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Conditional control of equivalence and the relations different and opposite: A behavior analytic model of complex verbal behavior

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The University of North Carolina at Greensboro, 1987

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CONDITIONAL CONTROL OF EQUIVALENCE AND THE RELATIONS DIFFERENT AND OPPOSITE: A BEHAVIOR ANALYTIC MODEL OF COMPLEX VERBAL BEHAVIOR

by

David Lee Steele

A Dissertation Submitted to
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Approved by

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APPROVAL PAGE

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Behavior analytic approaches to the explanation of verbal behavior have been criticized because of difficulty explaining verbal productivity---the ability to make novel verbalizations which are in some way appropriate to the context. Match to sample procedures have resulted in the formation of equivalence classes which allow productive responding to untrained stimulus combinations. The central hypothesis of this study is that arbitrarily applicable relations other than equivalence can come to control human responding in ways which are productive.

A second-order conditional discrimination procedure was used to establish control over sample-comparison selections where samples and comparisons were arbitrary visual stimuli. Pretraining with non-arbitrary stimuli gave second-order conditional stimuli the function of signaling which relation---same, different, or opposite---was to control sample-comparison discriminations. These pretrained second-order conditional stimuli were used to establish networks of relations between arbitrary visual stimuli. It was predicted that the network of relations could come to control untrained responding to probes which presented second-order conditional stimuli, samples, and comparisons in novel arrangements. The predicted pattern of responding was derived from formal logic.

Subjects who had received pretraining demonstrated the predicted pattern of responding. Subjects who had received no pretraining

demonstrated consistent responding to probe items, but their pattern of responding was different from that of the pretrained subjects.

Results are interpreted as supporting the theory that arbitrary stimuli within a relational frame can produce predictable control over novel behavior. It is suggested that a five-term unit of analysis (second-order conditional stimulus, conditional stimulus, discriminative stimulus, response, and reinforcer) is required for a thorough analysis of the experimental results.

ACKNOWLEDGMENTS

This research project was begun with the assistance of the late Aaron J. Brownstein, Ph.D., Professor of Psychology, the University of North Carolina at Greensboro. Dr. Brownstein offered much assistance in developing the operational definition of the relation "opposite." His careful thought and conceptual insight contributed greatly to the initial planning of the experiment.

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CHAPTER I

INTRODUCTION

Developing a thorough analysis of verbal behavior seems to be a critical part of a behavior analytic account of human behavior. Verbal behavior seems to enter into control of human performance even in fairly simple learning tasks. The findings from the experimental analysis of behavior with animal subjects have not been readily replicated with humans. Humans tend to show patterns of schedule performance that differ significantly from those of other animals (Lowe, Harzem, & Hughes, 1978; Weiner, 1964, 1969), to be relatively insensitive to changes in schedules of programmed contingencies (Ader & Tatum, 1961; Harzem, Lowe, & Bagshaw, 1978; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981), and to show greater intersubject variability (Lippman & Meyer, 1967; Lowe, 1979). Explanations of this difference have focused on the effect of verbal behavior in human performance (Baron & Galizio, 1983; Lowe, 1983).

Support for this theory comes from several findings. Pre-verbal human infants seem to perform like other animals on simple schedules (Lowe, Beasty, & Bentall, 1983; Bentall, Lowe, & Beasty, 1985). Experimental preparations designed to decrease the subjects' opportunity to apply verbal abilities have produced schedule performances more like those of other animals (Lowe, et al., 1978;

Lowe, Harzem, & Bagshaw, 1978). Humans are extraordinarily sensitive to instructional control (see Baron & Galizio, 1983, for a recent review), and instructed performances, as compared to shaped responding,are relatively insensitive to changes in programmed contingencies (Matthews et al., 1977; Shimoff et al., 1981). Instructions about the schedules themselves can produce performances that are similar in pattern to that in other animals (Baron & Galizio, 1983), but this performance can be shown to be insensitive to changes in the tacted contingencies (Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Hayes, Brownstein, Haas, & Greenway, 1986). Given these findings, detailed analyses of verbal behavior and its effects have become more critical to behavior analysis.

Critical Features of Human Verbal Behavior

What then are the characteristics of human verbal behavior which must be accounted for in such an analysis? For humans with well-established verbal repertoires, the roles of speaker and listener are interchangeable (Hockett, 1960). Generally a speaker can reproduce any message to which he can accurately respond. There is a symmetry between receptive and expressive functions. Language is semantic in that there are relatively fixed associations between elements in messages and recurrent features or situations in the environment.

In human verbal behavior the semantic linkages between message elements and their referents are arbitrary (Hockett, 1960). Words are arbitrary stimuli which are related to their referents (Lazar, Davis-Lang, & Sanchez, 1984). For example, the word "big" is not big;

in fact the word is smaller than the word "tiny". The arbitrary relation between a word and its referent is bi-directional (Hayes & Brownstein, 1986; Devany, Hayes, & Nelson, (1986); a word can be used to refer to an object, and presentation of an object may elicit production of the word which is its "name."

Human verbal behavior is productive (Hockett, 1960; Kuczaj,1982); persons who have well-established verbal repertoires can say things they have never heard said or said before themselves. Persons also have the capacity to understand messages they have never heard before. This is very different from most animal communication systems which have a small number of possible messages. Behavioral analyses of the development of verbal repertoires have been criticized for failure to convincingly account for this productive aspect of verbal behavior (Staats, 1974; Zuriff, 1985).

