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GENERATING DERIVED RELATIONAL NETWORKS VIA THE ABSTRACTION OF COMMON PHYSICAL PROPERTIES: A POSSIBLE MODEL OF ANALOGICAL REASONING

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The aim of this study was to provide a demonstration of equivalence-equivalence responding based on the abstraction of common formal properties, thus extending the functional-analytic model of analogical reasoning shown by Barnes, Hegarty, and Smeets (1997). In Experiment 1, 9 college students were taught, using a delayed matching-to-sample procedure, to choose a particular nonsense syllable in the presence of each of four blue and four red geometric shapes. In a subsequent test, all 9 subjects demonstrated equivalence formation based on the abstraction of color by consistently matching nonsense syllables related to same-colored shapes to each other. Of these 9 subjects, 8 then showed equivalence-equivalence responding in which equivalence relations from the previous part of the experiment were related to other equivalence relations and nonequivalence relations were related to other nonequivalence relations. In Experiment 2, 3 out of 4 additional subjects showed this analogical-type responding based on larger relational networks than those established in Experiment 1, and in Experiment 3, 3 further subjects showed analogical responding based on the abstraction of the relatively complex property of age.

Relational Frame Theory (Hayes, 1991) is one of a number of different behavior analytic theories that attempt to account for the phenomenon of stimulus equivalence and derived relational responding more generally (e.g., Hayes, 1991; see also Barnes & Roche, 1996; Hayes & Barnes, 1997). According to Relational Frame Theory (RFT), derived or arbitrarily applicable relational responding is established, to an important extent, by an appropriate history of multiple exemplar training (see Barnes, 1994, 1996; Barnes & Holmes, 1991; Barnes & Roche, 1996; Hayes, 1991, 1994; Hayes & Hayes, 1989, 1992). Naming

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constitutes, perhaps, one of the earliest and most essential forms of arbitrarily applicable relational responding. For example, a caregiver will often say the name of an object in the presence of an infant and then reinforce any orienting response that occurs towards the particular object. This interaction might be described as, hear name A → look at object B. Caregivers will also often present an object to the infant and then model and reinforce an appropriate "tact" (Skinner, 1957). This interaction might be described as, see object B → hear and say name A (see Barnes, 1994, for a detailed discussion). During the initial stages of language learning, each interaction may require explicit reinforcement for it to become wholly established in the behavioral repertoire of the child, but after a number of name-to-object and object-to-name exemplars have been taught, the generalized, higher-order, operant response class of derived naming will be established. In effect, the multiple-exemplar bidirectional training establishes particular contextual cues as discriminative for the derived response of naming.

Relational Frame Theory argues that any events may enter into arbitrarily applicable relational responding in the presence of the appropriate contextual cues, and in addition, explains stimulus equivalence as one example of such relational responding. For instance, when the generalized operant of derived naming is established as part of a young child's behavioral repertoire, and he or she is then exposed to a matching-to-sample preparation, contextual cues made available by this preparation may be discriminative for equivalence responding. Indeed, the matching-to-sample format itself may function as a particularly powerful contextual cue in this regard, because it is often used in preschool education exercises to teach word-to-picture equivalences (see Barnes, 1994, and Barnes & Roche, 1996, for detailed discussions). Relational Frame Theory thus defines equivalence formation as a generalized or overarching response class insofar as it is generated by a history of reinforcement across multiple exemplars, and once established any stimulus event, irrespective of form, may become part of an equivalence relation.

Relational Frame Theory takes the view that stimulus equivalence and other related phenomena provide an important basis for the behavior analysis of human language. To illustrate this more clearly, consider the following example. Suppose that a young girl gets bitten by a "dog" (Stimulus A). She may then learn at school that a "Terrier" (Stimulus B) is a type of dog. Later, upon hearing that she is to come in contact with a terrier, she may display signs of fear and anxiety, despite having had no direct experience of terriers. This transfer of function effect is based on the conditioned psychological function of Stimulus A (i.e., the word "dog" was paired directly with the experience of being bitten) and the derived relation between Stimulus A and Stimulus B. In effect, the girl does not need to experience any aversive consequences in the presence of a terrier in order to show signs of anxiety (see Hayes & Hayes, 1989, 1992; Hayes & Wilson, 1994). This hypothetical example illustrates one of the most centrally important assumptions of the relational frame approach to verbal events; *a stimulus (or response) is rendered verbal by its participation in an equivalence or other type of derived relation.*

Relational Frame Theory maintains that if equivalence can be treated as a type of generalized operant behavior, then so too should other forms of relational activity, such as responding in accordance with the arbitrarily applicable relations of opposition, distinction, before/after, equivalence-equivalence, and so forth. Indeed, an increasing body of data provides empirical support for this idea, thereby increasing the number of behavioral phenomena that might emerge from trained relational responding (e.g., Barnes & Hampson, 1993a, 1993b; Barnes et al., 1997; Barnes & Keenan, 1993; Dymond & Barnes, 1994; Roche & Barnes, 1997; Steele & Hayes, 1991). One behavioral domain to which RFT has recently been applied is that of analogical reasoning.

Analogical reasoning and other examples of complex human behavior have traditionally been perceived as the preserve of cognitive psychology. However, in a relatively recent study, Barnes et al. (1997) used RFT to construct a behavioral interpretation and empirical model of analogical reasoning. In the authors' own words:

> Consider . . . the following question based on the classic proportion scheme (A : B :: C : ?); "apple is to orange as dog is to: (i) sheep, or (ii) book?". If "apple" and "orange" participate in an equivalence relation in the context "fruit," and "dog" and "sheep" participate in an equivalence relation in the context "animals" then we would expect a person to pick "sheep" as the correct answer. In effect, the response would be in accordance with the derived equivalence relation between two already established separate equivalence relations. . . . We take the view that equivalence-equivalence responding is an example of a relational network as defined by relational frame theory (e.g., Barnes & Holmes, 1991; Barnes, 1994; Hayes, 1991, 1994). (1997, p. 3)

The first experiment reported by Barnes et al. (1997) examined the relations between two separate equivalence relations and between two separate nonequivalence relations. Subjects were first trained and tested for the formation of four 3-member equivalence relations (i.e., train: A1→B1, A1→C1, A2→B2, A2→C2, A3→B3, A3→C3, A4→B4, A4→C4, and test: B1↔C1, B2↔C2, B3↔C3, B4↔C4). After successfully passing the equivalence test, subjects were further tested to determine whether they would relate pairs of stimuli to other pairs of stimuli based on their participation in equivalence relations. In effect, subjects were presented with samples composed of two stimuli that were from one derived equivalence relation (e.g., B1C1), and they were given the opportunity to choose comparisons composed of two stimuli that were from a second, separate derived equivalence relation (e.g., B3C3). The result of this first experiment was that a range of subjects, including a 12-year-old boy, successfully related equivalence relations to other, separate equivalence relations, and nonequivalence relations (e.g., B1B2) to other, separate nonequivalence relations (e.g., C3C4), in the absence of explicit reinforcement. Experiment 2 of the study employed the same procedures as were used in Experiment 1, except that subjects were exposed to the equivalence-equivalence test before being exposed immediately, and without further training, to the standard equivalence test. Again, the result of this experiment was that all subjects, this time including a 9-year-old boy, successfully related equivalence relations to other separate equivalence relations, and nonequivalence relations to other separate nonequivalence relations.

