BRIEF REPORT

BREAKING EQUIVALENCE RELATIONS

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A number of researchers have argued that stimulus equivalence is, in large part, the product of a history of explicit reinforcement for responding in accordance with equivalence relations (e.g., Barnes, 1994; Boelens, 1994; Hayes, 1991; Schusterman & Kastak, 1993). In effect, equivalence responding is an over-arching, or generalized, operant class. One method for testing this "theory" of equivalence would involve "arranging operant procedures for weakening the generalized performances... The reasoning would be that if the performances can be produced with operant procedures it should also be possible to eliminate them with operant procedures" (Boelens, 1994, p. 599).

The experiments reported here attempted to eliminate or weaken equivalence responding in adult humans, by providing a history of reinforcement for non-equivalence responding. Specifically, we attempted to produce a pattern of relational responding that was incompatible with the frame of coordination as the most common frame (Hayes, 1991, p. 32; Barnes, 1994, p. 102). Meeting this criterion represented a relatively conservative approach, insofar as it would be relatively easy to establish a pattern that was *not* incompatible with previous patterns, but far more difficult to establish a pattern that was inconsistent with a previously established pattern. To accomplish this aim, we developed what we call a *Broken Equivalence Relation*.

To establish responding in accordance with a broken equivalence relation, we provided a history of explicit reinforcement for responding in accordance with symmetry and transitivity, *but not* equivalence. Interestingly, we found it very difficult to break equivalence relations, although the various failures along the way have been instructive. The procedures and data reported here provide a brief summary of our attempts to break equivalence relations. Interestingly, we found it very difficult to break equivalence relations, although the various failures along the way have been instructive. The procedures and data reported here provide a brief summary of our attempts to break equivalence relations.

This research was conducted while the first and second authors were working under the supervision of Dermot Barnes at the Behavior Analysis and Cognitive Science Unit, Department of Applied Psychology, University College Cork, Ireland.

EXPERIMENT 1

In our first attempt to break equivalence relations we exposed an experimentally naive undergraduate from University College Cork to a computerized, two-choice, matching-to-sample procedure using three-letter nonsense syllables as stimuli. Responding in accordance with broken equivalence relations was explicitly trained using differential feedback (i.e., CORRECT/tone and WRONG/no tone). The following conditional discriminations were trained: A1 as sample -> choose B1 and not B2, B1->A1 not A2, A2->B2 not B1, B2->A2 not A1, B1->C1 not C2, C1->B1 not B2, B2->C2 not C1, C2->B2 not B1, A1->C1 not C2, A2->C2 not C1, *C1->A2 not A1 and C2->A1 not A2***.** In effect, 12 matching-to-sample tasks were used to train responding in accordance with A-B and B-C relations, B-A and C-B symmetry relations, A-C transitive relations, and C-A *broken* equivalence relations (e.g., the subject was trained to choose A1 in the presence of C2, and A2 in the presence of C1, both of which are inconsistent with the other 10 relations). We refer to this training as *Train Break Equivalence*. The subject was exposed to each of these 12 tasks in a quasi-random order (the only constraint being that each task was presented once every 12 trials) until the subject produced 12 consecutively correct responses. The subject was then trained and tested using a *standard equivalence* procedure with a new set of nonsense syllables (completely different from set 1). The reader should note, that for the purposes of communication, we use the same alphanumeric labels for each stimulus set, although the actual nonsense syllables were totally different across sets. For the training with set 2, the following matching-to-sample tasks were used: A1->B1 not B2, A2->B2 not B1, B1->C1 not C2, B2->C2 not C1. The subject was exposed to each of these 4 tasks in a quasi-random order (the only

constraint being that each task was presented once every 4 trials) until the subject produced 8 consecutively correct responses. The subject was then exposed to an equivalence test without feedback to determine whether equivalence responding had been broken by the explicit history of conditional discrimination training using the first stimulus set. The equivalence test consisted of the following eight matching-to-sample tasks: B1 as a sample with A1 and A2 as comparisons, B2 - A2/A1, C1 - B1/B2, C2 - B2/B1, A1 - C1/C2, A2 - C2/C1, C1 - A1/A2, C2- A2/A1. These tasks were presented in a quasi-random order (the only constraint being that each task was presented once every eight trials) for a total of 40 trials (i.e., 5 responses to each task). If the previous history of explicitly trained, broken equivalence responding with set 1 had established "generalized" broken equivalence responding, the subject should produce the following matching performances with set 2: B1->A1, B2->A2, C1->B1, C2->B2, A1->C1, A2->C2, *C1->A2, C2->A1* (italicized matching performances would demonstrate that equivalence responding had been broken). We refer to this training and testing as *Train Standard Equivalence* and *Test For Standard Equivalence*, respectively. The subject cycled through Train Break Equivalence, Train Standard Equivalence and Test For Standard Equivalence, 4 times in succession (see Table 1, upper section), but failed to demonstrate broken equivalence responding (see Table 1, left-most column, for the pattern of broken equivalence responding that we sought to generate).