Finally, human verbal behavior is characterized by "duality of patterning" (Hockett, 1960). A relatively small number of sounds can be combined in different ways to produce a large number of different messages. This point is related to the arbitrariness of verbal behavior but is still distinct. It would be possible to have arbitrary pairing of message and referent without the capacity to build different messages from the same units.

In summary, the verbal behavior of humans is characterized by the symmetry of expressive and receptive function, arbitrary bi-directional linkages between words and their referents, productivity, and the capacity to form different messages by combining the same units in different orders. Traditional behavioral analyses of verbal behavior generally do not seem to account fully for these features of human verbal behavior.

Problems with Traditional Behavioral Analyses of Verbal Behavior

Hayes and Brownstein (1986) point out that the typical behavioral analysis of the reference of words is to see words as stimuli conditionally related to an event, object, or relation. In Skinner's analysis, "A referent might be defined as that aspect of the environment which exerts control over the response of which it is said to be the referent. It does so because of the reinforcing practices of the verbal community" (1974, p. 92). When we speak, the environment provides discriminative stimuli as to which verbal behavior will be reinforced by the social verbal community. For example, the social-verbal community will not reinforce calling an airplane a truck.

This arbitrary relation between a spoken word and its referent could be seen as the result of the establishment of a discriminative stimulus. But humans use words in flexible ways that seem to involve properties which go beyond those of the discriminative stimulus. In particular the relation between a word and its referent seems necessarily bi-directional. "A word 'stands for' another event only if the event 'is called' the word," (Hayes & Brownstein, 1986; cf. Devany, Hayes, & Nelson, 1986).

This symmetrical relation between a word and its referent is readily apparent in verbal behavior. With persons who have competent verbal repertoires, the expressive and receptive repertoires often do not require separate explicit training. For example, if a person has learned to point to a wrench when someone says "wrench," separate training will generally not be needed for that person to say "wrench" when shown a wrench. The relation between a discriminative stimulus and a response is not necessarily symmetrical; a response cannot be interchanged for its discriminative stimulus. It should be remembered, however, that the symmetry of speaker's and listener's abilities (in those with well-established verbal repertoires) is the result of an extensive learning history. Developmental studies by psycholinguists document discrepancies between receptive and expressive abilities in children (see Bloom, 1974 and Ingram, 1974 for reviews). Behavior analytic studies of children's verbal behavior have also demonstrated the independent acquistion of speaker's and listener's repertoires (Lamarre & Holland, 1985). Identification of the types of learning histories that allow symmetry between speaker's and listener's repertoires may enhance our understanding of verbal behavior.

The demonstration of a behavioral phenomenon which has been labeled "stimulus equivalence" has implications for an analysis of verbal behavior. These research findings have particular relevance to the arbitrary, symmetrical, and productive features of verbal behavior. The experimental results will be summarized with comments about the relevance to understanding verbal behavior. Procedures and outcomes will be described first. Theoretical explanations of the experimental findings will be taken up in a subsequent section.

Stimulus Equivalence: Experimental Findings

Experiments using an arbitrary match to sample procedure with humans have demonstrated the emergence of what has been termed stimulus equivalence. The arbitrary match to sample task involves the presentation of physically different sample and comparison stimuli (Cumming & Berryman, 1965). Selection of one of the comparison stimuli (by pointing to one of the comparison stimuli or pressing buttons on which the comparison stimuli are displayed) is reinforced given the presence of a particular sample stimulus. The control of responding is totally arbitrary because the pairing of sample and reinforced comparison is not based on any physical attribute of the two stimuli. The arbitrary relation between the sample and the comparison parallels the arbitrary relation between words and their referents in verbal behavior (Lazar, Davis-Lang, & Sanchez, 1984).

The initial behavior analytic work in this area was done by Sidman (1971) in an attempt to teach reading skills to a moderately retarded boy. Prior to the experiment this boy could select pictures of objects when the name of the object was spoken to him and could name pictures. In the course of the experiment he was taught to select a printed word when the spoken word served as the sample stimulus. This procedure is presented diagrammatically in Figure 1. (Throughout this paper solid arrows will be used to symbolize discriminative choices explicitly taught with the arrow pointing from the sample to the comparison. Arrows drawn with broken lines will indicate the untaught discriminations tested for in unreinforced probes.)

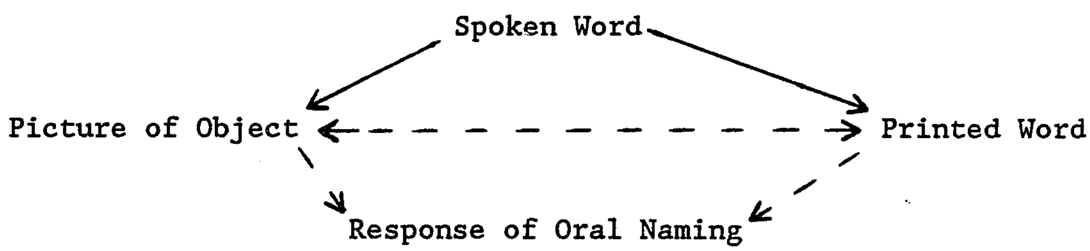


Figure 1. Representation of training and testing paradigm for Sidman (1971).

Following training, the boy could select the correct picture given the printed word, select the printed word when given a picture, and pronounce the written word. None of these three behaviors was explicitly trained. Sidman concluded that the pictures and printed words became equivalent stimuli in that they could serve interchangeably as the sample that controlled the selection of the other and the response of oral naming. They also are equivalent in the sense that the same spoken word presented as a sample will result in the selection of the corresponding picture or printed word depending on which is required.

