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THE RELATION BETWEEN STIMULUS FUNCTION AND EQUIVALENCE CLASS FORMATION

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Fifty participants were exposed to a simple discrimination-training procedure during which six S+ functions were established for six arbitrary stimuli, and S− functions were established for a further six stimuli. Following this training, each participant was exposed to one of five conditions. In the S+ condition, participants were exposed to a stimulus equivalence training and testing procedure using only the six S+ stimuli as samples and comparisons. In the S+/S− condition, participants were exposed to the same training and testing sequence as in the S+ condition, the difference being that three S+ and three S− stimuli were used as sample and comparison stimuli, with each set of three corresponding to the trained equivalence relations. In the S+/S− mixed condition, the S+ and S− stimuli were assigned to their roles as samples and comparisons in a quasi-random order. In the S− condition, all six S− stimuli were used. The no-function condition served as a control condition and employed stimuli for which no stimulus-control functions had been established. The results showed that, on average, participants required more testing trials to form equivalence relations when the stimuli involved were functionally similar rather than functionally different. Moreover, participants required more test trials to form equivalence relations when novel arbitrary stimuli, rather than functionally distinct stimuli, were used as samples and comparisons. The speed of acquisition of stimulus equivalence was also related to the number of functionally similar stimuli established before training. These findings indicate a variety of ways in which the emergence of equivalence relations is affected by the functional classes in which the relevant stimuli participate.

Key words: stimulus function, functional classes, stimulus equivalence, anxiety, humans

Stimulus equivalence research typically involves teaching subjects to match comparison stimuli to sample stimuli using the matching-to-sample (MTS) procedure (Sidman, 1994; Sidman & Tailby, 1982). In the simplest version of the procedure, participants who are taught to match one stimulus (A) (e.g., nonsense syllables, Chinese symbols, or Greek letters) to another stimulus (B), and the B stimulus to a third stimulus (C), are also able to match B to A, A to C, and C to A without further training. Stimulus equivalence is said to have emerged if the relations between the stimuli can be shown to have the properties of reflexivity (i.e., A to A, B to B, C to C), symmetry (i.e., B to A and C to B), and transitivity (i.e., A to C and C to A; Sidman & Tailby, 1982).

One particularly exciting feature of the stimulus equivalence phenomenon is the *transfer of functions* effect. If one of the stimuli is established as a discriminative stimulus for a simple response then other class members also will spontaneously acquire discriminative properties. This effect is known in the literature as ''transfer-of-function'' effect (e.g., Dougher, Auguston, Markham, Greenway, & Wulfert, 1994), and we will henceforth refer to this transfer of stimulus control as the transfer-of-function effect. Specifically, when a particular behavioral function is established for one of the stimuli in an equivalence relation, the function often transfers to the remaining class members without further training. For instance, if stimulus C in the foregoing example is paired with an aversive stimulus such as electric shock, then B and A also may elicit similar responses. This transfer-of-function effect has been demonstrated with a wide range of operant and respondent behavior (e.g., Barnes & Keenan, 1993; de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; Dougher et al., 1994; Dougher, Perkins, Greenway, Koons, & Chiasson, 2002; Hayes, Kohlenberg, & Hayes, 1991; Roche & Barnes,

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1997; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGready, 2000).

Researchers have been quick to use the potential explanatory power of the derived transfer-of-function effect for the analysis of complex behavior. For instance, in one study, Augustson and Dougher (1997) trained 8 participants in the formation of two 4-member equivalence classes. They then established an avoidance response for a discriminative stimulus that was also a member of one of the equivalence classes. The avoidance response was shown to transfer to the other members of that particular equivalence class and not to members of other equivalence classes. The authors used the observed transfer of function across stimulus equivalence classes to help explain, at least in part, the etiologies of avoidance responses that appear to have emerged in the absence of any explicit history of reinforcement for avoidance in the natural environment (see also Dougher et al., 1994; Friman, Hayes, & Wilson, 1998; Roche et al., 2000).