Barnes et al. thus provided one of the first empirical behavioral models of analogical reasoning by employing the relational frame concept of equivalence-equivalence responding. However, their model lacked one critical element involved in analogical reasoning as typically observed in the natural environment. For illustrative purposes, consider the classic proportion scheme as seen earlier: A : B :: C : D (i.e., A is to B as C is to D). In this highly abstract case, the actual stimuli A, B, C, and D are completely arbitrary. However, in most cases of analogical reasoning, the arbitrary relations are determined to some degree by the nonarbitrary relations that obtain among some of the stimuli that participate in the network. Consider the example provided by Barnes et al. (1997) as outlined earlier; apple is to orange as dog is to sheep. In this example, the arbitrary equivalence relation between the words "apple" and "orange" is based, to some degree, on the nonarbitrary or physical relation of similarity between actual apples and actual oranges (i.e., both are small, spherical, edible, sweet, etc.). Similarly, the arbitrary equivalence relation between the words "dog" and "sheep" is based on the nonarbitrary relation of similarity between actual dogs and actual sheep (i.e., in general, they are four legged, mobile, hairy, etc). Thus, the equivalence-equivalence or analogical relation between the equivalence relations 'apple-orange' and 'dog-sheep' may be traced back to the formal relations that obtain between particular objects in the environment. This view of analogical reasoning is entirely consistent with the RFT argument that derived relations are arbitrarily applicable but are rarely arbitrarily applied (see Hayes, 1994, pp. 24-25). In fact, from the RFT point of view, analogy often involves the abstraction of both formal and arbitrary relations between or among relational networks. The Barnes et al. model, however, emphasized arbitrary relations and did not address the role of formal relations in analogical reasoning. The current study, therefore, attempted to incorporate into this model the nonarbitrary qualities of analogical reasoning as found in the natural environment. In addition, incorporating nonarbitrary relations into the model would be consistent with Skinner's (1957) interpretation of analogical/metaphorical verbal behavior, and thus the current work may contribute towards a synthesis of Skinner's treatment of verbal behavior with RFT's approach to human language (Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000; Stewart, Barnes-Holmes, Hayes, & Lipkens, 2001).

An Experimental Model

In the present study, as in the Barnes et al. study, subjects were trained and tested for the formation of equivalence and equivalence-equivalence relations. However, in contrast to the Barnes et al. study, the initial training was designed such that nonarbitrary relations, as well as arbitrary relations, would be involved in the emergence of the relational network. This was achieved by using different colored geometric shapes so that color could participate in the formation of the relational network. In the first stage of the experiment, subjects were trained in four conditional discriminations using the colored shapes, and randomly selected nonsense syllables, in a matching-to-sample format. The four conditional discriminations were as follows: Blue Cross → A1 and Red Cross → A2; Blue Circle → B1 and Red Circle → B2; Blue Square → C1 and Red Square → C2; Blue Triangle → D1 and Red Triangle → D2. Subjects were then given two separate equivalence tests.

Test 1 probed for equivalence based on the abstraction of the formal property of color. That is, to see if those nonsense syllables matched with same-color shapes would be consistently matched to each other during testing. Imagine, for example, that D1 (matched with a Blue Triangle) is the sample and that A1 (matched with a Blue Cross) and A2 (matched with a Red Cross) are the comparisons on one particular test trial. Will a subject now choose A1 in the presence of D1 on the basis of the abstraction of the common property of color (i.e., blue)?

Test 2 probed for derived equivalence-equivalence responding. This equivalence-equivalence test was similar to that employed by Barnes et al. (1997), except that the to-be-related equivalence relations involved the abstraction of color. In one trial, for example, A1 and B1 were presented as a compound sample stimulus with two additional compound stimuli as comparisons; C1/D1 and C1/D2. In this case, choosing the C1/D1 comparison was defined as responding in accordance with an equivalence-equivalence relation. In another similar trial, the comparisons were C2/D2 and C2/D1 and choosing C2/D2 (in the presence of A1/B1) was defined as an equivalence-equivalence response. Similar trial types were also presented that probed for nonequivalence/nonequivalence relations (e.g., probing for A1/B2 → C1/D2 relations).

Out of 9 subjects in Experiment 1, 5 completed training and were then given Tests 1 (equivalence) and 2 (equivalence-equivalence), in that order. A further 4 subjects were provided with training and were then presented immediately with Test 2. If subjects failed this test they were then exposed to Test 1. If they completed this test, they were presented with Test 2 once again. The purpose of this procedural variation was to gauge the importance of Test 1 (equivalence formation) with regard to subsequent equivalence-equivalence responding. Experiment 2 repeated the procedure used with the first 5 subjects in Experiment 1 except that additional stimuli were incorporated into the relational networks. Experiment 3 repeated Experiment 2 except that pictures of old and new objects replaced the colored shapes.

Experiment 1

Method

Subjects

Nine subjects, 1 male and 8 female, participated in this experiment. The ages of the subjects ranged from 19 to 25 years (mean = 22.1). Three of the subjects (1, 3, and 9) were nonpsychology postgraduates, five (4, 5, 6, 7, and 8) were nonpsychology undergraduates, and one (2) was a first-year psychology undergraduate. All subjects were recruited through personal contacts and none of them had any prior experience of research in the areas of stimulus equivalence or Relational Frame Theory.

All subjects were exposed to the experimental procedures individually. If subjects did not complete the experiment in one session then they were asked to return on a subsequent day (usually the following day). To ensure that the previously established performances were still intact, at the beginning of the next session, subjects were reexposed to those stages of the experiment that they had previously completed. On some occasions, therefore, subjects could successfully complete a particular stage in the experiment, but would be reexposed to that stage for a second time. All subjects were asked not to discuss their participation in the experiment with anyone, and sessions were arranged so that subjects did not meet each other in the vicinity of the laboratory. When the experiment was finished all subjects were thanked and fully debriefed.

Apparatus and Materials

Each subject was seated at a table in a small experimental room containing an Apple Macintosh TM Microcomputer (Performa 630) which displayed both colored stimuli and black characters on a white background. Stimulus presentation and the recording of responses were controlled by the computer application 'Psyscope,' a graphical system for the design of psychology experiments (see Cohen, McWhinney, Flatt, & Provost, 1993; Roche, Stewart, & Barnes-Holmes, 1999). A response involved using the computer mouse to click on the chosen stimulus.

Computer-generated stimuli. The experimental stimuli included eight colored shapes: a blue cross (Blue1), a red cross (Red1), a blue circle (Blue2), a red circle (Red2), a blue square (Blue3), a red square (Red3), a blue triangle (Blue4), and a red triangle (Red4). Each colored shape measured approximately 3 square inches. Eight nonsense syllables were also employed: YIM(A1), CUG(A2), DAX(B1), VEK(B2), PUK(C1), JOM(C2), MAU(D1), and ZID(D2). These nonsense syllables and the eight colored shapes will be referred to using their respective alphanumeric labels (subjects were not exposed to these labels).

Matching-to-sample. The experiment involved conditional discrimination 'matching-to-sample' training during which the colored shapes served as sample stimuli and the nonsense syllables served as comparisons. For matching-to-sample (MTS) trials, the sample stimulus appeared in the center of the screen, approximately 1.5 in. from the top. Following a 1.5-s delay, the comparison stimuli appeared in positions to the left and right of the sample, approximately 1.5 in. from the bottom of the screen.

On each MTS trial the positions of the comparison stimuli were varied randomly from left to right (i.e., on any trial the reinforced comparison could appear on either the left or the right with equal probability). Participants chose a comparison using the mouse. This involved moving the cursor over the to-be-chosen comparison and then clicking the mouse button. The correct completion of a MTS training trial removed the stimulus display (i.e., the screen went blank) and produced the word "Correct" in the center of the screen, accompanied simultaneously by the computer-generated, spoken word "correct." The incorrect completion of a MTS training trial removed the stimulus display and produced the word "Wrong" in the center of the screen accompanied simultaneously by the computer-generated, spoken word "wrong." A 1-s intertrial interval (i.e., the screen cleared and remained blank) followed all programmed consequences. On all test trials the computer omitted all feedback messages and proceeded directly to the intertrial interval.

Procedure

Experimental sequence. All 9 subjects were trained and tested individually during sessions that lasted between 40 and 140 minutes each. The maximum number of sessions required to complete the experiment was two.

All subjects were exposed initially to conditional discrimination training in which reinforcement was contingent on choosing a particular nonsense syllable in the presence of each of eight colored shapes (Figure 1, upper panel). Subjects 1 to 5 were then exposed to Test 1 which tested for equivalence based on the abstraction of color (i.e., the consistent pairing of nonsense syllables previously chosen in the presence of same-color shapes). If subjects passed Test 1 they were then exposed to Test 2 which tested for equivalence-equivalence relations (for the purposes of communication, 'equivalence-equivalence' refers to both equivalence-equivalence and nonequivalence/nonequivalence relations). Subjects 6 to 9 were exposed immediately after initial training to Test 2. If they *failed* this latter test they were then exposed to Test 1 and if they passed this test they were then reexposed to Test 2. The procedural details of each of these training and testing sessions are outlined subsequently.