The arbitrary match to sample procedure has been used to establish control by stimuli without direct training using arbitrary visual stimuli (Spradlin, Cotter, & Baxley, 1973; Wetherby, Karlan, & Spradlin, 1983; Lazar, Davis-Lang, & Sanchez, 1984; Lowe, 1986; Stromer, 1986; Devany, Hayes, & Nelson, 1986) and using arbitrary auditory and arbitrary visual stimuli (Spradlin & Dixon, 1976; Dixon, 1978; Sidman & Tailby, 1982; Sidman, Kirk, & Willson-Morris, 1985; Saunders, Wachter, & Spradlin, 1986). Subjects have ranged from retarded children and adolescents (e.g., Sidman & Cresson, 1973; Devany et al., 1986) to children and adults of normal intellectual ability (e.g., Sidman et al., 1985; Lazar et al., 1984). All of these investigators have described their findings in terms of Sidman's idea of stimulus equivalence. Untrained control of behavior by stimuli is thought to occur because the training experience establishes a class of equivalent stimuli.

Comprehensive requirements for demonstrating stimulus equivalence have been defined by Sidman and Tailby (1982). They borrow a definition of equivalence from number theory and suggest that equivalence is observed when the relations among the members of a class are reflexive, symmetric, and transitive. These properties also seem to be appropriate criteria for the definition of equivalent stimuli in psychology. These properties do describe the responding of experimental subjects following the match to sample training.

Reflexive relations take the form "if a then a." In the match to sample paradigm reflexivity is demonstrated by generalized identity matching. Symmetry in relations requires the following condition: if a bears the relation to <u>b</u> (<u>a</u>R<u>b</u>), then <u>b</u> also bears the relation to <u>a</u> (<u>b</u>R<u>a</u>). In the matchto sample paradigm this relation can be stated as "If with a as the sample, b should be selected, then with b as the sample, a should be selected." In transitive relations if "aRb" and "bRc" are true then "aRc" is also true. In the match to sample task, transitivity is tested for after teaching the subject to choose b with a as the sample and to choose c with b as the sample. Transitivity is observed if the subject chooses c with a as the sample without any prior training. Table 1 demonstrates equivalence for the relation of numerical equality and the match to sample task.

Symmetry involves the development of backward association. After being taught to respond to B in the presence of A, the "backwards" control allows the selection of A in the presence of B. The symmetrical relation which develops between sample and comparison is very similar to the previously discussed symmetry between a word and its referent. To date the development of symmetrical control without explicit training has only been found in humans. Attempts to develop symmetrical control in pigeons (Kendall, 1983), monkeys and pigeons

Table 1.
Relations Required for Equivalence

Mathematical equality	Match to sample
Reflexive: a=a.	With a as the sample and a as one of the comparisons, choose a.
Symmetric: If a=b, then b=a.	If with a as the sample choosing b is reinforced, with b as the sample choose a.
Transitive: If a=b and b=c, then a=c.	If b is the reinforced choice with a as the sample, and c is a reinforced choice with b as the sample, then with a as the sample choose c.

(D'Amato, Salmon, Loukas, & Tomie, 1985), and monkeys and baboons (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982) have all yielded negative results.

The development of transitive control demonstrates the emergence of novel behavior without explicit training. When the stimuli involved are academic materials, such as the words and pictures used in Sidman's experiments (1971; Sidman & Cresson, 1973), the novel behavior can be objectively judged as appropriate to the new combination of stimuli (e.g., correctly matching words and pictures). Transitivity seems to be a demonstration of "productivity" in the same sense that "language" is productive. A striking example comes from the work of Sidman, Kirk, and Willson-Morris (1985) who established three six-member equivalence classes by providing training with 15 pairs of stimuli. After the establishment of the equivalence classes, control by an additional 60 pairs of stimuli was observed.

Figure 2 illustrates one example of the training and the untrained control which must be observed to demonstrate the establishment of stimulus equivalence with three stimuli (a three-member equivalence

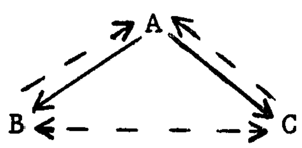


Figure 2. Trained and untrained control of responding for a three-member stimulus equivalence class.

class). The experimental procedure provides AB and AC training, and then tests for BA, CA, BC, and CB control during unreinforced probe trials. Stimuli A, B, and C are equivalent in the sense that each stimulus can be an effective sample or comparison in combination with every other stimulus.

In actual practice more than one three-member class is developed. If responses to B and C were the only responses reinforced, their selection during probe trials could be controlled by simple reinforcement history, not the presence of the sample. The necessary control is provided by using multiple stimuli in each set (A, B, and C) with each established as a member of a separate equivalence class. Figure 3 illustrates a possible experimental procedure.

