of research. Participation was voluntary, and subjects were informed that their names would be entered into a raffle for a prize of £20 on completion of the research. Subjects were free to terminate their participation at any time.

Apparatus and Setting

The general apparatus and settings were the same as those used in Experiment 1 with the following exceptions: The three separate stacks of drawing sheets used in experiment 1 (two containing 60 sheets and one containing 100) were now replaced by seven stacks of drawing sheets (three containing 20 sheets, three containing 100 sheets, and one containing 60 sheets).

Procedure

Equivalence training and testing. The materials and procedures were identical to those used in the equivalence training and testing in Experiment 1. In this phase the prerequisites for two equivalence classes (A1-B1-C1, D1, E1 and A2-B2-C2, D2, E2) were trained and tested.

Training of A1 and A2 functions. At this point, due to the requirement for each participant to draw in the presence of various stimuli, a pen and paper methodology was introduced. Each subject was moved to the adjoining experimental room and given instructions almost identical to the training and testing of functions in the corresponding stage in experiment 1. This time, however, instead of training and testing the functions at A1, A2, B1, B2, C1, and C2, only the functions at A1 and A2 were trained and tested.

Once read, the instructions outlining the procedure involved in the training of the functions were passed back under the partition to the experimenter. The experimenter then passed the stimulus A1 under the partition alongside the function card containing the “bust” of the stickman. After 10 seconds the stimulus and function card were removed and then replaced by stimulus A2 with no picture.

After these presentations a single sheet of paper was passed under the partition toward the subject. At the top of this sheet was a replication of either stimulus A1 or stimulus A2. Under this stimulus was a sectioned area called the “Drawing area” in which there was space for each subject to respond. On the right-hand side of the sheet were the following instructions:

Look at the stimulus situated above the drawing area and then respond. To respond you can either draw in the space provided OR you can respond by not drawing in the space provided. When
you have made your response then place the sheet in the box provided.

A total of 20 sheets were presented in this phase across two trial blocks. Each trial block consisted of all stimuli being presented once. Overall, 20 trials were carried out and all stimuli were presented in a semirandom order across trials.

The experimenter, who had visual access to the sheets through the hole at the back of the box, assessed each subject's responses. Verbal feedback, consisting of either "correct" for an appropriate response or "incorrect" for an inappropriate response, was given initially. After 14 correct responses in a row, this feedback was removed. If 100% appropriate responding in relation to the correct picture being drawn in the space under stimulus A1 and no picture being drawn in the space under stimulus A2 was achieved in both reinforcement and extinction conditions (20 correct responses in total), then the test for function transfer 1 was initiated. If this 100% criterion was not achieved, then the training of the A1 and A2 functions was repeated until responding was 100% correct.

**Test for function transfer 1.** Instructions identical to that given in the test for function transfer in Experiment 1 were administered. At this point a systematic replication of the sheets used in the training of the functions was administered individually to each subject (with the addition of extra sheets containing stimuli B1, D1, E1, B2, D2, and E2). One hundred sheets were presented in this phase across 10 trial blocks. Each trial block consisted of all stimuli being presented once. Once all the sheets had been presented, the next stage was initiated.

**Training of C1 and C2 functions.** The procedures were similar to those used in training of the A1 and A2 functions, with the exception that the stimuli to which functions were trained were now C1 and C2. The functions trained were to draw the "torso" of a stickman at C1 and to refrain from drawing at C2.

**Test for function transfer 2.** The procedure was identical to that for the test of transfer of functions 1.

**Training of E1 and E2 functions.** The procedures were similar to those used in training and testing the A1, A2, C1, and C2 functions, with the exception that the stimuli to which functions were trained were now E1 and E2. The functions trained were to draw the "legs" of a stickman at E1 and to refrain from drawing at E2.