Training. All subjects were trained initially in eight MTS tasks in which the sample stimuli were colored shapes and in which the comparison stimuli were three-letter nonsense syllables (e.g., CUG, DAX, etc.). Each subject was seated in front of the computer monitor and keyboard and was asked to wear a set of headphones through which they could receive aural feedback (see 'Matching-to-sample' section) from the computer. The experimenter left the room and the subject then read the following instructions, which appeared on the computer screen:

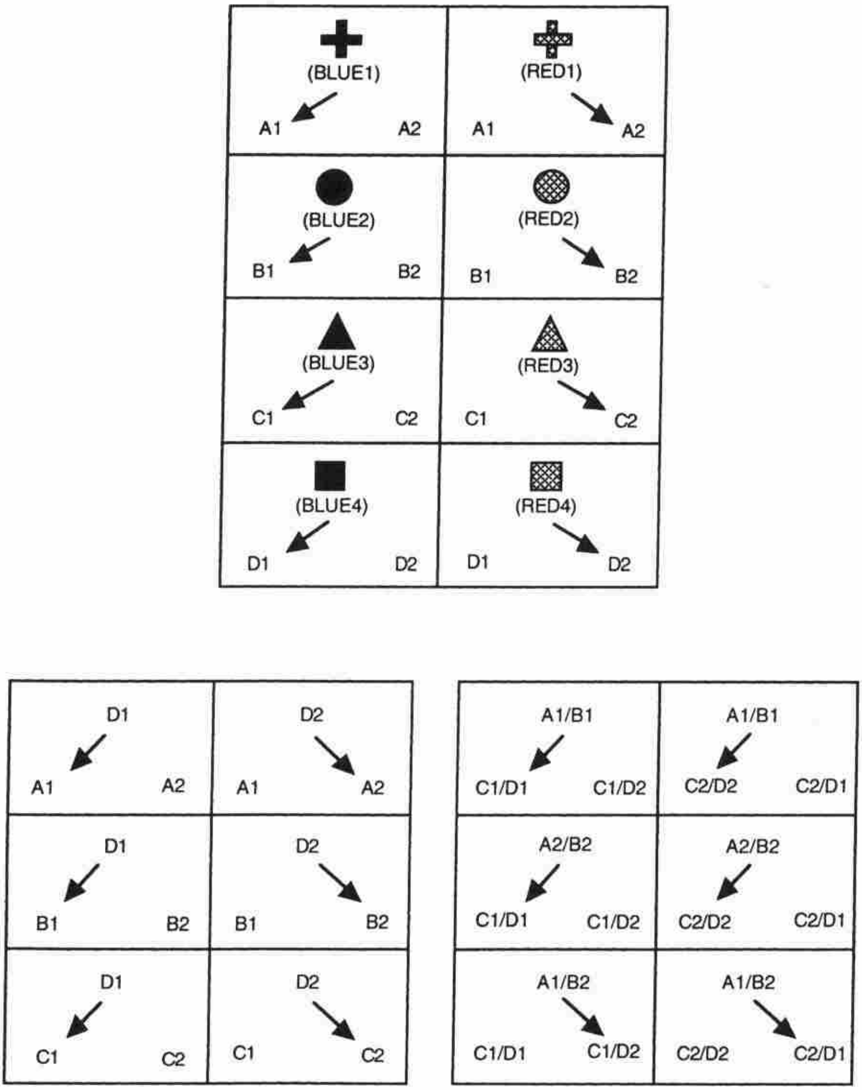

Figure 1. (i) Upper panel: A schematic diagram of the eight trial types employed in training for Experiment 1. (ii) Lower left panel: A schematic diagram of the six trial types employed in equivalence testing for Experiment 1. (iii) A schematic diagram of the six trial types employed in equivalence-equivalence testing for Experiment 1.

> In a moment some objects will appear on this screen. First, an object will appear at the top of the screen and then two objects will appear at the bottom. Your task is to choose one of the two objects at the bottom of the screen. You can do this by placing the mouse cursor on

> top of it and then 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.
>
> Click the mouse when you are ready to begin.

On each MTS trial one of eight colored shapes (Blue1, Blue2, Blue3, Blue4, Red1, Red2, Red3, or Red4) was presented as a sample, followed 1.5 s later by two comparison stimuli. This training phase involved four conditional discriminations, each of which involved two tasks (see Figure 1, upper panel). For the first conditional discrimination, Blue1 was the sample in one task while Red1 was the sample in the other. The comparisons in both tasks were A1 and A2: When Blue1 was the sample A1 was the correct choice whereas when Red1 was the sample A2 was the correct choice. Thus, these tasks trained the relations Blue1-A1 and Red1-A2. The remaining stimulus relations trained in this way are as follows: Blue2-B1, Red2-B2, Blue3-C1, Red3-C2, Blue4-D1, Red4-D2.

Each of the eight MTS trial types was presented in a quasi-random order in separate blocks of 40 trials (i.e., each trial type was presented five times per block) until a subject produced at least four out of five correct responses on each of the eight trial types in one individual training block. At this point, the subject proceeded to one of the two test phases.

Test 1. This was a matching-to-sample equivalence test in which the equivalence relations were based on the abstraction of color. Note that, A1, B1, C1, and D1 had all been matched during training to blue shape stimuli whereas A2, B2, C2, and D2 had all been matched to red shape stimuli. Before exposure to Test 1 and all subsequent testing phases, subjects were provided with the following instructions that appeared on the computer screen:

> In a moment some objects will appear on this screen. First, an object will appear at the top of the screen and then two objects will appear at the bottom. Your task is to choose one of the two objects at the bottom of the screen. You can do this by placing the mouse cursor on top of it and then clicking the mouse button. During this phase, THE COMPUTER WILL NOT TELL YOU WHETHER OR NOT YOUR CHOICES ARE CORRECT. If you want to choose the object on the left then you should click on the object on the left. If you want to choose the object on the right then you should click on the object on the right.
>
> Click the mouse when you are ready to begin.

During Test 1, subjects were not tested for all of the possible emergent relations that would normally define complete equivalence. A full test was not presented for three reasons. First, we wished to avoid exposing subjects to any of the colored shapes during the test phases. Presenting colored shapes during test phases may have led to unexpected forms of stimulus compounding among the shapes and nonsense syllables *during the test*, and thus it would be difficult to isolate the abstraction of color *during training* as the basis for equivalence responding. Second, the experiment also included an equivalence-equivalence test, which functioned as an additional test for equivalence responding, thereby compensating for the use of a partial equivalence test. Third, because we expected that subjects may require multiple exposures to blocks of training and testing, we aimed to minimize the number of trial types contained within each of these blocks. In so doing, we hoped to avoid undue subject fatigue and high dropout rates that had occurred in earlier pilot studies (see also Barnes et al., 1997).

Test 1 consisted of six MTS trial-types that were designed to test for a subset of the experimenter-designated emergent relations. Three trial types presented D1, and three presented D2, as sample stimuli. The three comparison pairs, A1 and A2, B1 and B2, and C1 and C2, were presented across the six trial types (see Figure 1, left lower panel). These trial types were presented in a quasi-random order, with each type appearing five times across a block of 30 trials. No feedback was presented on any trial.

Stability criterion. Subjects were required to reach a stability criterion of 80% consistent responding. This meant that subjects were exposed to Test 1 until they chose the same comparison at least four times out of every five exposures to a particular trial type, irrespective of whether their response patterns were in accordance with the predicted relations. It should be noted, therefore, that if a subject chose the correct comparison five times out of five across seven of the trial types, but emitted only three correct responses on the eighth, he or she would fail the test despite achieving a 95% correct performance. It was agreed that inconsistency after four exposures to the test would be taken as a subject's final performance, and interpreted as 'consistent inconsistency.'

Test 2. During this second test, which probed for equivalence-equivalence relations, subjects were presented with one pair of nonsense syllables as the sample stimulus and two other nonsense syllable pairs as comparison stimuli. Each nonsense syllable pair included either two nonsense syllables that participated in an experimenter-designated equivalence class (e.g., A1/B1) or two nonsense syllables that participated in two separate experimenter-designated equivalence classes (e.g., A1/B2). The test consisted of six MTS trial-types, two of which presented the complex stimulus A1/B1 as sample, two of which presented the complex stimulus A2/B2 as sample, and two of which presented the complex stimulus A1/B2 as sample (see Figure 1, right lower panel). The two comparison pairs C1/D1 and C1/D2, and C2/D2 and C2/D1, were presented across the six trial types. Based on the findings reported by Barnes et al. (1997), it was predicted that subjects would match comparisons that contained two members of an equivalence class (e.g., C1/D1) to samples that also contained two members of an equivalence class (e.g., A1/B1). It was also predicted that subjects would match nonequivalent comparisons (e.g., C1/D2) to nonequivalent samples (e.g., A1/B2). These six trial types were presented in a quasi-random order, with each occurring five times within a block of 30 trials. No feedback occurred on any of the trials.