<u>Descriptive Analyses of Training Arrangements</u>

It should be noted that there are a number of different ways of arranging sets of stimuli in training. Varying the training sequences may have practical implications for applied settings in that one procedure or another may produce faster acquisition, more accurate

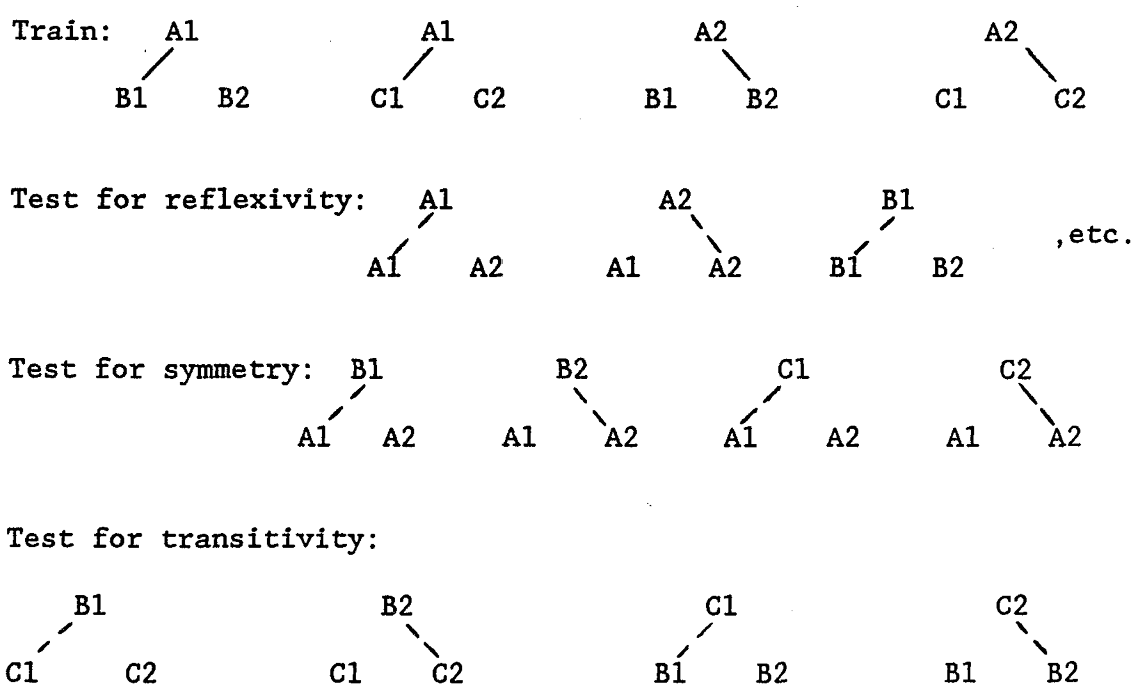


Figure 3. Example of an experimental paradigm for demonstrating the establishment of two three-member stimulus equivalence classes.

performance, or better maintenance. The different training procedures may also require different theoretical explanations, and for this reason they will be considered. With three sets of stimuli, training could be conducted using the AB and BC pairs (see Figure 4) instead of the AB and AC training previously discussed (see Sidman et al., 1974).

Figure 4. Alternative training and testing arrangements for three stimulus sets.

The possible arrangements grow even more complex as the number of stimulus sets involved increases. Fields, Verhave, and Fath (1984) have provided a conceptual analysis of these possible combinations. They point out that the number of different two-term combinations possible is given by the formula: (N-1)N/2 where N is the number of different stimuli. To provide a description of the ways that stimuli could be linked in training, the concept of a "node" is defined as a stimulus that is related to more than one other stimulus during training. Thus, in Figure 4, stimuli of set A are nodes. With more than three stimulus sets variety in the number of nodes used in training is possible. Figure 5 illustrates this for training with 5 stimulus sets.

Sidman and his colleagues (Sidman & Tailby, 1982; Sidman et al., 1985) use a different terminology to describe arrangements of training combinations. Pairs of stimuli are referred to as "stages". Using the

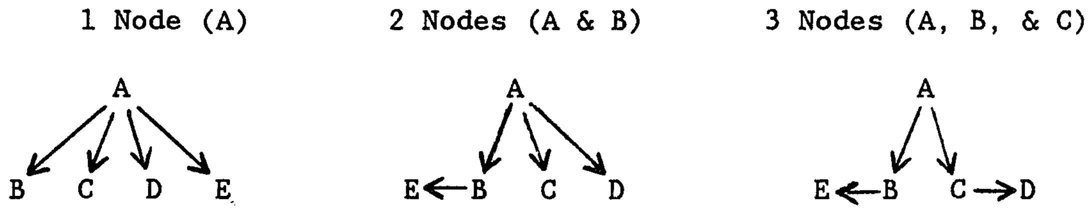


Figure 5. The three possible nodal arrangements for five stimulus sets.

diagram on the right in Figure 5, the EB, EA, EC, and ED relations would be one, two, three, and four stage relations respectively.

Fields and his colleagues (1984) have speculated that the number of nodes required to relate two stimuli may provide a measure of "associative distance". They argue that associative distance may be related to the degree of transitive control developed through training. It is possible that "associative distance "might also be related to performance variables such as response latency and error rates. There is currently little experimental evidence relevant to this prediction. When higher order derived relations have failed to emerge, testing has often revealed that component lower order relations have not been established (Sidman, Kirk, & Willson-Morris, 1985; Saunders et al., 1986). Saunders and his colleagues (1986) report that one subject in their study showed better acquisition of a one-node relation than a two-node relation that was simultaneously trained and tested. In the same study, response latencies were not, however, related to the number of nodes involved in control of a response.

The analysis of stimulus arrangements by identifying nodes or stages ignores the sample-comparison directionality (Saunders et al., 1986). Spradlin and Saunders (in press) have given attention to this dimension and have compared the use of a multiple-comparison procedure with the use of a multiple-sample arrangement. (These two arrangements are diagrammed in Figure 6.) They report that with retarded subjects it was easier to establish stimulus equivalence using the multiple-sample procedure as compared to the multiple-comparison method. An attempt to replicate this finding produced equivocal results (Saunders et al., 1986), but Saunders and his colleagues think that this comparison of training procedures warrants further investigation.