Although the above findings have generated interest among behavioral researchers, it must be acknowledged that the relation between stimulus function and the emergence of stimulus equivalence classes is not yet clear. More specifically, we do not yet understand the extent to which respondent or operant stimulus functions may enhance or attenuate the formation of stimulus equivalence classes. Indeed, Wirth and Chase (2002) have noted that few studies have specifically addressed the effects of known stimulus functions (e.g., stimulus control) on the emergence of equivalence relations among such stimuli. Those authors suggested that studying classes of functional stimuli under experimental manipulations typically used to test for the emergence of stimulus equivalence relations may help to shed light on the relation between functional stimulus classes and the emergence of stimulus equivalence.

The issue of the relation between stimulus function and the emergence of stimulus equivalence has been of practical concern to those interested in investigating equivalence-based accounts of anxiety and related disorders. In one study, Leslie et al. (1993) examined the possibility that aversive stimuli might interfere with the formation of stimulus equivalence classes. In the Leslie et al. study, the experimenters and the subjects chose as stimuli a series of English words that functioned as aversive stimuli for the subjects. These aversive stimuli served as the A-elements (e.g., *public speaking, exams, job interview*), nonsense syllables as B-elements, and pleasant adjectives as C-elements (e.g., *relaxed, fulfilled, content*). Seven of 8 patients diagnosed with generalized anxiety failed to show evidence of equivalence relations formation, whereas 6 of the 8 students not diagnosed with an anxiety disorder derived the appropriate relations. Leslie et al. proposed that the failure to obtain equivalence in the former participants stemmed from preexperimentally established equivalence relations in which anxiety provoking and pleasant words do not "go together." In effect, previously established aversive stimuli in the world outside the laboratory interfered with the formation of equivalence relations involving these stimuli. These authors acknowledged, however, that such an appeal to behavior–behavior relations is not sufficient in identifying manipulable environmental variables.

Plaud (1995) also investigated the relation between aversive stimuli and the formation of equivalence relations. Specifically, 51 female participants were exposed to a stimulus equivalence training and testing procedure with aversive and innocuous stimulus sets using a crossover design that controlled for serial-order effects. The aversive stimuli were six snake-related words, and the innocuous stimuli were six flower-related words. The participants' task was to form two 3-member equivalence classes from each set of six stimuli (i.e., two 3-member classes consisting entirely of snake-related words, and two 3-member classes consisting entirely of flower-related words). The results showed that 29 of the 51 participants required significantly more training and testing blocks to form equivalence classes in the snake-related condition than in the flower-related condition. Analysis of responses to a questionnaire on snakes indicated that the interference in forming equivalence classes with snake stimuli correlated with self-reported fear of snakes.

Plaud (1995) suggested that interference with the formation of stimulus equivalence classes was due to the aversive nature of the stimuli and equated his findings with those found in several studies (see Mathews &

MacLeod, 1994; Musa & Lepine, 2000 for reviews). For example, using modified versions of the Stroop paradigm (see Williams, Mathews, & MacLeod, 1996), researchers have found that clinically anxious people take longer to name the ink color of aversive words (e.g., spider-related words for spider phobic people) than the color of neutral words (Watts, McKenna, Sharrock, & Trezise, 1986). However, in a subsequent study employing male and female participants, Plaud (1997) failed to observe a relation between the interference effect and a fear of snakes. Any explanation for the foregoing effect in terms of fear and anxiety is incomplete in the absence of a functional analysis of underlying behavioral processes. Specifically, what is required is a systematic analysis of the observed ''interference effect'' with stimuli whose stimulus-control properties are known. In so doing, we will circumvent the need to make recourse to poorly understood terms such as anxiety and fear.