The reader should note from Figure 1 (right lower panel) that the A2/B2-C1/D1 and A1/B1-C2/D2 trial types constitute the most robust test probes for equivalence-equivalence responding. Specifically, these relational responses involve matching the members of one equivalence class to a completely separate equivalence class. In the other four trial types, subjects could emit the predicted responses based on complex forms of equivalence (rather than equivalence-equivalence) responding. For example, C1/D1 could be matched to A1/B1 based on the participation of all four stimuli in a single equivalence class. In addition, C1/D2 could be matched to A1/B2 based on the participation of A1 and C1 in one class and B2 and D2 in another class (i.e., this would involve matching within two separate classes rather than matching one class to another). However, if subjects respond in accordance with equivalence, rather than equivalence-equivalence, they should choose the incorrect comparisons on the two "robust" trial types. For example, given A1/B1 as a sample and the comparisons C2/D2, C2/D1, a subject could choose the latter "incorrect" comparison because D1 participates in an equivalence class with A1 and B1. However, the subject could not choose the "correct" comparison C2/D2, because neither of these elements participates in an equivalence class with the two sample elements.

Stability criterion. Subjects were exposed to Test 2 until they chose the same comparison at least four times out of every five exposures to a particular trial type, irrespective of whether their response patterns were in accordance with the predicted relations. In effect, subjects were required to reach a stability criterion of 80% consistent responding. It should be noted, however, that if subjects chose the correct comparison five times out of five across five of the trial types, but emitted only three correct responses on the sixth, they would fail the test despite achieving 93.3% correct. It was agreed that inconsistency after four exposures to the test would be taken as the subject's final performance, and interpreted as 'consistent inconsistency.'

Results and Discussion

Subjects' performances across training and testing phases can be seen in Table 1. Subjects 1-5 were exposed to training followed by Tests 1 (equivalence based on the abstraction of the common property of color) and 2 (equivalence-equivalence relations) respectively. Exposure to the latter test was contingent on the successful completion of the first. Subjects 6-9 were exposed to training followed immediately by Test 2. If subjects failed to complete this test then they were subsequently exposed to Test 1, until they passed (within a maximum of four exposures), before being re-exposed to Test 2.

Four of the subjects (1, 2, 3, and 4) who received Test 1 before Test 2 completed training within 200 trials. Subjects 1, 2, and 4 passed Test 1 on the first exposure, and Subject 3 passed after just one further exposure to training. All 4 of these subjects then passed Test 2 within three exposures. Subject 5 received 440 training trials and then failed on her first exposure to Test 1. She was exposed to a further 80 training trials before passing the test. However, she failed to produce consistent responding after four exposures to Test 2. The remaining 4 subjects, who received Test 2 immediately after training, required a maximum of 240 training trials. Two of these subjects (8 and 9) passed the equivalence-equivalence test during their first series of exposures. The remaining 2 subjects (6 and 7) failed Test 2 on the first series of exposures, but passed it on the second series after successfully completing Test 1 in the interim.

In summary, these data clearly show that subjects could successfully demonstrate (a) equivalence responding on the basis of the abstraction of the common formal property of color, and (b) equivalence-equivalence responding also based on color abstraction. Furthermore, the data indicate that passing Test 1 (equivalence) might function, for some subjects, as an important historical variable for the successful completion of Test 2 (equivalence-equivalence).

Experiment 2

Experiment 2 replicated and extended Experiment 1 by increasing the number of stimuli that participated in the derived relational networks. Rather than simply training Blue1→A1, for example, two matching-to-sample trial-types were used to establish Blue1→A1 *and* A1→W1. The remaining seven trial-types from Experiment 1 were similarly extended (e.g., Red1→A2 and A2→W2, Blue2→B1→X1). Consequently, Experiment 2 involved a total of 16 trial types, and the test trials probed for multinodal equivalence and equivalence-equivalence relations. The general purpose behind this extension to Experiment 1 was based on the assumption that analogical reasoning is a relatively advanced form of verbal behavior. Consequently, the relational networks on which analogical reasoning is based may sometimes involve relatively extended and complex relations. Consider, for example, the analogical network 'apple' (A) is to 'orange' (B) as 'dog' (C) is to 'sheep' (D). Each of these words is in an equivalence relation with other words. 'Apple' (A), for example, might be equivalent in certain contexts to 'Golden Delicious' (E); 'orange' (B) might be equivalent to 'Jaffa' (F); 'dog' (C) might be equivalent to 'Terrier' (G); while 'sheep' (D) might be equivalent to 'ram' (H). Thus, a new analogy might be formed as follows: 'Golden Delicious' (E) is to 'Jaffa' (F) as 'Terrier' (G) is to 'Ram' (H). Demonstrating multinodal equivalence and equivalence-equivalence would also extend the Barnes et al. (1997) study, which utilized only three-member equivalence classes across each of three experiments.

Table 1

Training Trials and Correct Responses Across Tests 1 and 2 for Subjects 1-9 in Experiment 1

Subject No.	Training	Test 1	Test 2
S 1	120	30/30 (Pass)	23/30 (Fail)
	40		30/30 (Pass)
S 2	120	30/30 (Pass)	17/30 (Fail)
	40		27/30 (Fail)
	40		28/30 (Pass)
S 3	80	21/30 (Fail)	
	40	30/30 (Pass)	27/30 (Pass)
S 4	200	30/30 (Pass)	24/30 (Fail)
	40		29/30 (Pass)
S 5	440	20/30 (Fail)	
	80	30/30 (Pass)	21/30 (Fail)
	40		19/30 (Fail)
	40		13/30 (Fail)
	40		13/30 (Fail)
S 6	200		18/30 (Fail)
	40		19/30 (Fail)
	40		14/30 (Fail)
	40		16/30 (Fail)
	40	28/30 (Pass)	15/30 (Fail)
	40		19/30 (Fail)
	40*	30/30 (Pass)	19/30 (Fail)
	40		26/30 (Pass)
S 7	240		15/30 (Fail)
	40		14/30 (Fail)
	40		14/30 (Fail)
	40		17/30 (Fail)
	80	18/30 (Fail)	
	80	16/30 (Fail)	
	40	23/30 (Fail)	
	40	29/30 (Pass)	
	40*	30/30 (Pass)	22/30 (Fail)
	40		30/30 (Pass)
S 8	120		16/30 (Fail)
	40		27/30 (Pass)
S 9	160		17/30 (Fail)
	40		24/30 (Fail)
	40		24/30 (Fail)
	40		29/30 (Pass)

Note. An asterisk after a figure (e.g., 40*) indicates the beginning of the next session of training and testing.

Method

The general procedures employed in Experiment 2 were similar to those used in Experiment 1, except that additional training and testing stages were employed. These are described below.

Subjects

Four subjects, 3 female and 1 male, participated in this experiment. Their ages ranged from 18 to 23 (mean = 21.4). Two of the subjects (10 and 11) were nonpsychology postgraduates, and the other two (12 and 13) were nonpsychology undergraduates. All subjects were recruited through personal contacts and none of them had any prior experience of research in the areas of stimulus equivalence or Relational Frame Theory. The same general conditions of participation as specified for Experiment 1 (e.g., training and testing individually) also applied in Experiment 2.

Apparatus and Materials

The apparatus and materials were identical to those used in Experiment 1 except that the experimental stimuli included eight additional nonsense syllables as follows; PAF(W1), TOB(W2), ROG(X1), KED(X2), BEH(Y1), YUB(Y2), KAS(Z1), BOC(Z2). Once again, the alphanumeric labels provided in brackets will be used to identify each of the nonsense syllables.

Experimental Tasks

Matching-to-sample. There were two separate stages of MTS training. In Stage 1, colored shapes served as samples and nonsense syllables served as comparisons. In Stage 2, nonsense syllables served as both samples and comparisons. In all other respects MTS training and testing were the same as in Experiment 1.

Procedure

Experimental sequence. All 4 subjects were trained and tested individually during sessions that lasted between 60 and 150 minutes each. The maximum number of sessions required to complete the experiment was two.