Table 1

Subject 1

		4 Exposures			
Train Break Equivalence (Set1) Trials		96	350	132	36
Train Standard Equivalence (Set2) Trials		16	28	16	16
Test For Standard Equivalence (Set2)					
Predicted Breaking Pattern	Actual Pattern				
5	B1-A1:	1	0	1	5
5	B2-A2:	5	5	5	5
5	C1-B1:	1	1	0	3
5	C2-B2:	2	2	2	3
0	C1-A1:	4	0	2	5
5	A1-C1:	1	0	0	5
0	C2-A2:	0	0	1	4
5	A2-C2:	3	1	2	5
	RESULT	NO	NO	NO	NO

Subject 2

Train Break Equivalence Training Trials: Stimulus sets and number of trials (in parentheses)

Set 1(trials: 720) -> 2(420) -> 3(12) -> 2(1032) -> 1(60) -> 2(696) -> 2(156) 1(132) -> 3(252) -> 1(36) -> 2(156) -> 3(216) -> 2(84) -> 1(60) -> 1(48) -> 3(84) 2(24) -> 2(108) -> 3(36) -> 1(12)

Train Standard Equivalence (Set 4) Trials 36

Test For Standard Equivalence (Set 4)

Predicted Breaking Pattern	Actual Pattern	
5	B1-A1:	5
5	B2-A2:	5
5	C1-B1:	2
5	C2-B2:	1
0	C1-A1:	0
5	A1-C1:	0
0	C2-A2:	0
5	A2-C2:	2
	RESULT	NO

At this point we reasoned that perhaps the history of reinforcement for broken equivalence responding had been insufficient for Subject 1. We therefore exposed a second subject (S2: another experimentally naive undergraduate) to these procedures, except that the subject was provided with multiple exposures to Train Break Equivalence across three *different* stimulus sets (see Table 1, lower section), before being exposed once to Train Standard Equivalence and Test Standard Equivalence, using a fourth stimulus set. Nevertheless, this subject also failed to show evidence of broken equivalence responding (Table 1, lower section). Interestingly, however, both subjects also failed to show clear evidence of standard equivalence responding. This pattern of results was also obtained from a number of other subjects that we exposed to these and similar procedures.

EXPERIMENT 2

At this stage, we recognized that if responding in accordance with broken equivalence relations was to emerge, the subjects would have to discriminate the structure of the to-be-broken equivalence relations. That is, they would have to discriminate the A stimuli as being the "first stimuli" in each relation and the C stimuli as being the "last stimuli" in each relation. To address this issue, the nonsense syllables used in Experiment 1 were replaced by stimuli that varied in size so as to make the structure of the relations more salient. That is, the A stimuli were composed of single elements, the B stimuli of two elements, and the C stimuli of three elements. For example: A1 = X, B1 = S S,C1 = W W W, A2 = O, B2 = T T, C2 = * * *. We refer to these types of stimuli as *Structured Stimuli.*

We used structured stimuli with two experimentally naive undergraduates from University College Cork. The results were more promising than those obtained in Experiment 1, but were still relatively weak. Specifically, Subject 3 produced inconsistent responding during the equivalence test, whereas Subject 4

produced almost perfect broken equivalence responding (Table 2, lower section). Unfortunately, however, further attempts to replicate the data obtained with Subject 4 failed with two additional subjects (i.e., a success rate of only 25%).

Table 2

Subject 3

Train Break Equivalence/
Structured Stimuli (SET1) 108 Trials

Train Standard Equivalence/
Structured Stimuli (SET2) 16 Trials

Test for Standard Equivalence/Structured Stimuli (SET2)

Predicted Breaking Pattern	Actual Pattern	
5	B1-A1:	5
5	B2-A2:	4
5	C1-B1:	5
5	C2-B2:	5
0	C1-A1:	2
5	A1-C1:	5
0	C2-A2:	4
5	A2-C2:	5
	RESULT	NO

Subject 4

Train Break Equivalence/
Structured Stimuli (SET 1) 76 Trials

Train Standard Equivalence/
Structured Stimuli (SET2) 16 Trials

Test for Standard Equivalence/Structured Stimuli (SET2)

Predicted Breaking Pattern	Actual Pattern	
5	B1-A1:	5
5	B2-A2:	5
5	C1-B1:	5
5	C2-B2:	5
0	C1-A1:	1
5	A1-C1:	5
0	C2-A2:	0
5	A2-C2 :	5
	RESULT	YES

EXPERIMENT 3

At this point we speculated that our failure to obtain reliable broken equivalence responding might be related to the following procedural artifact. During the training sequences outlined in Experiments 1 and 2, subjects were explicitly trained to respond in accordance with broken equivalence relations, but were not given the opportunity to respond in accordance with these relations in the absence of feedback until a second set of stimuli was introduced. In effect, when a subject was exposed to the Test for Standard Equivalence there were two differences between this test and the Train Break Equivalence phase (i.e., a different set of stimuli were used andfeedback was no longer provided). Would we obtain more reliable evidence of broken equivalence responding if there was only one difference between Train Break Equivalence and Test for Standard Equivalence? To answer this question we made the following modification to the experimental sequence. Subjects (two experimentally naive undergraduates) were exposed to Train Break Equivalence followed by Test for Standard Equivalence with the same set of structured stimuli. Subjects were thereby exposed to an equivalence test (without feedback) after an explicit history of reinforcement for producing broken equivalence responding with the same set of stimuli.