A useful starting point for a basic analysis of the relation between stimulus equivalence and stimulus function is to establish simple stimulus functions for a range of stimuli, under laboratory conditions, none of which could be considered aversive, and to attempt to form equivalence relations with these stimuli. It may emerge, for instance, that any functional class of stimuli, even those not containing aversive stimuli, will hinder the formation of equivalence classes with those stimuli. If this is the case, then the relation between stimulus function and stimulus equivalence will be considerably illuminated.

In the current study, therefore, a discrimination-training procedure was used to establish six nonsense syllables as discriminative stimuli for response emission (S+) and a further six nonsense syllables were established as S− stimuli in that choices of these stimuli were punished. This training was followed by MTS training that was used to establish conditional discriminations consistent with the formation of two 3-member stimulus equivalence classes. There were four experimental conditions employing different combinations of S+ and S− stimuli during the MTS procedure. The first condition (S+ stimuli) consisted of training two classes of S+ stimuli only. The second condition (S+/S− stimuli) established either three S+ *or* three S− stimuli as classes using the MTS procedure. The third condition (S+/S− mixed) involved the establishment of two 3-member classes consisting of both S+ *and* S− stimuli in MTS training. The fourth condition (S− stimuli) consisted of training two classes of S− stimuli only. A fifth, control, condition (no-function training) involved training and testing for stimulus equivalence using stimuli for which no prior stimulus control had been established.

It was hypothesized that participants would take longer to form equivalence classes in the S+ than the S− stimulus condition. The S+ stimulus class was established directly through a process of positive reinforcement. We might consider this class analogous to Plaud's snake-related stimulus class. In addition, we might consider the S− class that was not established directly through reinforcement to be roughly analogous to Plaud's flower-related class. The foregoing analogy obtains because the current study involves establishing two functional classes of stimuli, but with the important difference that the current design does not involve any stimuli that could be described as aversive. Furthermore, it might be expected that participants in the S+/S− condition would have little difficulty in partitioning S+ and S− stimuli into separate equivalence classes according to their function, whereas in the S+/S− mixed condition they would have more difficulty in forming equivalence classes containing opposing stimulus functions as elements (c.f., Moxon, Keenan, & Hine, 1993; Watt, Keenan, Barnes, & Cairnes, 1991). Due to the role of stimulus familiarity in stimulus equivalence acquisition (see Holth & Arntzen, 1998), it also might be predicted that participants would take longer to form equivalence classes when the stimuli used are entirely novel (i.e., no functions have been established) than when stimuli share a S− function.

METHOD

Subjects

Fifty-seven students (42 undergraduates and 15 postgraduates, ages 17 to 49 years) participated in the present study. Seven participants who failed to meet the criterion for the MTS training phase were subsequently dropped from the study, leaving a total of 50 participants with a mean age of 21.96 years (*SD* = 6.24 yrs). Thirteen participants were male and 37 were female. Forty-five of the participants were students of psychology, but none was familiar with the phenomenon of stimulus equivalence. Most participants were acquaintances of the experimenter (ITT) and participated without remuneration. The remaining participants received course credit for their participation. All participants were fully debriefed at the end of the experiment.

Materials and Apparatus

Participants sat at a desk in a small laboratory cubicle (2.5 m by 2 m), facing a Dell® PC running an Apple Macintosh® Platform Emulator (Basilisk II). The experimental software, written using PsyScope 1.2.4 PPC (Cohen, MacWhinney, Flatt, & Provost, 1993; Roche, Stewart, & Barnes-Holmes, 1999), controlled all stimulus presentations and the recording of responses.

Stimuli

Stimuli used in the experiment consisted of 12 nonsense syllables (i.e., CUG, PAF, VEK, MAU, VIB, ZID, LEK, KER, LEF, MUS, DOJ, NEZ) arbitrarily assigned as samples and comparisons. They appeared on the computer screen in black *Times* 24-point font on a white background. Feedback presented during training phases was presented in red in the center of the screen. For convenience, the stimuli were designated by alphanumeric labels (i.e., A1, B1, C1, A2, B2, C2, A3, B3, C3, A4, B4, C4), although the participants did not see these designations. The number refers to the class of which the stimulus is a member, and the letters designate the individual members of the respective classes.