Experiment 2 consisted of two stages of training and testing. The procedures for Stage 1 were identical to those specified for Subjects 1-5 in Experiment 1 (i.e., initial training followed by Tests 1 and 2, respectively). Those who successfully completed this first stage went on to Stage 2, the procedures for which included additional training, followed by Tests 3 and 4 (see Figure 2). The additional training was similar to Stage 1 training, except that across the eight trial types the eight arbitrary stimuli from Experiment 1 were presented as samples, with eight additional arbitrary stimuli (W1, W2, X1, X2, Y1, Y2, Z1, Z2) presented as comparisons (see Figure 2, upper panel). Subjects who successfully completed the training were then exposed to Tests 3 and 4. These tests were similar to Tests 1 and 2, respectively, except that the novel W, X, Y, and Z stimuli replaced the A, B, C, and D stimuli, respectively (see Figure 2, lower left and lower right panels).

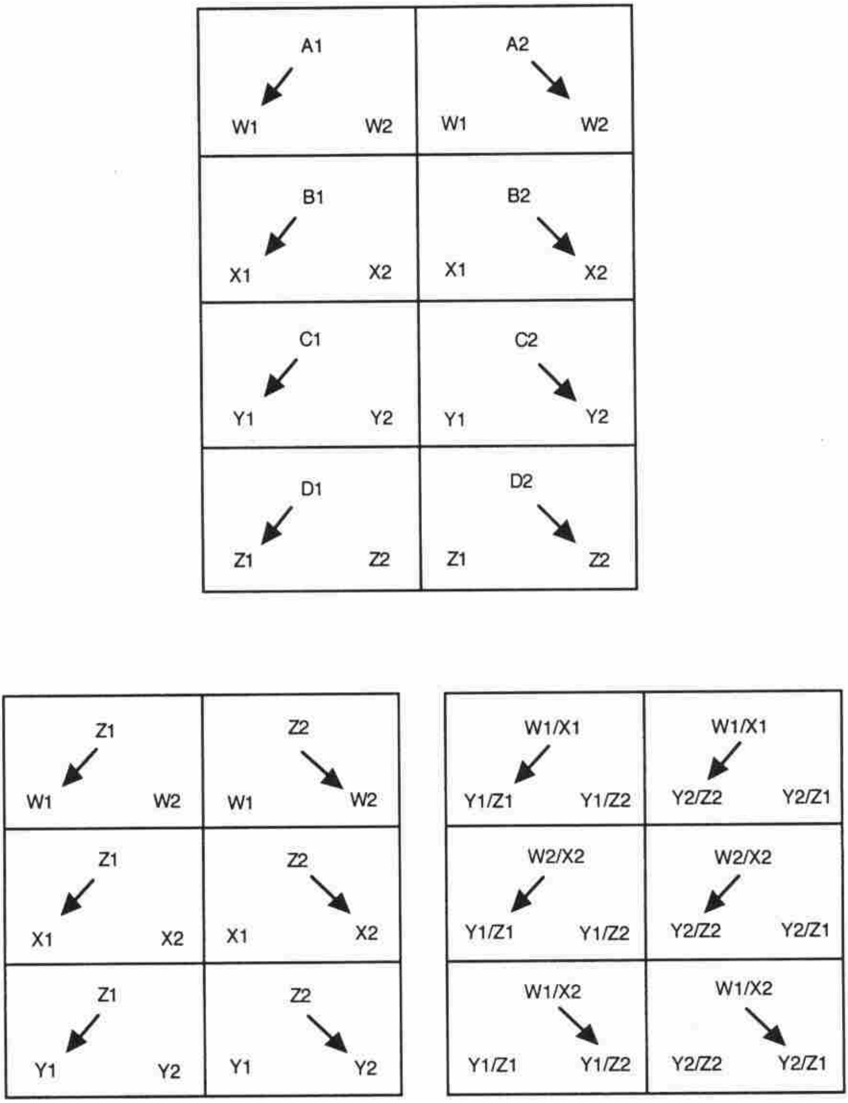

Figure 2. (i) Upper panel: A schematic diagram of the eight trial types employed in Stage 2 training for Experiment 2. (ii) Lower left panel: A schematic diagram of the six trial types employed in Stage 2 equivalence testing for Experiment 2. (iii) A schematic diagram of the six trial types employed in Stage 2 equivalence-equivalence testing for Experiment 2.

Results and Discussion

The results of Experiment 2 are presented in Table 2. Subject 10 reached the training criterion (Stage 1) after only 80 trials. He then passed on his first exposure to Test 1, and required only two exposures to Test 2 before passing the second test. This subject successfully trained in Stage 2, again after 80 trials, and then he successfully passed Test 3, and then Test 4. A broadly similar pattern of results was observed for Subjects 11 and 13, although the former required many more training and testing trials (across two separate sessions) than were required for Subjects 10 and 13. The remaining subject (12) successfully completed Stage 1 training and passed Test 1, but failed Test 2 across four consecutive exposures, and her participation was therefore terminated at that point.

These data support and extend the findings of Experiment 1, in that an additional 3 subjects demonstrated both equivalence and equivalence-equivalence responding based on the abstraction of the common physical property of color. Furthermore, in Experiment 2 the derived equivalence and equivalence-equivalence responding involved extended relational networks, thereby making more plausible the RFT model of analogical reasoning presented in Experiment 1.

Table 2

Training Trials (Stages 1 and 2) and Correct Responses Across Tests 1, 2, 3, and 4 for Subjects 10-13 in Experiment 2

Subject No.	Training (Stage 1)	Test 1	Test 2	Training (Stage 2)	Test 3	Test 4
S 10	80	28/30 (P)	26/30 (F)			
	40		30/30 (P)	80	28/30 (P)	29/30 (P)
S 11	80	30/30 (P)	15/30 (F)			
	40		17/30 (F)			
	40		17/30 (F)			
	40		29/30 (P)			
	40*	30/30 (P)	30/30 (P)	80	21/30 (F)	
	40			40	10/30 (F)	
	40			40	27/30 (F)	
	40			40	29/30 (P)	26/30 (F)
	40			40		27/30 (P)
S 12	160	30/30 (P)	20/30 (F)			
	40		20/30 (F)			
	40		25/30 (F)			
	40		22/30 (F)			
S 13	80	17/30 (F)				
	40	30/30 (P)	28/30 (P)	80	29/30 (P)	30/30 (P)

Note. An asterisk after a figure (e.g., 40*) indicates the beginning of the next session of training and testing.

Experiment 3

One possible criticism of Experiments 1 and 2 is that they lack ecological validity. In these experiments, subjects' derived equivalence-equivalence responding was based on the abstraction of the simple property of color rather than shape. In real life, however, analogical responding typically involves the abstraction from multidimensional stimuli of much more complex properties than color. Consider, for example, the analogy, 'chick' is to 'baby' as 'hen' is to 'adult.' Responding in accordance with this more realistic analogy involves the same basic relational network (i.e., equivalence-equivalence) as demonstrated in Experiments 1 and 2. However, whereas the latter involved the abstraction of the simple property of color from relatively simple stimuli, the former involves the abstraction of the property of age from relatively complex stimuli. The purpose of Experiment 3 was to provide an ecologically valid model of analogical reasoning, in which equivalence-equivalence responding was based on the abstraction of age rather than color. In effect, this experiment was similar to Experiment 2, except that subjects received pretraining in which discriminating between old and new stimuli (e.g., an old bridge, a young lamb, an old man, a new van) was established. The main purpose of this pretraining was to ensure that subjects could first abstract the property of age. Only then were subjects trained and tested for age-related analogical reasoning.

Method

Subjects

Three subjects, 2 female (both 18 years old) and 1 male (19 years old), participated in this experiment. All 3 were first-year psychology undergraduates. They were recruited through personal contacts and none had any prior experience of research in the areas of stimulus equivalence or relational frame theory. The same general conditions of participation, as specified for Experiments 1 and 2, also applied in Experiment 3.

Apparatus and Materials

The apparatus and materials were identical to those used in Experiment 2 except for the following. A range of color pictures measuring approximately 5 square inches, each of either a 'new' or an 'old' object, were used as sample and comparison stimuli during the pretraining/pretesting and training stages. In addition, some of the stimuli used during pretraining/pretesting consisted of similar color pictures but with a nonsense syllable superimposed upon them in light blue.