**Test of function transfer 3.** The procedure was identical to that for the test of transfer of functions 1 and 2.

**Test of original functions.** Instructions identical to that in the corresponding stage in Experiment 1 were presented. Subsequently the sheets used in the training of the functions were administered individually to each subject (excluding stimuli B1, D1, B2, and D2). Sixty sheets were presented in this phase. Each block of trials consisted of all stimuli being presented once. The order in which the stimuli were presented varied on each trial. Overall, 10 blocks of trials were carried out.

**Equivalence retest.** Finally a replication of the equivalence testing was tested. Once all the relations for symmetry and equivalence had been carried out, each subject was informed that the experiment was now officially finished and that any queries that they may have could now be answered.


Prior to the training and testing of the functions, all 5 subjects met the 95% testing criterion for the establishment of two five-member equivalence classes.

**Results for Functions Test**

One subject (S9) responded in accordance with the originally trained responses across all stimuli and trials (Figure 5). Responding for other subjects varied unsystematically and included representations of the stimuli that comprised both classes; 1 subject (S10) occasionally reproduced combinations of the training stimuli (Figures 6 and 7).

**Figure 5.** Responses obtained during tests for transfer of function for Subject 9 with stimuli from Class 1 during test for function transfer 1 (left panel), test for function transfer 2 (middle panel), and test for function transfer 3 (right panel).

**Figure 6.** Responses obtained during tests for transfer of function for Subject 10 with stimuli from Class 1 during test for function transfer 1 (left panel), test for function transfer 2 (middle panel), and test for function transfer 3 (right panel).
In the test for original functions, all subjects responded by drawing the originally trained function in the presence of the stimulus in which it was initially trained. In the equivalence retest, all subjects responded 100% accurately in the tests for symmetry and equivalence among the stimuli in Classes 1 and 2.

These findings are similar to those reported in experiment 1. The only conclusion to be drawn is that some other aspect of the procedure apart from simultaneous or sequential training of multiple functions is responsible.

Experiment 3

One possible explanation for the findings in experiments 1 and 2 is the nature of the stimuli comprising the classes. For instance, the inclusion of the square and octagon within the equivalence classes (symbols that are traditionally drawn), coupled with the trained drawing function at various stimuli within the class, may act as a cue for a generalized “drawing” response representing the members within an equivalence class.

In this next experiment the stimuli D1 (□), E1 (£), D2 (●), and E2 (%) were replaced by arbitrary three-letter words so that the topography of all the stimuli in each class was standardized.

Method

Subjects

Five adult college students (3 male and 2 female) volunteered to take part in the study. All subjects were aged between 18 and 32 years old, and all were native English speakers with no prior knowledge of the subject area of research. Participation was voluntary, and subjects were informed that their names would be entered into a raffle for a prize of £20 on completion of the research. Subjects were free to terminate their participation at any time.

Apparatus and Setting

The general apparatus and settings were the same as those used in...
Experiment 2 with the following exceptions: The stimuli at D1, E1, D2, and E2 throughout the experiment were replaced by arbitrary three-letter words so that the topography of all the stimuli in each class was standardized. These stimuli were now D1-DEX, E1-WOL, D2-RAH and E2-MUJ.

Procedure
The materials, other than the change in stimulus topography at D1, E1, D2, and E2, and procedures were identical to those used in Experiment 2.

Results and Discussion
Prior to the training and testing of the functions, all 5 subjects met the 95% testing criterion for the establishment of two five-member equivalence classes.

Results for Functions Test
Across all subjects there was consistency in the responses drawn at each stage. Thus, all subjects produced the responses trained respectively to the A, C, and E stimuli across most trial blocks. However, in each testing stage there was only one response, the one trained at that stage. For example, only a bust was drawn at all stimuli in the test for function transfer 1, only the torso was drawn at all stimuli in the test for function transfer 2, and only legs were drawn at all stimuli in the test for function transfer 3. This was so for all subjects, though on a couple of trials exceptions were found; S15 drew a completed stickman in Block 4 (transfer test 1) in the presence of A1; S11 drew a number of arrows in the shape of the original function in Block 6 (transfer test 2) in the presence of B1 (Figure 8); S11 also drew a blend of both arms and legs of the stickman in Block 6 (transfer test 3) in the presence of C1, and he drew a wiggly line in the shape of the original function in Block 7 (transfer test 3) in the presence of E1 (see Figure 8). Also, in the presence of the stimuli from Class 2, each subject refrained from drawing across most trial blocks.