Procedure

There were five conditions; four experimental conditions (S+, S+/S−, S+/S− mixed, and S− conditions) and one baseline control condition (no-function condition). Each participant was exposed to one condition only. All conditions were comprised of three phases. Phase 1 established S+ or S− functions for each of 12 stimuli. Phase 2 consisted of equivalence training (MTS) using a subset of those 12 stimuli. Phase 3 consisted of equivalence testing. The following message

Table 1

Stimuli employed across Phases 1–3.

Block A	Block B
S+ A1	S+ A3
S+ B1	S+ B3
S+ C1	S+ C3
S− A2	S− A4
S− B2	S− B4
S− C2	S− C4

appeared on the computer screen after every block of training and testing in all conditions: "Thank you. You have finished this stage of the experiment. Please contact the experimenter now."

Phase 1: S+/S− training phase (function training). This phase was the same for all participants in the S+, S+/S−, S+/S− mixed, and S− conditions, but not in the no-function condition. To begin, the following instructions were presented on the computer screen:

> Your task is to choose between each of two items that will appear on this computer screen by using the mouse to "click on" one of the objects. You will be provided with feedback on your choice. Click the mouse when you are ready to begin.

The experiment began when the participant pressed the mouse button. Two nonsense syllables then appeared simultaneously on the screen, one on the right side and the other on the left side. The participant's task was to click (using the mouse) on the stimulus they thought was the correct choice. Feedback ("Correct" for a response to an S+ stimulus or "Wrong" for a response to an S− stimulus) appeared immediately after a response (in function training and MTS training) and remained on the screen for 2 s. In each pair, one nonsense syllable was always designated as an S+ stimulus, and the other was an S− stimulus (see Table 1). The left/right positions of the stimuli were randomized across trials. There were 180 trials in the function-training phase, divided into two identical parts of 90 trials. Parts 1 and 2 each consisted of 18 different trial types repeated five times each in a quasi-random order (i.e., 90 trials; see Table 2). Because of the large number of stimuli involved, stimulus function training trial-types were massed into two

Table 2

The 18 trial types employed in Phase 1 (function training). Each trial type was repeated five times in a quasi-random order for a total of 90 trials. The correct choice (S+) on each trial is indicated by the asterisk.

Block A	Block B
B1*–B2	B4–C3*
A1*–C2	B3*–B4
A2–C1*	C3*–C4
A1*–A2	A3*–A4
A2–B1*	A4–C3*
B1*–C2	B3*–C4
C1*–C2	A3*–B4
A1*–B2	A3*–C4
B2–C1*	A4–B3*

blocks, A and B. The PsyScope program first ran Block A, which involved the first nine trial types presented five times each in a quasi-random order. The stimuli used in Block A were A1, B1, C1, A2, B2, and C2, where A1, B1, and C1 were established as S+ stimuli, and A2, B2, and C2 were established as S− stimuli. There was no break in the training phase when the program began to run Block B, which consisted of the remaining nine trial types, again presented five times each in a quasi-random order. The stimuli in Block B were A3, B3, C3, A4, B4, and C4, where A3, B3, and C3 were established as S+ stimuli, and A4, B4, and C4 were established as S− stimuli. Thus there were 45 trials in each block.

The criterion for completing function training was at least four out of five correct responses on each of the 18 trial types in Part 2. None of the participants failed function training using this criterion. Function training served to establish two functional classes, with six stimuli in each class. A1, B1, C1, A3, B3, and C3 were all S+ stimuli. A2, B2, C2, A4, B4, and C4 were all S− stimuli.