Procedure

Experimental sequence. All 3 subjects were trained and tested individually during sessions that lasted between 40 and 130 minutes each. The maximum number of sessions required to complete the experiment was two. Experiment 3 consisted of a stage of pretraining followed by two separate stages of training and testing similar to those in Experiment 2.

Pretraining/pretesting. This stage of the experiment consisted of four substages designated Pretraining 1, Pretesting 1, Pretraining 2, and Pretesting 2. This whole stage emerged out of an extensive process of pilot research, the details of which are beyond the scope of the current paper (interested readers may contact the authors for the background details of this work). Subjects reached a particular substage only after successfully completing each of the previous substages. For example, in order to reach Pretraining 2, subjects were required to first pass Pretraining 1 and then Pretesting 1. Only after the successful completion of all four substages could subjects proceed to Stage 1 training in the main experiment.

In Pretraining 1, subjects were presented with a sequence of 10 matching-to-sample tasks. In each task, one particular color picture was used as the sample stimulus and two others as comparison stimuli. The same 10 trial types were used for all 3 subjects. A schematic representation of all 10 trial types is shown in the top section of Figure 3, whilst an example of one of the trial types is shown in the bottom section. In five of these tasks (on the left side of Figure 3, top section) the sample stimulus was a picture of a new or young object, whilst in the other five tasks (on the right side of Figure 3, top section) the sample stimulus was a picture of an old or aged object. The two comparisons always included a picture of an old object and a picture of a new object. Reinforcement was contingent upon picking an old object in the presence of an old object, and a new object in the presence of a new object. The 10 trial types were presented in 10-trial blocks, each task being presented once. Only after subjects demonstrated 10 correct responses across one 10-trial block were they allowed to proceed to the next substage. If subjects failed to produce such a performance they were repeatedly exposed to blocks of 10 trials until they completed a block without error.

Pretesting 1 was similar to Pretraining 1. However, whereas Pretraining 1 involved the presentation of 10 MTS tasks, each of which contained a particular set of predesignated pictures, the tasks presented in Pretesting 1 included novel pictures drawn at random from four different picture-pools (i.e., 'old pictures as sample,' 'new pictures as sample,' 'old pictures as comparison,' and 'new pictures as comparison'; see Figure 4). Each pool contained six novel pictures (i.e., not used in Pretraining 1). Once again, subjects were required to choose 'old' in the presence of 'old' and 'new' in the presence of 'new' across a block of 10 trials, but this time no feedback was provided after any trial. If subjects failed to produce such a performance they were reexposed to Pretraining 1 and then to Pretesting 1. This cycle of pretraining and pretesting continued until they successfully completed both substages in sequence.

Pretraining 2 was identical to Pretraining 1 except that each of the color pictures used as samples and comparisons had a particular nonsense syllable superimposed upon it in light blue coloring (see Figure 3, bottom section). As in Pretraining 1, reinforcement was contingent upon choosing 'new' in the presence of 'new' and 'old' in the presence of 'old.' However, in this particular substage, subjects were also, incidentally, matching nonsense syllables. More specifically, the following nonsense-syllable matching performances were 'inadvertently' reinforced; E1-E1, F2-F2, E1-F1, F1-E1, E2-F2, F2-E2 (see Figure 3, top section). Given this

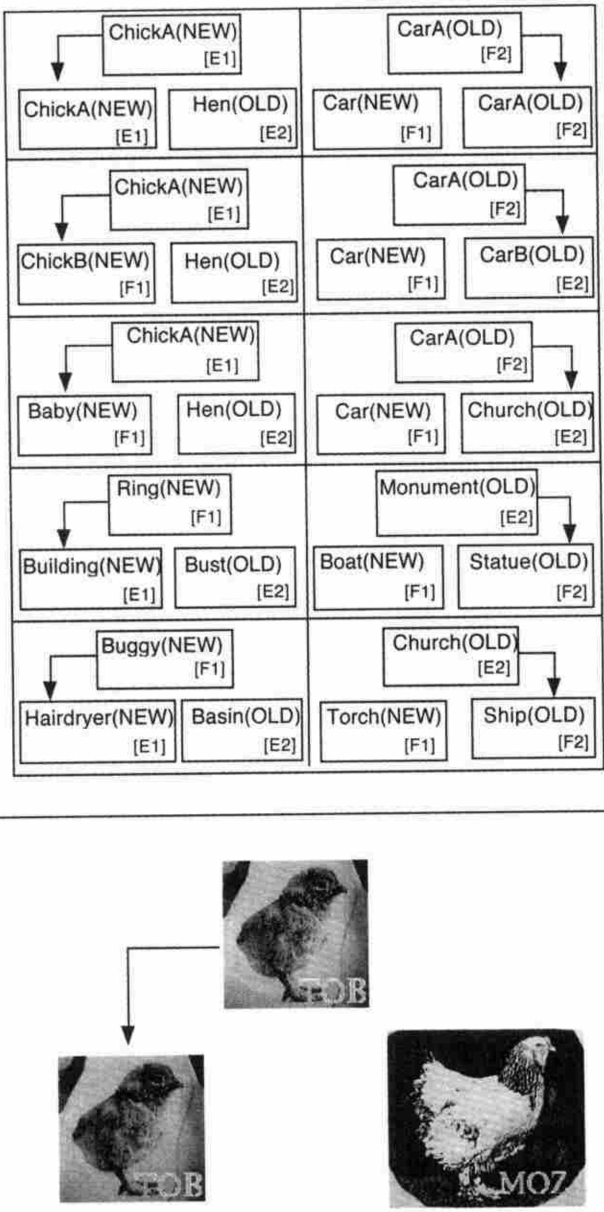

Figure 3. (i) Top: A schematic diagram of the 10 trial types employed in Pretraining 1 and Pretraining 2 in Experiment 3. The alphanumerics in the lower left of each of the pictures represent nonsense syllables which appeared during Pretraining 2 only. (ii) Bottom: An example of one of the trial types employed in Pretraining 1 and Pretraining 2 in Experiment 3. The nonsense syllables in the lower left of each of the pictures appeared during Pretraining 2 only.

history of reinforcement, it was predicted that E1 would become equivalent to F1 and that E2 would become equivalent to F2. That is, following this training, subjects should match E1 to F1, and vice versa, and E2 to F2, and vice versa, in a matching-to-sample context (i.e., the next substage). As before, only after subjects demonstrated 10 correct responses across one 10-trial block were they allowed to proceed to the next substage. If subjects failed to produce such a performance they were returned to Pretraining 1 and proceeded once again through each substage. This iterative cycle continued until they completed all three substages without error.

	Samples	Comparisons
Old	-coin -watch -plate -fossil -stone circle -statue	-bowl -motor vehicle -old woman -cup -garden pot -chest
New	-plane -mixer -necklace -pen -kettle -calf	-clock -phone -disc -train -fax -toaster

Figure 4. The four picture pools from which the stimuli appearing as samples and comparisons in Pretesting 1 in Experiment 3 were chosen randomly.

Pretesting 2 was the fourth and final substage of pretraining. In this particular substage, subjects were presented with four trial-types, each repeated twice in a block of eight trials (see Figure 5). On each trial, one nonsense syllable was the sample stimulus and two others were the comparisons (E1-F1/F2; E2-F2/F1; F1-E1/E2; F2-E2/E1). If subjects failed to produce eight correct responses across a block of eight trials, they were returned to Pretraining 1 and proceeded once again through each substage. This iterative cycle continued until they completed all four substages without error. Only at this point were they allowed to proceed to the initial training phase of the main experiment.