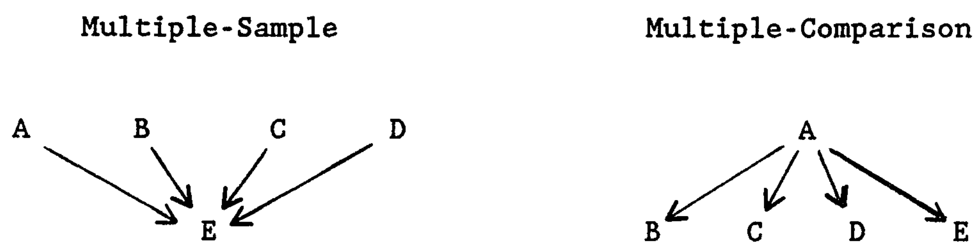


Figure 6. Multiple-sample and multiple-comparison training arrangements for five-member stimulus classes.

There are also arrangements that mix the sample-comparison directionality. An example comes from the establishment of six-member equivalence classes (Sidman et al., 1985). Two independent three-member equivalence classes were formed using A-B and A-C training for one class and D-E and D-F training for the other class. Then E-C training combined the two three-member classes into one six-member class.

The variety of procedures used in the studies conducted to date suggests that equivalence classes can be formed using any arrangement of nodal clustering and sample-comparison directionality possible.

Different procedures may offer advantages in terms of the amount of training necessary to develop equivalence classes. There may be advantages to one procedure or another which are specific to particular populations of subjects. The available experimental findings do not yet allow any firm conclusions in this area. Learning paradigms other than the match to sample task may also establish stimulus equivalences.

Establishment of Equivalence with Compound Stimuli

Stromer (1986) developed a novel approach for the addition of stimuli to an equivalence class. He used a compound stimulus as a sample. The compound consisted of a tone and a color on a key, presented simultaneously. An observing response to the visual part of the compound was required. The compound stimulus was related to arbitrary visual stimuli which served as comparisons. After training, testing for derived control showed that for two of four subjects each separate part of the compound stimulus (tone or color) came to control selection of each of the arbitrary visual stimuli which had served as comparisons. In addition, presentation of tones controlled the selection of the color which had been paired with it in the compound. Even though tones and colors were redundant (in the sense that correct choice of the comparison could be made on the basis of one stimulus alone), both came to control the choice of comparisons. In the second stage of the experiment, a new set of arbitrary visual stimuli was presented as part of a compound sample with the tone. Comparisons consisted of the colors which had previously been presented as components of the compound stimulus. Presentation of tones already controlled selection of colors for the subjects, so the addition of the arbitrary visual stimulus was again redundant. Nevertheless, the arbitrary visual stimuli came to control selection of colors.

It is not clear that the presentation of compound stimuli as samples will always result in both components of the compound entering into equivalence classes. Stromer's procedure required an observing response to the visual component of the compound before a comparison could be selected. Since a response to the key on which the visual component was displayed allowed the subject to make the reinforced response, the visual part of the sample may have acquired the function of a secondary reinforcer. The tone becomes a discriminative stimulus which indicates that it is time to make a response. Simultaneous presentation of two visual stimuli as a compound sample without a required observing response might not produce comparable results.

Stimulus Equivalence and Transfer of Function

The studies discussed so far show that the match to sample procedure can result in stimuli acquiring interchangeable functions in the context of the match to sample task. Stimulus equivalence may also provide a mechanism for the transfer of function from one stimulus to another in learning tasks other than the match to sample paradigm. Lazar (1977) presented subjects with pairs of stimuli and instructed them that their task was to learn to point to each stimulus in the pair in the correct order. Training established generalized sequence classes of stimuli which were "firsts" and "seconds." A "first" stimulus could be presented with a "second" stimulus from another training pair and still control sequential pointing in the "correct" order. A match to sample procedure then related novel stimuli to the stimuli that controlled sequential pointing. When these novel stimuli were used in the sequential pointing task, control of sequential pointing was observed in two of three subjects. The match to sample procedure caused stimuli to be added to the generalized sequence classes of "firsts" and " seconds". The function of discriminative stimuli for a complex operant was transferred to other stimuli within the class.

In a related study Lazar and Kotlarchyk (in press) established two five-member equivalence classes using the match to sample procedure. In a sequential pointing task, a stimulus from one class was given the function of being the first stimulus to be pointed to, and a member of the other class was second.

This relation was true in the presence of a high-pitched tone, but the sequence was reversed in the presence of a low-pitched tone. Thus the function of one member of the stimulus class ("first" or "second") was brought under the conditional control of the tones. When other members of the stimulus class were presented, the conditional control of sequential pointing was maintained. The conditional function was transferred to all members of the class. This experiment demonstrated two processes---transfer of function and conditional control of function---in one additional training step. This is an example of complex stimulus control of behavior without a direct reinforcement history. The productive control of order is a process which is related to an understanding of verbal behavior. Syntax often depends on the order of words.

The procedure in both of the previously discussed experiments (Lazar,1977; Lazar & Kotlarchyk, in press) assigned functions to stimuli which served only as the sample during training. Transfer of control to comparison stimuli did not require symmetric and transitive relations. Hayes, Brownstein, Devany, Kohlenberg, and Shelby (1985) demonstrated transfer of discriminative and conditioned reinforcement functions from trained comparison stimuli to other comparison stimuli associated with the same sample. In this case, symmetric and transitive relations had to be involved in the transfer of control to other tested members of the stimulus class.