Phase 2: MTS training. In Phase 2, participants were exposed to an MTS procedure designed to establish two 3-member equivalence classes. This phase differed across conditions insofar as each condition employed a different subset of S+ and S− stimuli. In the S+ condition, 10 participants were exposed to an equivalence training procedure that employed only the six S+ stimuli as samples and comparisons. In the S+/S− condition, a further 10 participants were exposed to equivalence training using three S+ and three S− stimuli as samples and comparisons. In the S+/S− mixed condition, the S+ and S− stimuli were assigned to their roles as samples and comparisons in a quasi-random order (see below) for a further group of 10 participants. In the S− condition, another 10 participants were exposed to MTS training using six S− stimuli. The 10 participants in the no-function condition were exposed to the same equivalence training and testing trials as those in the S+ condition, but were not exposed to the prior S+/S− function training. Instructions for each of the five conditions in the MTS training phase of the experiment were presented on the computer screen and read as follows:

> In a moment some images will appear on this screen. Your task is to first look at the image at the top of the screen and then at the two objects at the bottom of the screen. You should choose one of these two objects at the bottom of the screen by placing the mouse cursor on top of it and clicking the mouse button. So, if you want to choose the object on the left, click on the object on the left. If you want to choose the object on the right, click on the object on the right. If you have any questions please ask the experimenter now. Click or hit any key when done.

On all trials, the participants first saw a sample stimulus (e.g., PAF) appear at the top of the screen and 1 s later two comparison stimuli appeared at the bottom of the screen, one to the left and the other to the right (e.g., VEK and LEK). Feedback (i.e., the word Correct or Wrong) was delivered via the computer screen for 2 s following a response. A-B and B-C relations were trained simultaneously, with all tasks interspersed in a quasi-random order. There was a total of 16 trials in MTS training (i.e., four trial types presented four times each in a quasi-random order).

The four trial types in the S+ condition were A1-*B1*/B3, A3-B1/*B3,* B1-*C1*/C3, and B3-C1/*C3* (where italicized comparisons indicate a correct choice). The criteria for passing the MTS training phase were a minimum of three out of four (75%) responses correct on each trial type, and the final 12 successive responses correct.

In the S+/S− condition, the procedure was the same as in the S+ condition. However, three S+ stimuli and three S− stimuli

Table 3

Trained and tested relations during equivalence training (Phase 2) and equivalence testing (Phase 3). The specific subset of stimuli used in each condition is also indicated.

	Conditions				
	Six S+ stimuli	Three S+/3 S− stimuli	Three S+/3 S− mixed stimuli	Six S− stimuli	No-function training stimuli
Equivalence training (Phase 2)	A1–B1	A1–B1	A1–B1	A2–B2	A1–B1
	A3–B3	A4–B4	A4–B4	A4–B4	A3–B3
	B1–C1	B1–C1	B1–C4	B2–C2	B3–C1
	B3–C3	B4–C4	B4–C1	B4–C4	B3–C3
Equivalence testing (Phase 3)	A1–C1	A1–C1	A1–C4	A2–C2	A1–C1
	C1–A1	C1–A1	A4–C1	A4–C4	C1–A1
	A3–C3	A4–C4	C4–A1	C2–A2	A3–C3
	C3–A3	C4–A4	C1–A4	C4–A4	C3–A3

were used as samples and comparisons. The relations trained were A1-*B1*/B4, A4-B1/*B4,* B1-*C1*/C4, B4-C1/*C4*. Participants had no previous history of discriminating between the comparisons presented on these trials (see Table 1). In effect, the predicted equivalence classes (i.e., A1-B1-C1 and A4-B4-C4) conformed to the functional S+ and S−classes established during function training.

The S+/S− mixed condition employed the same procedure and criteria for passing as the first two conditions. It employed the same set of stimuli as the S+/S− condition. In this condition, however, the S+ and S− stimuli were assigned to their roles as samples and comparisons in a quasi-random manner, such that one of the emergent classes consisted of one S+ and two S− stimuli, whereas the other consisted of one S− and two S+ stimuli. Thus the predicted equivalence classes did not conform to the functional classes established during function training. The relations trained were A1-*B1*/B4, A4-B1/*B4,* B1-C1/*C4,* and B4-*C1*/C4.