Figure 8. Responses obtained during tests for transfer of function for Subject 11 with stimuli from Class 1 during test for function transfer 1 (left panel), test for function transfer 2 (middle panel), and test for function transfer 3 (right panel).

There were, however, exceptions; S11 drew an unidentifiable object at E2 (Block 7), a face at B2 (Block 8), an unidentifiable drawing at C2 (Block 8), and
a face at D2 (Block9), all in transfer test 3 (Figure 9). S13 also responded in the presence of certain stimuli from Class 2; at B2 (transfer test 1) the originally trained function at A1 (bust of a stickman) was drawn across the first 5 trial blocks; at C2 (transfer test 2) the originally trained function at C1 (arms and legs of a stickman) was drawn across trial blocks 4 and 5.

Figure 9. Responses obtained during tests for transfer of function for Subject 11 with stimuli from Class 2 during test for function transfer 3.

In the test for original functions, all subjects responded by drawing the originally trained function in the presence of the stimulus in which it was initially trained. In the equivalence retest, all subjects responded 100% accurately in the tests for symmetry and equivalence among the stimuli in Classes 1 and 2.

The purpose of experiment 3 was to replace the geometric shapes and mathematical symbols that comprised the D and E stimuli in Class 1 and 2 with arbitrary three-letter words so that the topography of all the stimuli in each class was standardized. For the first time it was found that, apart from a couple of trials, drawings across all stimuli for all subjects mostly consisted of the original drawings.

Experiment 4

The findings from experiment 3 indicate that we now have control over the drawing response. An obvious next step is to return to our original procedure in experiment 1 to examine the effects of adding all functions on simultaneously. In Experiment 4 the procedure from Experiment 1 was therefore replicated by using the stimuli from Experiment 3.

Method

Subjects

Five adult college students (2 male and 3 female) volunteered to take part in the study. All subjects were aged between 18 and 29 years old, and all were native English speakers with no prior knowledge of the subject area of research. Participation was voluntary, and subjects were informed that their names would be entered into a raffle for a prize of £20 on completion of the research. Subjects were free to terminate their participation at any time.
Apparatus and Setting

The general apparatus and settings were the same as those used in Experiment 1 with the following exceptions: The stimuli at D1, E1, D2, and E2 throughout the experiment were replaced with arbitrary three-letter words so that the topography of all the stimuli in each class was standardized. These stimuli were now D1-DEX, E1-WOL, D2-RAH, and E2-MUJ.

Procedure

The materials, other than the change in stimulus topography at D1, E1, D2, and E2, and procedures were identical to those used in Experiment 1.

Results and Discussion

Prior to the training and testing of the functions, all 5 subjects met the 95% testing criterion for the establishment of two five-member equivalence classes.

Results for Functions Test

For 3 subjects (S16, S17, and S18) responses to A1, C1, and E1 consisted of the originally trained response trained to the respective stimulus (Figure 10). There were no drawing responses in the presence of B1 and D1. Also, these subjects, along with S19 and S20, refrained from drawing in the presence of all stimuli in Class 2. S20’s responding was similar to that observed for S16, S17, and S18 except that responding also occurred in the presence of B1 and D1. During all presentations of B1, the response associated with A1 was produced, while during all presentations of D1, the responses associated with C1 (blocks 1–3) and E1 (blocks 4–10) were produced (Figure 11). Responding produced by S19 was similar to that of the other subjects at A1, C1, and E1. However, during B1 and D1, combinations of responses appeared after Block 2. At B1 his responses consisted of the drawings associated with A1 and C1 placed side by side, whereas at D1 his responses consisted of the drawings associated with C1 and E1 placed side by side (Figure 12).