In light of the evidence that stimulus equivalence may result in transfer of function, it seems possible that establishing identical function of stimuli might result in equivalence class membership. This could be investigated by establishing an equivalence class and then giving its members a function in a learning task. If a novel stimulus were given the same function, it might become a member of the class. This could be tested in a match to sample procedure.

Conditional Equivalence and Transfer of Function

Wulfert and Hayes (1987) have demonstrated transfer of a conditional ordering response through equivalence classes and conditional equivalence classes. Adults were taught conditional discriminations which led to the formation of two equivalence classes.

Subjects were then taught to pick one stimulus from each class in a set order. This ordering response then transferred to all other members of the equivalence class. Conditional equivalence classes were created by bringing class membership under second-order conditional control. In the presence of one conditional stimulus, and A1 as the sample, responses to B1, C1, and D1 were reinforced. In the presence of the other conditional stimulus and A1 as the sample, responses to B1, C2, and D2 were reinforced. The ordering response was also brought under conditional control. When Tone 1 sounded a particular order of responding to the stimuli was reinforced, but when Tone 2 sounded the opposite order of responding was reinforced. Ordering and conditional ordering transferred to all members of the conditional equivalence classes.

<u>Stimulus Equivalence and Verbal Behavior</u>

Previous discussion has already pointed out the relevance of the phenomena observed in stimulus equivalence to some of the phenomena observed in verbal behavior. In addition, there is some direct experimental evidence to suggest that the ability to learn equivalence relations may be related to verbal behavior. Stimulus equivalence is not observed in retarded children with no spontaneous spoken or signed language, but is observed in both retarded and normal children of equivalent mental age who do have some verbal ability (Devany, Hayes, & Nelson, 1986).

A recent study reported by Lowe (1986) also seems to indicate a relation between verbal ability and equivalence. Lowe and his colleagues attempted to establish equivalence classes with three groups of children---ages 2-3, 3-4, and 4-5 years old. All of the children in the oldest group demonstrated equivalence, but only half of the second group and only one of the six children in the youngest group did so. A standardized test of language ability indicated that the groupings by age did generally divide the children by language ability. In addition, the one child from the youngest group who demonstrated equivalence had language skills which were much better than average for a child of that age.

If verbal competence is related to the ability to form equivalences, one would not expect infrahuman subjects readily to demonstrate stimulus equivalence, and this appears to be the case. Sidman, Rauzin, Lazar, Cunningham, Tailby, and Carrigan (1982) attempted to demonstrate stimulus equivalence in infrahuman primates and reviewed the animal learning literature. They concluded that stimulus equivalence has not been demonstrated in any infrahuman subjects. D'Amato, Salmon, Loukas, and Tomie (1985) were able to demonstrate transitivity of conditional relations in monkeys, but symmetric associations were not observed. Kendall (1983) was unable to establish equivalence classes with pigeons. While this is not conclusive evidence that verbal behavior and stimulus equivalence are related in any functional way, it is suggestive. It may be that the learning history required for developing verbal repertoires facilitates the formation of equivalence classes. Alternatively, the ability to form equivalence classes may be necessary for the development of verbal abilities. Sidman (in press) says that stimulus equivalence is a prerequisite of language.

As with any correlational observation, there is also the possibility that the co-occurence of the two phenomena is due to a third variable which accounts for both sets of observation. Hayes and Brownstein (1986) have argued that verbal behavior and stimulus equivalence may be the result of an ability to respond to arbitrary relations between stimuli. This proposal and other theoretical formulations will now be reviewed.

Theoretical Explanations

The observations regarding stimulus equivalence have been presented without any discussion of theoretical formulations that might provide interpretation or explanation of the experimental data. We now turn from examination of the "what" of stimulus equivalence to the "why."

Mediational accounts. The first analyses attempted to relate the equivalence class findings to previous research in the area of mediated learning (see Jenkins, 1963) and to make the analysis within the context of the three-term contingency (discriminative stimulus - response - reinforcer). Sidman and Cresson (1973) and Spradlin, Cotter, & Baxley (1973) discussed their work in terms of possible mediational accounts.

Careful consideration needs to be given to the mediational analyses and the previous research findings in this area. There are clear similarities between mediated verbal learning and the current stimulus equivalence work done with the match to sample task. In both experimental preparations correct responses can only be defined in terms of stimulus properties. In the match to sample task a correct response typically consists of pointing to a particular stimulus or pushing a button on which the stimulus is projected. In verbal learning experiments a correct response consists of saying or writing a word in response to another word presented as a stimulus. Words that are responses in one context can be used as stimuli to elicit other responses. The topography of the response consists of the creation of a stimulus to be evaluated by the experimenter. While any response has stimulus consequences, these particular tasks have particularly salient stimulus properties associated with the response.

An additional similarity is that both research areas are concerned with the emergence of behavior which is not explicitly taught. In mediated verbal learning, novel control of behavior very similar to that produced by stimulus equivalence procedures can be observed. If, for example, a subject is taught to say "ball" when "hat" is presented as a stimulus and then is taught to say "dog" when given "hat", learning to say "dog" when "ball" is presented may be facilitated. The same sort of derived control could be generated from match to sample training. Perhaps both sets of research findings can be explained with one set of principles.

Jenkins and Palermo (1964) provide an analysis of three mediation paradigms that were used in the analysis of verbal learning. Sometimes stimulus-response linkages were built by giving subjects an explicit learning history. In other studies experimenters took advantage of naturally occurring word associations (e.g., "table"-"chair").