The S− condition employed six S− stimuli as samples and comparisons. The four relations trained were A2-*B2*/B4, A4-B2/*B4,* B2-*C2*/C4, and B4-C2/*C4.* The no-function condition served as a baseline condition. The participants in this condition received no prior function training (i.e., Phase 1). The stimuli employed were the same as for the S+ condition. The four relations trained were A1-*B1*/B3, A3-B1/*B3,* B1-*C1*/C3, and B3-C1/*C3.*

In all five conditions, the participants were exposed to blocks of training trials until they met the response criterion. Participants could not proceed to the test phase until they passed the MTS training phase. If a participant did not pass equivalence training after 10 trial blocks (i.e., 160 trials), they were thanked for their participation and dropped from the study.

Phase 3: Equivalence testing. The procedure employed for this phase was very similar to that employed during MTS training, with the important difference that no feedback was provided. Equivalence testing probed for transitivity and combined symmetry and transitivity (i.e., A-C and C-A relations, respectively; see Table 3). There were 16 trials in each block. The four trial types were repeated four times each in a quasi-random order (see Table 3). The criterion for passing this phase was the same as in MTS training. The PsyScope software recorded the number of trials and blocks required for each subject to reach criterion responding during MTS training and equivalence testing.

RESULTS

Seven of the original 57 participants did not meet the performance criterion in MTS training (Phase 2) of the experiment and were dropped from the study. Forty-four of the remaining 50 participants formed equivalence classes within 10 blocks of test trials. All data are summarized in Table 4.

Equivalence Training

The 10 participants in the S+ condition reached the MTS training criterion within 10 blocks. The mean number of MTS training

Table 4

The number of blocks to criterion during function training (Phase 1), equivalence training (Phase 2), and equivalence testing (Phase 3) for each participant. Each block of function training consisted of the same 90 trials. Each block in equivalence training and testing consisted of 16 trials. The asterisks denote those participants who did not pass the equivalence test.

		Number of blocks		
Condition	Participant	Phase 1: function training	Phase 2: equivalence training	Phase 3: equivalence testing
Six S+ stimuli	S1	2	3	2
	S2	2	1	1
	S3	2	6	6
	S4	2	5	6
	S5	2	9	2
	S6	2	2	10*
	S7	2	3	1
	S8	2	2	7
	S9	2	3	1
	S10	2	2	10*
			Mean 3.6	Mean 4.6
Three S+/S− stimuli	S11	2	1	2
	S12	2	1	1
	S13	2	1	1
	S14	2	1	1
	S15	2	5	2
	S16	2	1	1
	S17	2	1	1
	S18	2	1	1
	S19	2	2	6
	S20	2	1	2
			Mean 1.5	Mean 1.8
Three S+/S− mixed stimuli	S21	2	3	7
	S22	2	4	10*
	S23	2	3	9
	S24	2	3	1
	S25	2	7	2
	S26	2	3	3
	S27	2	5	1
	S28	2	3	10*
	S29	2	4	3
	S30	2	3	10*
			Mean 3.8	Mean 5.6
Six S− stimuli	S31	2	2	1
	S32	2	6	1
	S33	2	4	1
	S34	2	6	2
	S35	2	6	4
	S36	2	2	1
	S37	2	1	1
	S38	2	3	6
	S39	2	2	1
	S40	2	1	2
			Mean 3.6	Mean 2.0
No-function training stimuli	S41	2	7	3
	S42	2	6	2
	S43	2	9	1
	S44	2	2	1
	S45	2	3	7
	S46	2	7	10*
	S47	2	5	8
	S48	2	3	2
	S49	2	4	4
	S50	2	3	1
			Mean 4.9	Mean 3.9