In the test for original functions all subjects responded by drawing the originally trained function in the presence of the stimulus in which it was initially trained. In the equivalence retest, all subjects responded 100% accurately in the tests for symmetry and equivalence among the stimuli in Classes 1 and 2.

The purpose of Experiment 4, given that control over the drawing response was achieved with the stimuli in Experiment 3, was to return to our original procedure in Experiment 1 to examine the effects of adding all functions on simultaneously. The results are in marked contrast to the findings in Experiment 1. In the present experiment, each subject responded in the presence of A1, C1, and E1 by producing the drawings originally trained in their presence. In the presence of A2, C2, and E2, each subject responded by refraining from drawing. In the presence of the remaining stimuli in Class 2 (B2 and D2), all subjects also refrained from drawing across all trial blocks.
More surprising, however, was the finding that for 3 of the 5 subjects (S16, 17, and 18), a no-drawing response was recorded in the presence of stimuli from Class 1 (B1 and D1) across all 10 trial blocks. For the remaining 2 subjects (S19 and S20), drawing responses at B1 and D1 consisted of either 1 (S20) or 2 (S19) of the originally trained functions recorded at B1 and D1. In keeping with the majority of the findings from the previous experiments, the blending of these functions was not evidenced on any occasion.
General Discussion

In the present experiments two five-member equivalence classes were established with the use of a linear series matching-to-sample format (A1, B1, C1, D1, E1 and A2, B2, C2, D2, E2). Distinct “drawing” responses were then trained to each of three stimuli within one class. Subjects were required to draw separate components of a stickman at A1 (head), C1 (torso and arms), and E1 (legs), respectively. The members of each class were then examined in relation to the stability of the trained functions, the transfer of the functions to other members of the class, and the possible blending of these functions so that a completed stickman might appear at B1 and D1.

Experiments 1 and 2 produced some unexpected findings, including a wide range of drawings that were not directly traceable to the original training, at least topographically. In the majority of cases these drawings consisted of representations of the stimuli that comprised both classes. On a number of occasions a completed stickman was drawn but the frequency of occurrence was limited. The procedures used in experiments 3 and 4 were successful in eliminating the extensive variability in drawings across subjects. However, blending of functions again was rather limited. Indeed we don’t know why all the stimuli did not control all of the responses that were trained to each of the three stimuli.

Research into function transfer in stimulus equivalence classes typically has involved training a relatively simple function to one member of a stimulus equivalence class (e.g., Barnes & Keenan, 1993). While there are good reasons for adopting this strategy, the findings reported here indicate that perhaps there have been hidden limitations to date in either the kinds of questions that can be asked or in the phenomena that can be uncovered. In the current study, by contrast, we examined how multiple complex functions in a stimulus equivalence class might interact (cf. Dymond & Barnes, 1995; Fields et al.,
1995; Bones et al., 2001). We have already noted the consistent variability in response topographies that was observed (cf. Keenan & Kerr, 2002). On one level this variability might be viewed as problematic, because it indicates a loss of experimental control, hence the reason for conducting Experiment 3. It should not be forgotten, though, that the variability in responding involved drawing and not some other function. That is to say, the general operant class of drawing did not disappear.

On another level the extent of the variability is intriguing and, to our knowledge, has not been reported before in the equivalence literature. From this perspective the concern shifts from loss of control of a particular topography to questions about control over variability. Thus findings here indicate that conclusions drawn from the analysis of transfer of function depend to a large extent on the behavior being studied, as well as on the methods used for establishing functional equivalence classes.

Perhaps future studies should examine whether the nature of the responses trained will determine the way they interact. For example, what would happen if the responses studied were categorized as compatible or incompatible? Does the level of compatibility determine the nature of the responses propagated at various locations in an equivalence class?