The first of these paradigms is stimulus-response chaining. This analysis is applied to the situation where there is a history of A-B learning and B-C learning, and then A comes to elicit C. The mediational analysis is that in the last stage the presence of A elicits B as an implicit response and the stimulus properties of B elicit C [A-(B)-C].

Jenkins and Palermo's analysis of "response "equivalence" is applied to the situation in which A elicits B, A also elicits C, then B will tend to elicit C. The mediational analysis is that after A-B learning, B is present as an implicit response in the A-C learning, A-(B)-C. The stimulus properties of the implicit response (B) become associated with C, and then when B is presented as a stimulus it elicits C.

Mediation by "acquired stimulus equivalence" takes place when two stimuli (A and C) are "functionally equivalent" in that they elicit the same response (A-B and C-B). If one of the equivalent stimuli comes to elicit a novel response (A-D), then the other stimulus will also elicit the novel response (C-D) . The mediational analysis is that during the A-D training the common response (B) is present as an implicit response, A-(B)-D, and the novel response is conditioned to its stimulus properties. When C is presented it also elicits B as an implicit response, and the previous association of B to D elicits D, C-(B)-D.

One possibility is that the "implicit" covert response is a "coding response" (Lawrence, 1963; Schoenfeld & Cumming, 1963; Carter & Werner, 1978). The coding response is related to behavioral accounts the stimulus in the environment, but to a coding response made covertly to the environmental stimulus. The assumed response operates on the sensory input to produce a new event. This new event---the coded or labeled stimulus---is then associated with the overt response. Schoenfeld and Cumming (1963) have provided a detailed analysis of how the coding response could be used to interpret mediation phenomena.

There are overt behavioral indications that may indicate that a coding response is taking place. Among these are observations of different observing responses to different samples, different superstitious behavior following different samples, and enhanced performance when differential observing responses were explicitly required (Carter & Werner, 1978). Carter and Werner conclude that while it is theoretically compelling to speak of a coding event, it is not clear whether the coding event is a response or a central process.

Jenkins (1963) reviews a series of studies that showed mediated facilitation of learning. Subjects were given training which paired three sets of words in two of three possible arrangements (e.g., A-B and A-C). The dependent measure was the ease with which subjects could learn the other possible combination (in this example B-C) as compared to pairs of novel words. Previous training with two of the pairs was found to facilitate learning of the third pair. When this type of procedure was extended to four sets of stimuli there was no evidence of facilitation.

The match to sample procedure has resulted in the creation of equivalence classes of up to nine members (Saunders, Wachter, & Spradlin, 1986). What could account for the failure in the paired associate research? It should be noted that the procedure used in the paired associate experiments only measured the dependent variable once. Facilitation was evaluated through the acquisition of mastery. The match to sample procedure allows the repeated testing of control by the derived relation. If a subject needs further training, this can be done without invalidating the dependent measure. There have also been some consistent findings that the unreinforced testing process can result in the development of derived control (Sidman, et al, 1974; Sidman, et al, 1985; Spradlin, et al, 1973; Spradlin & Saunders, 1986). Perhaps the development of control across more than three sets of stimuli could be observed in paired associate learning if it could be done with an experimental procedure which allowed for repeated cycles of training and testing.

Given this possible explanation of the failure to develop control across higher stage relations, the mediational accounts of transitive control may provide a viable explanation of the stimulus equivalence findings. It is possible to provide an explanation of stimulus equivalence within the framework of the three-term contingency if one accepts three basic propositions. First, that responses to different comparisons are different responses. For example, pushing the key with a circle on it is one response and pushing the key with a square on it is another response. The second necessary assumption is that backward associations with human subjects are possible, and this process seems to be clearly demonstrated in the symmetrical control demonstrated in the stimulus equivalence research. Third, one must assume the possible occurrence of implicit responses (which may be coding responses). The following example will illustrate this.

Mediational analysis of stimulus equivalence. In Figure 7 a complex arrangement for match to sample training is illustrated. This example involves two nodes and both the multiple-comparison (A-B and A-C) and multiple-sample (A-C and D-C) arrangements. Previous studies using single (as opposed to compound) stimuli and match to sample procedures have not included any procedure which involves greater

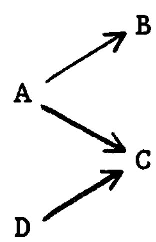


Figure 7. Illustration of a complex match to sample arrangement.

conceptual complexity. More elaborate training arrangements have only consisted of the addition of elements, not the addition of a conceptually different process. Table 2 presents a derivation of all symmetrical and transitive control from the processes of backward association and implicit responses. This demonstration establishes the possibility of a mediational account of all stimulus equivalence phenomena. In Table 2 the stimulus pair (in sample-comparison order) for which control is being explained is presented in the left column. The combinations of stimuli involved in a process are presented in brackets following the name of the process. For example, in line 2, B-A control is assumed to be derived by backward association from the previously trained A-B relation. It is assumed that once control by a stimulus pair is established, this relation is available as the raw

Table 2

Mediational Analysis of Stimulus Equivalence Developed by Training Diagrammed in Figure 7

	Stimulus Pair	Process for Establishing Control
1.	A-B	Training
2.	B-A	Backward association [A-B]
3.	A-C	Training
4.	C-A	Backward association [A-C]
5.	B-C	Mediation [B-(A)-C]
6.	C-B	Backward association [B-C] or mediation [C-(A)-B]
7.	D-C	Training
8.	C-D	Backward association [D-C]
9.	D-A	Mediation [D-(C)-A]
10.	A-D	Backward association [D-A] or mediation [A-(C)-D]
11.	D-B	Mediation [D-(C)-(A)-B] or mediation [D-(C)-B]
12.	B-D	Backward association [D-B] or mediation [B-(A)-(C)-D]

material on which further processes may act. In mediation derivations, the hypothetical implicit response is presented in parentheses. For example, in line 5, B-C control is explained by mediation with the implicit response of A coming from the B-A relation developed in line 2. It should be noted that for some relations derived control could have been established by a number of different processes.