blocks-to-criterion for the S+ condition was 3.6 with a range of one to nine blocks. Eight of the 10 participants in the S+/S− condition reached the MTS training criterion on their first exposure. The mean number of training blocks-to-criterion for the S− condition was 1.5 with a range of one to five blocks. The 10 participants in the S+/S− mixed condition met the training criterion within the 10 blocks permitted, with all 10 requiring seven training blocks or fewer. The mean number of training blocks to criterion for this condition was 3.8 with a range of three to seven blocks. All 10 participants in the S− condition reached the MTS training criterion within six blocks. In the S− condition, the mean number of training blocks-to-criterion was 3.6 with a range of one to six blocks. All 10 participants in the no-function condition met the MTS training criterion within 10 blocks. The mean number of training blocks-to-criterion in the no-function condition was 4.9 blocks with a range of two to nine.

Equivalence Testing

Eight of the 10 participants in the S+ condition formed the predicted symmetry and combined symmetry and transitivity relations (i.e., showed equivalence). Participants S6 and S10 did not meet the response criterion and testing was terminated after the 10th block (i.e., 160 trials). The mean number of blocks-to-criterion was 4.6 with a range of one to 10 blocks. Nine of the 10 participants in the S+/S− condition showed stimulus equivalence within two blocks of test trials. The mean number of blocks-to-criterion in the S+/S− condition was 1.8 blocks with a range of one to six blocks. Seven of the 10 participants in the S+/S− mixed condition showed stimulus equivalence, with participants S22, S28, and S30 failing to meet the criterion within the permitted 10 blocks of test trials. The mean number of blocks-to-criterion in the S+/S− mixed condition was 5.6 with a range of one to 10 blocks. All 10 participants in the S− condition formed the predicted relations within six blocks of test trials. The mean number of blocks-to-criterion in the S− condition was 2.0 with a range of one to six blocks. Nine of the 10 participants in the no-function condition showed stimulus equivalence within 10 blocks, with 1 participant (S46) failing to meet the criterion. The mean number of blocks-to-criterion was 3.9 with a range of one to 10 blocks.

Statistical Analysis

An analysis of covariance (ANCOVA) was applied to the five conditions in order to examine if participants' performances in the MTS training phase of the experiment had a significant impact on subsequent performance in the equivalence test phase. No significant effect of training scores on subsequent test scores was found, suggesting that scores on the equivalence test were independent of training scores, $F(1, 44) = 1.34$, $p = .25$. A one-way between-subjects ANOVA was performed on the blocks-to-criterion scores across the five conditions in the Phase 2 MTS training. There was a significant effect for conditions, $F(4, 45) = 4.15$, $p = .01$. As no specific a priori predictions had been made regarding any differences in mean blocks-to-criterion among conditions during MTS training, Scheffé post hoc tests were employed to establish where the condition differences lay. The Scheffé tests indicated that only the comparison between the S+/S− and no-function conditions was significant, $p = .01$.

A further one-way between-subjects ANOVA was carried out to examine the number of blocks of test trials participants required to form stimulus equivalence relations in Phase 3 equivalence testing across the five conditions. A significant effect for condition was found, $F(4, 45) = 3.34$, $p = .02$. Given that specific predictions, relevant to the current experimental manipulations, had been made, planned (a priori) tests (see Brace, Kemp, & Snelgar, 2000) were employed to examine further the effects of the differing stimulus function training histories on performance. These tests revealed that participants in the S+ condition required significantly more blocks of test trials to reach criterion than participants in the S− condition, $t = 2.0$, $df = 45$, $p = .03$. Further planned comparisons revealed that participants in the S+ condition took significantly longer to form equivalence classes than participants in the S+/S− condition, $t = 2.27$, $df = 45$, $p = .01$. Participants in the S+/S− condition required fewer blocks to meet the criterion than those in the S+/S− mixed and no-function conditions, $t = 3.03$, $df = 45$, $p = .002$; $t = 1.74$, $df = 45$,

p = .04, respectively. A further planned comparison revealed that participants in the S+/S− mixed condition required significantly more test trial blocks-to-criterion than those in the S− condition, t = 2.73, df = 45, p = .01.