Table 3

Subject 5

Train Break Equivalence/Structured Stimuli (SET1)

		2 Exposures	
	Trials:	744	96

Test for Standard Equivalence/Structured Stimuli (SET1)

Predicted Breaking Pattern		Actual Pattern	
5	B1-A1:	5	5
5	B2-A2:	5	5
5	C1-B1:	4	5
5	C2-B2:	5	5
0	C1-A1:	0	1
5	A1-C1:	5	5
0	C2-A2:	0	0
5	A2-C2:	5	5
	RESULT	YES	YES

Train Standard Equivalence/
Structured Stimuli (SET2) 16 8 Trials

Test for Standard Equivalence/Structured Stimuli (SET2)

	B1-A1:	5	5
	B2-A2:	5	5
	C1-B1:	5	5
	C2-B2:	3	0
	C1-A1:	1	4
	A1-C1:	0	3
	C2-A2:	0	1
	A2-C2:	4	2
	RESULT	NO	NO

Train Standard Equivalence/
Normal Stimuli (SET 3) Trials: 20 12

Test for Standard Equivalence/Normal Stimuli (SET 3)

	B1-A1:	1	0
	B2-A2:	5	5
	C1-B1:	2	3
	C2-B2:	5	5
	C1-A1:	5	3
	A1-C1:	5	4
	C2-A2:	2	4
	A2-C2:	0	0
	RESULT	NO	NO

Subjects were then exposed to Train Standard Equivalence and Test Standard Equivalence with a second set of structuredstimuli and then subsequently with a third set of normal (non-structured) stimuli (e.g., A1 = @@@, C1 = +++). Using the normal stimuli in the final part of the experimental sequence allowed us to determine whether the use of structured stimuli was always necessary for broken equivalence responding to emerge.

Although Subject 5 produced broken equivalence responding using stimulus set 1 (i.e., consistent with the explicit training), this pattern failed to generalize to stimulus sets 2 and 3 (Table 3). In contrast, however, Subject 6 produced almost perfect broken equivalence responding across all three stimulus sets (Table 4). Nevertheless, one further attempt to replicate the data obtained from Subject 6 failed (i.e., a success rate of 33.3%).

CONCLUSIONS

Clearly, our work on breaking equivalence relations is far from over. However, the following four tentative conclusions may be drawn from the research conducted thus far. First, producing broken equivalence responding is extremely difficult, although simply disrupting standard equivalence responding appears to be somewhat easier. Second, using stimuli that make the structure of the equivalence classes more salient appears to facilitate the breaking of equivalence relations. Third, results across subjects are variable -- some subjects demonstrate broken equivalence responding whereas others do not. Further research is needed to identify the sources of this variability. Fourth, successfully breaking equivalence relations after a history of reinforcement for breaking equivalence relations supports the idea that equivalence responding is a generalized or over-arching class of operant behavior. Of course, evidence that operant procedures can be used to weaken equivalence responding, or produce new patterns of relational responding, does not prove conclusively that equivalence was originally established via the operant process. Nevertheless, the evidence is suggestive.

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Table 4

Subject 6

Train Break Equivalence/

Structured Stimuli (SET1) 80 Trials

Test for Standard Equivalence/Structured Stimuli (SET1)

Predicted Breaking Pattern		Actual Pattern
5	B1-A1:	5
5	B2-A2:	5
5	C1-B1:	5
5	C2-B2:	5
0	C1-A1:	0
5	A1-C1:	5
0	C2-A2:	0
5	A2-C2:	5
	RESULT	YES

Train Standard Equivalence/

Structured Stimuli (SET2) 16 Trials

Test for Standard Equivalence/Structured Stimuli (SET2)

	B1-A1:	5
	B2-A2:	5
	C1-B1:	5
	C2-B2:	5
	C1-A1:	0
	A1-C1:	5
	C2-A2	0
	A2-C2:	5
	RESULT	YES

Train Standard Equivalence/

Normal Stimuli (SET 3) 12 Trials

Test for Standard Equivalence/Normal Stimuli (SET 3)

	B1-A1:	5
	B2-A2:	5
	C1-B1:	5
	C2-B2 :	5
	C1-A1:	0
	A1-C1:	5
	C2-A2:	0
	A2-C2:	4
	RESULT	YES