The possibility that different behaviors might produce different degrees of variability impacts directly on how one categorizes variability both within and across subjects. This point is made clearer if we look at the kinds of questions that might appear when a simple function like clapping is added to an equivalence class. Tests for transfer of function normally would be designed to measure whether clapping occurs in the presence of the appropriate members of an equivalence class. With multiple drawing functions, though, not only do we need to be concerned with whether, and where, the original drawing responses occur, but we also need to attend to the question of what is drawn. In addition, the nature of the stimuli comprising an equivalence class may also determine response outcomes. One of the most intriguing questions that arises from the current findings concerns the replication of the stimuli comprising class members. Subjects were not trained to replicate these stimuli, but they did so nevertheless. This unusual finding could not have appeared if the function being examined was clapping. While clapping might occur in the presence of a stimulus, clapping cannot create a stimulus. You cannot clap a "●"!

Another feature of the current findings is their relevance to the literature on contextual control. Hayes et al. (2001) note:

A given stimulus always has many functions, and if all functions of one stimulus transferred to another and vice versa, there would no longer be two separate psychological stimuli. Thus, just as the relational response to be brought to bear on the relata is controlled by context, the specific psychological functions that can be transformed must also be under contextual control. (p. 32)

The sensitivity of the drawing function to context was highlighted when subjects who had previously responded by replicating various members of each equivalence class responded in accordance to the originally trained functions in the presence of different instructions. In fact across all three experiments, each subject responded by replicating the originally trained functions at A1, C1, and E1 when explicitly instructed to respond in the way
that they had been trained originally. These findings are in stark contrast to
the variable nature of many of the results, both across and within subjects,
when the instructions were to respond by simply drawing or not drawing in
the space provided.

To date a basic finding in the study of transfer of function is that a response
trained to one stimulus in an equivalence class appears at other members
without direct training. As a general rule, and leaving aside the variability
of responses already mentioned, similar findings were reported here. It is of
particular interest, though, that in Experiment 4 3 subjects consistently did
not respond at B1 and D1. There is nothing in the equivalence literature that
could have predicted this finding. An obvious question that arises is whether
the absence of a drawing response is related in some way to a “blocking
effect” (Catania, 1992). At the very least these findings show that it is possible
to control this kind of response, but again further studies would have to
determine how to control it more consistently than we managed here.

It is clear from our findings that conclusions to date from research on
functional equivalence classes are dependent on the kinds of responses
chosen for study. What’s more, the kinds of responses used traditionally
would not have demonstrated that interactions can occur between response
functions and nature of the stimuli comprising the classes. The findings
reported here also prompt new questions about the necessary and sufficient
conditions for the establishment of variability in responding (Shahan &
Chase, 2002) in functional equivalence classes; equally, though, we can ask
about the necessary and sufficient conditions for establishing the absence
of variability in responding. These questions are all the more interesting if
we examine them in the context of the kinds of blending of functions we
tried to achieve here. In many respects this latter point is reminiscent of
issues that arise in applied work. Put simply, the basic question posed in an
applied study is “Do I know enough about controlling variables to be able to
control the particular behavior I want to produce?” Here we tried to produce
a completed stick man but got something else instead. Perhaps future
studies aimed at determining what needs to be done to enhance blending
of behavioral units in relational networks could benefit from the applied
perspective. For example, lessons from Precision Teaching indicate that we
should perhaps give more attention to ensuring that component behaviors
are at fluency levels if we want to see them merge into compounds (Kubina
& Morrison, 2000; McDowell & Keenan, 2002; McDowell, Kerr, & Keenan,
2002; McDowell, C., McIntyre, C., Bones, R., & Keenan, 2002). At the very
least we should guard against the possibility that unusual combinations of
behaviors are merely products of dysfluency.

In concluding, within the literature the evidence to date suggests that
transfer/transformation of function is a relatively robust phenomenon.
That is, the basic effect is easily established. However, as with any scientific
enterprise, the findings obtained are determined by the tools used. Here we
used a more complex behavior than had hitherto been used and uncovered
some results that challenge accepted findings. It might be argued that the
combination of multiple functions and the novel behavior together produced
the observed effects and that this relationship negates the integrity of the
empirical study. However, given that research to date has not moved beyond
the study of simple responses in simple combinations, the findings reported
here point to the future in terms of where this research could go.
References