DISCUSSION

In the present study, participants took longer to form stimulus equivalence classes when all of the stimuli involved were discriminative for reinforced operant responses (S+), rather than for avoidance response functions (S−). Although the current study employed a procedure different from that employed by Plaud (1995), strong parallels exist in the findings of both studies. Specifically, both studies demonstrated a robust relation between the acquisition of stimulus equivalence and participants' histories with the relevant stimuli. The present study, however, investigated the behavioral process underlying this effect by examining the phenomenon ab initio in the laboratory using arbitrary nonaversive stimuli.

The current results suggest that Plaud's (1995, 1997) findings could have been obtained, at least in principle, using nonaversive stimuli. In other words, the important controlling factor in the observed interference effect may not be the preexisting stimulus-control functions of the relevant stimuli per se, as suggested by some authors (e.g., Leslie et al., 1993; Plaud, 1995, 1997), *but the trained functional similarity of the relevant stimuli*. It would appear, therefore, that humans may form equivalence relations more slowly when the entire array of stimuli used in training are all functionally identical (i.e., control the same response) and have been established through a process of positive reinforcement, compared to stimuli whose functions have been established through S− control procedures. The implications of this finding are somewhat similar to those suggested by Leslie et al. and Plaud (1995, 1997), but the current study contributes substantially to our understanding of the interaction between functional stimulus control and stimulus equivalence by specifying a process for these interactions.

It was observed that participants in the S+/S− condition formed equivalence classes more rapidly than those in the S+, S+/S− mixed, and no-function conditions. However, the present research cannot ascertain whether the participants in the S+/S− condition had actually formed stimulus equivalence classes in the test phase of the experiment as these participants may have been simply separating the S+ and S− stimuli into their distinct functional groups. Therefore, it may not be surprising that the participants in this condition obtained the lowest mean blocks-to-criterion score across the study. In general, participants in the S+/S− mixed condition formed the required equivalence classes slowly as the trials involved matching S+ with S+, S− with S−, or S+ with S− stimuli. This is consistent with the notion that people often find it difficult to form equivalence classes with stimuli that do not have a history of association (Watt et al., 1991; see also Moxon et al., 1993).

It is interesting that participants required more blocks to form equivalence classes in the no-function condition than participants in the S− and the S+/S− conditions. The participants in the no-function condition also required the largest mean number (4.9) of blocks-to-criterion in MTS training. The observation that participants in the S− condition formed equivalence relations more rapidly than those in the condition with no prior stimulus function training suggests that stimulus familiarity may also have played a role in determining the speed of equivalence class formation (see Holth & Arntzen, 1998). Similarly, it is possible that participants in the no-function condition required more time to form equivalence relations because, unlike the participants in the other four conditions, they had no prior discrimination training with the various training stimuli and they first had to learn to make simple discriminations (either simultaneous or successive) between certain stimuli (cf., Saunders & Green, 1999).

Although it is the case that no stimuli with emotional functions were employed in the present study, the findings are relevant to the behavioral analysis of anxiety because, for persons diagnosed with phobias, many aversive stimuli may participate in well-established functional classes. For instance, for a person with a spider phobia, actual spiders, and words such as "spider," "cobwebs," "venomous," "creeping," "lurking," and "hairy legs," may all be functionally similar in that they control avoidance responses. It might not be surprising, therefore, that persons diagnosed with phobias would find it difficult to partition such functional classes into smaller and distinct equivalence classes. Thus the current findings may help to inform us how preexperimental stimulus functions for phobic populations influence the formation of novel equivalence classes. The current research extends the growing body of empirical and theoretical research into the role of derived relations in facilitating a transfer-of-function effect in persons diagnosed with phobias. Thus, although previous research has tended to explain the emergence of novel stimulus functions in terms of stimulus equivalence, the current study explains the emergence, or nonemergence, of novel stimulus equivalence relations in terms of stimulus functions.

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