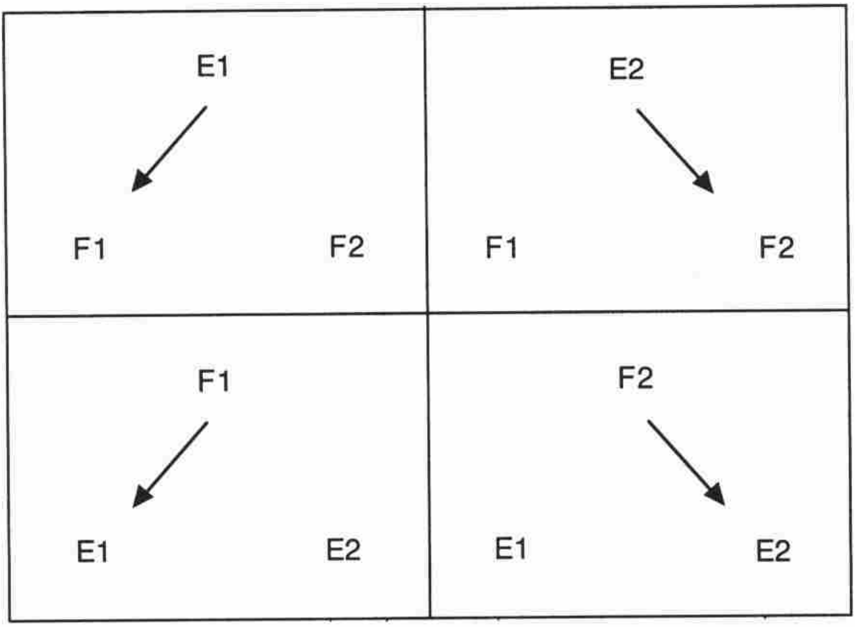

Figure 5. A schematic representation of the four trial types employed in Pretesting 2 in Experiment 3.

Training and testing. Following the whole pretraining stage, Experiment 3 consisted of two further stages of training and testing similar to those employed in Experiment 2. In summary, subjects were first trained and tested for the formation of two 4-member equivalence classes (A1-B1-C1-D1 and A2-B2-C2-D2) based on the abstraction of a common formal property and were then tested for equivalence-equivalence responding (e.g., A1/B1→C1/D1). Further training and testing then extended the equivalence-equivalence relations to include the novel W, X, Y, and Z stimuli. Unlike Experiment 2, however, the sample stimuli employed in the initial training stage (Stage 1 training) were old and new objects rather than colored shapes. Specifically, in Experiment 3, the sample stimuli used were color pictures of new and old 'objects'; a young lamb, a new truck, a rose bud, a new pot, an old bridge, an old man, an old monument, and an old bench (see Figure 6 for a schematic representation of the training tasks). All subsequent trial types were identical to those employed in Experiment 2. Thus, Experiment 3 tested for the abstraction of the common property of age and for the derivation of analogical relations based on this abstraction.

The reader should note that, if there was a break of more than 24 hr between sessions, subjects were returned to the very beginning of the experiment (i.e., commencing with pretraining/pretesting). If, in one particular session, subjects failed any of the four tests subsequent to

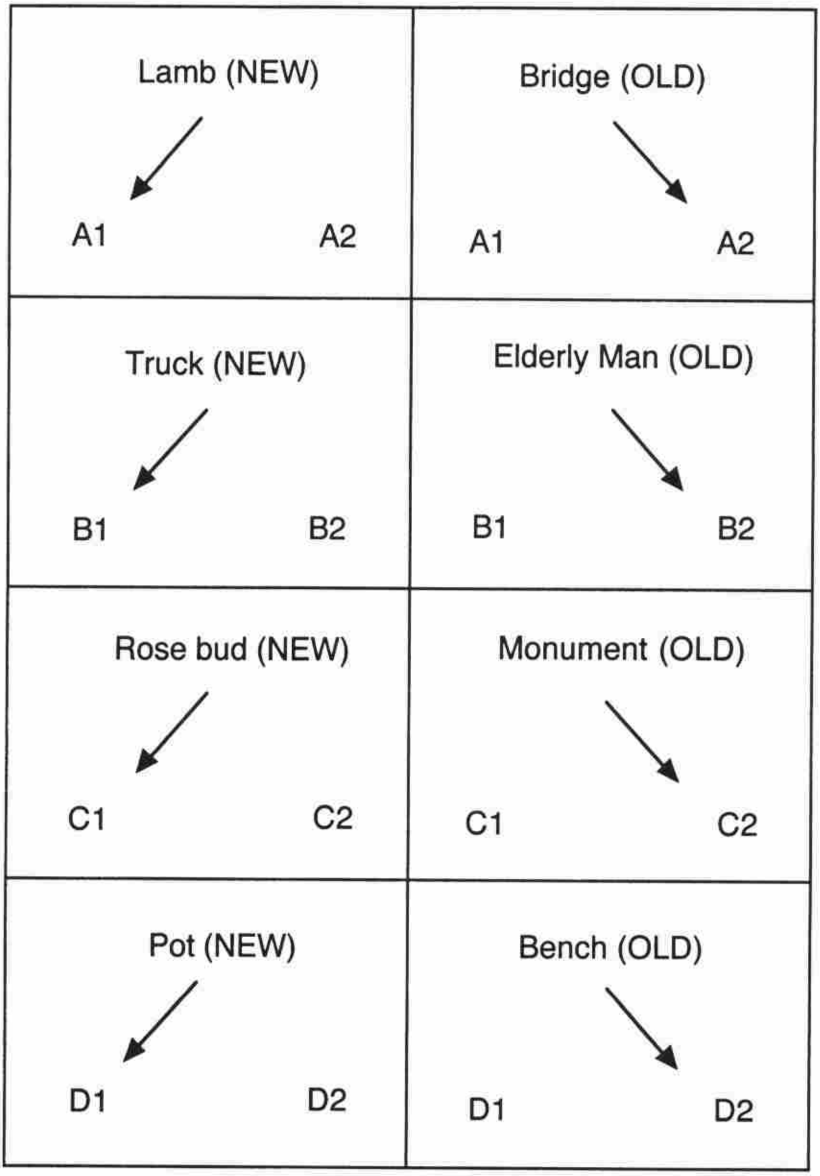

Figure 6. A schematic representation of the eight trial types employed in Stage 1 training in Experiment 3.

pretraining/pretesting, they were not given pretraining again but were simply reexposed to the relevant training stages from the main experiment (i.e., those training stages to which they had already been exposed). Note that, subjects were not exposed to test stages that they had previously passed.

Results and Discussion

Subjects' performances across pretraining/pretesting, and the training and testing phases from the main experiment, may be seen in Table 3. Subject 14 completed Pretraining 1 in 10 trials. He then passed on his first exposure to Pretesting 1 and also completed Pretraining 2 after 10 trials. However, he failed on his first exposure to Pretesting 2 and was thus reexposed to the previous substages. He successfully completed all three substages once again and then passed Pretesting 2 on the second attempt. This subject was then exposed to 40 training trials and subsequently passed Test 1 (equivalence) with 100% correct responding. He failed Test 2 (equivalence-equivalence) on his first exposure, was reexposed on this basis to Stage 1 training, and passed Test 2 on his second exposure. He then

Table 3

Pretraining Trials, Correct Responses in Pretesting, Training Trials (Stages 1 and 2), and Correct Responses Across Tests 1, 2, 3, and 4 for Subjects 14, 15, and 16 in Experiment 3

S. No.	Pre. Tr.1	Pre. Tt.1	Pre. Tr.2	Pre. Tt.2	Train Stg.1	Test 1	Test 2	Train Stg.2	Test 3	Test 4
S14	10	10 P	10	7/8 F						
	10	10 P	10	8/8 P	40	30/30P	20/30F			
					40		29/30P	80	28/30P	28/30P
S15	20	10 P	10	8/8 P	80	30/30P	28/30P			
	10*	10 P	10	8/8 P	40	30/30P	30/30P	40	30/30P	30/30P
S16	20	10 P	10	6/8 F						
	10	10 P	10	8/8 P	80	30/30P	29/30P			
	10*	10 P	10	8/8 P	40	29/30P	30/30P	40	30/30P	30/30P

Note. 'Pre.Tr.1' is an abbreviation of 'Pretraining 1'; 'Pre.Tt.1' is an abbreviation of 'Pretesting 1'; 'Pre.Tr.2' is an abbreviation of 'Pretraining 2'; and 'Pre.Tt.2' is an abbreviation of 'Pretesting 2.' An asterisk after a figure (e.g., 40*) indicates the beginning of the next session of training and testing.

received 80 Stage 2 training trials (extending the equivalence classes) and went on to successfully complete Tests 3 (equivalence) and 4 (equivalence-equivalence). Broadly similar response patterns were observed for Subjects 15 and 16, although both of these subjects required two sessions rather than one, as was the case for Subject 14.

These results support and extend the findings of Experiments 1 and 2, in that an additional 3 subjects demonstrated both equivalence and equivalence-equivalence responding based on the abstraction of a common physical property. Furthermore, in Experiment 3, the equivalence and equivalence-equivalence responding was based on the abstraction of the relatively complex property of age as opposed to the simple physical property of color.

General Discussion

The experiments in the present study provide further empirical support for the RFT definition of analogical reasoning as equivalence-equivalence responding. Out of a total of 16 subjects, 14 demonstrated both equivalence and equivalence-equivalence responding over the course of this study. These experiments also demonstrate an extension of the behavioral model of analogical reasoning provided by Barnes et al. (1997). This was accomplished in two ways. First, the equivalence-equivalence responding in the Barnes et al. study was based on arbitrarily applicable relational responding only, but in the current work equivalence-equivalence responding was based on nonarbitrary as well as arbitrary relational responding. Specifically, in Experiments 1 and 2, the nonarbitrary relations involved color, whilst in Experiment 3, they involved age. According to RFT, analogical reasoning necessarily involves nonarbitrary as well as arbitrary relational responding, and thus these experiments provide a more complete model of this phenomenon, from the RFT perspective, than that provided by Barnes et al. (1997). Second, in addition to demonstrating derived relational responding based on the abstraction of common formal properties, Experiments 2 and 3 of the present study also generated a more complex equivalence-equivalence network than was shown in Experiment 1. This extension of the network involved the demonstration of equivalence-equivalence responding based on five-member, as opposed to only three-member equivalence classes. This more complex and arguably more ecologically valid relational network, provides further support for the plausibility of the current RFT model of analogical reasoning.

Overall, subjects required more training and/or testing to pass the equivalence-equivalence test than to pass the equivalence test, and furthermore, 2 subjects consistently failed to show equivalence-equivalence responding in the current study, whereas Barnes et al. (1997) reported no such failures. Consider, for example, that all subjects in the current study passed the equivalence test within four exposures, but 4 subjects (5, 6, and 7 in Experiment 1, and 12 in Experiment 2) failed their first four exposures to the equivalence-equivalence test. Consider also, that Subjects 6 and 7 repeatedly failed the equivalence-equivalence test until they were exposed to and passed an equivalence test. As suggested earlier, these data indicate that passing an equivalence test might function, in some contexts, as an important historical variable for responding in accordance with equivalence-equivalence relations. However, this issue is not clear-cut. The other 2 subjects (5 and 12) passed the equivalence test but then failed the equivalence-equivalence test. The failure of these 2 subjects to show equivalence-equivalence responding after passing an equivalence test departs somewhat from the data reported by Barnes et al. (1997). Specifically, those authors found that all subjects who passed an equivalence test went on immediately to pass the equivalence-equivalence test. At the present time, it remains unclear as to why Subjects 5 and 12 did not produce performances that were broadly similar to the 25 other subjects who participated in both the current study and that reported by Barnes et al. (1997). One relevant variable might be that subjects in the current study were required to derive equivalence and equivalence-equivalence relations based on the abstraction of common formal properties. Perhaps derived relational responding based on such abstraction is in some way a more complex type of behavior than derived relational responding per se, and this may account for the two failures in the current study. Further research will be needed to investigate this possibly important issue.

A related and perhaps equally important finding is that subjects in Experiment 3 completed training and testing in the main experiment (i.e., excluding the pretraining) with fewer failures in testing than subjects in Experiments 1 and 2. Once again, the reason for this difference remains unclear, but the exposure to pretraining and the use of (real-life) photographic stimuli appear to be likely causal variables in accounting for the relatively low number of test exposures required in Experiment 3. For present purposes, let us consider the possible role of the photographic stimuli (see also Holth and Arntzen, 1998, for evidence that familiar stimuli may facilitate equivalence class formation). Perhaps the use of these stimuli established two separate equivalence classes (composed of 'old' and 'new' stimuli) that were simply extended by the equivalence training and testing. Certainly, previous researchers have found that extending already existing equivalence classes is achieved more readily than establishing completely novel classes (Leader, Barnes-Holmes, & Smeets, 2000; Saunders, Saunders, Kirby, & Spradlin, 1988). The more rapid emergence of derived relational responding in Experiment 3, as compared with Experiments 1 and 2 in the current study, is therefore consistent with earlier research on creating versus extending equivalence classes. Of course, extensions of the current work will need to separate out possible practice and other effects provided by the pretraining from the use of nonarbitrary photographic stimuli.

One possible criticism of this study is that the critical equivalence-equivalence test performances involved a type of stimulus control that is not best described as equivalence-equivalence responding. Consider, for example, the (equivalence-equivalence) test trial A1B1-C1D1/C1D2. Perhaps subjects responded correctly on this trial by responding *away from* the comparison with an equivalence relation between only one sample element and one comparison element. That is, both the elements in the sample are equivalent to C1, but neither of them is equivalent to D2, and thus, a subject could respond away from C1/D2 and thus, by default, choose C1/D1. Although this form of S- control could in principle account for correct responding in each of the equivalence-equivalence tasks in the current study, this outcome seems highly implausible. Recall that each subject successfully trained and tested in equivalence class formation, and thus S- control was not present during the successful equivalence test performances (S- control would produce incorrect responding on tests of equivalence relations involving odd numbers of nodes; Carrigan & Sidman, 1992; see also Barnes, 1994). Thus, subjects who passed the equivalence test would have had to switch spontaneously from S+ to S- control when exposed to the subsequent equivalence-equivalence test. In fact, in many cases, subjects would have had to vacillate between S+ and S- control when they moved back and forth between equivalence and equivalence-equivalence tests. Clearly, this interpretation pushes the bounds of plausibility. As an aside, postexperimental anecdotal reports supported the view that subjects were responding in accordance with equivalence-equivalence relations rather than S- or some other form of stimulus control.

Another possible criticism of the current study is as follows. The first two experiments involved the abstraction via equivalence of the formal property of color from colored shapes. It might be argued, that because some of the colored shapes used as samples during conditional discrimination training shared the property of shape with each other, then subjects might somehow have abstracted shape rather than color. However, this would not have been possible because of the way the experiments were designed. First, the trained conditional discriminations always involved either the presentation of a blue shape as S+ and an identical shape in red as S-, or vice versa. Thus, subjects were taught that stimuli that had the same shape but a different color never 'went together.' Furthermore, in the context of testing, subjects were always presented with the option of matching two comparison stimuli that had been matched to same-color stimuli during training, but they were never presented with the option of matching comparison stimuli that had been matched to same-shape stimuli. Thus, although the experimental context allowed the abstraction of color, it did not allow the abstraction of shape. In one sense, therefore, the study could be criticized for being overly constrained in this regard (i.e., if subjects were to abstract anything, it had to be color). In response, however, one could argue that this very constraint means that the current model simulated an effective or 'good' analogy, in that such analogies facilitate only one interpretation.

A third criticism of the current model of analogy is that subjects required extensive training and testing to complete the experiment. Analogical reasoning in the natural environment, however, occurs relatively quickly. Indeed, the utility of analogy is *based* upon the fact that it allows the relatively rapid comparison of diverse environmental events and thus the current 'protracted' model of analogical responding may appear to lack validity. On balance, 'real-life' analogical reasoning requires previously established relational networks, but in the present study, completely new relational networks had to be established ab initio prior to testing for analogical responding. In effect, the vast majority of the time required before subjects showed analogical responding was time spent in MTS training and testing. One way in which to expedite the process might be to use alternative experimental preparations such as the Relational Evaluation Procedure (REP; see Barnes-Holmes, Healy, & Hayes, 2001; Hayes & Barnes, 1997), which is currently being developed in our laboratory, in place of the matching-to-sample procedure. We have found that large numbers of relational responses may be observed with little or no training using the REP, once a number of appropriate contextual cues has been established. We are currently developing the REP to model analogical reasoning. In addition to increasing ecological validity, the expedition of relational responding via the REP might also make possible the examination of much more complex and thus more 'life-like' analogical networks.

In fact, in this regard, we should emphasize that equivalence-equivalence is not the only possible type of analogical relational network that might be modeled. Any derived relation may appear in this type of network. Consider the following analogies, for example: (a) 'He is to his brother as chalk is to cheese' (opposition-opposition); (b) 'Grief is to sadness as euphoria is to happiness' (greater than-greater than); (c) 'Hand is to arm as foot is to leg' (hierarchical relation-hierarchical relation). Relational networks such as these might be modeled in the behavioral laboratory, thus providing further support for the RFT view of analogical reasoning as well as for RFT in general. Indeed, one particularly important application of the REP discussed in the previous paragraph might be to expedite the training and testing of such potentially complicated relational networks.

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