Analyses of Mediational Accounts. Sidman and his colleagues (Sidman et al., 1974; Sidman & Tailby, 1982; Sidman, in press) argue against mediational accounts on theoretical grounds. They point out that responding to different comparisons does not require a differential response topography. In each case, the overt response (pointing or pressing a key) is identical and responses to different comparisons can only be differentiated in reference to the stimuli.

These same writers reject the idea of covert responses as the addition of an unnecessary hypothetical construct which is not easily testable. One possible covert mediating response, naming the stimuli, could have been a factor in the transitive and symmetric control observed in stimulus equivalence. There has been no evidence of the development of common names for members of visual equivalence classes (Lazar et al, 1984), and even when spoken names have been matched to visual stimuli subjects who were unable to provide consistent names for members of a class demonstrated stimulus equivalence (Sidman, Kirk, & Willson-Morris, 1985).

Lowe (1986) also examined the possibility that covert naming might play a mediational role in the development of equivalence classes. The spontaneous utterances of retarded adolescents were tape recorded during match to sample training. Lowe reports that occasionally the spontaneous utterances of some subjects did seem to include some common names of members of the stimulus class. When the subjects were given a naming test following training, some subjects labeled the stimuli in ways that differed from their previous spontaneous utterances. Lowe suggests that this result calls into question previous failures of the naming test to reveal consistent names for members of a class.

A weakness of the mediational accounts is that they rely on hypothesized covert processes. Experimental evidence for the occurrence of mediational responses is fragmented at best. The strength of the mediational approach is that it attempts to explain the current experimental findings without any appeal to a new process. Sidman, however, sees equivalence as the demonstration of a basic learning process which has not been previously included in behavior analytic theory.

Equivalence as an emergent process. Sidman (in press) suggests that research that uses the match to sample paradigm can be more properly viewed as an instance of conditional discriminative control. The sample stimulus is a conditional (or contextual) stimulus which exercises conditional control over the comparison stimuli which function as discriminative stimuli. Sidman suggests a widening of our unit of analysis from the three-term contingency (discriminative stimulus-response-reinforcing stimulus or SD-R-S+). The four-term unit of analysis is contextual stimulus - discriminative stimulus - response - reinforcing stimulus (SC-SD-R-S+). The control established by the combination of the conditional stimulus and the discriminative stimulus is due to stimulus association without assuming any intervening response.

How then would Sidman account for stimulus equivalence? He does not provide an explanation other than to say that stimulus equivalence is a basic behavioral phenomenon which emerges as a result of conditional discrimination training in humans. The only further point which is made is the suggestion that equivalence classes may not exist until they are tested (Sidman, Kirk, & Willson-Morris, 1985). The testing process may provide the context for forming the relations among the stimuli. Sidman and his colleagues point out that equivalence classes could have been formed based on irrelevant dimensions of the stimuli used. Classes could also be based on physical characteristics, the subject's own reinforcement history, or the separation of the stimuli into "sample " or "comparison" classes. In their opinion, the testing process serves to define the relevant dimensions for the formation of classes.

Sidman argues for viewing the four-term contingency as a new unit for behavior analysis which will extend the explanatory power of this approach. He is satisfied with assuming that stimulus equivalence is just a basic behavioral phenomenon which emerges as a result of conditional discrimination procedures with humans. Sidman goes on to suggest that the conditional discriminations of the match to sample task might be brought under control of an additional conditional stimulus (second-order conditional control and a five-term contingency in his view). This speculation has been confirmed by Wulfert and Hayes' (1987) demonstration of conditional equivalence classes. He speculates that another new behavioral phenomenon may result from the addition of another conditional stimulus (a six-term unit in his view). There is not however, any prediction of the nature of this phenomenon. While predictive power of Sidman's theoretical formulation may be weak, his descriptive approach has an economy that is appealing. A strength of his approach is that he relies on no covert responses or other intervening variables.

Equivalence as verbal behavior. Lowe (1986) points out that differences in the operant responding of humans and other animals have been explained as being due to human verbal behavior. He suggests that the difference in the ability of humans and other animals to form equivalence classes may also be accounted for by verbal behavior. Lowe reports a study in which the ability to form equivalence classes of visual stimuli was tested for children at different ages. Five of six children who were two to three years of age failed to develop equivalence classes. The children who failed to develop equivalence classes were trained to label the sample and comparison stimuli verbally. Four of these five children then showed control by equivalent stimuli.

Lowe uses these results to argue for a role of language in the development of equivalence classes. But it should be noted that the children were not taught to use a common name (which could serve as a mediator) for the members of a stimulus class. Instead, they were taught to label very different stimuli with different names (e.g., "triangle, green, line"). On a given trial the children would say together the names of the two items which were to be paired. So Lowe would still have to account for the development of equivalence among the names of the stimuli. His study could be interpreted as indicating that young children form equivalence classes with auditory stimuli more easily than they form classes with visual stimuli.

Relational frames. Hayes and Brownstein (1986) provide an alternative theoretical formulation to account for the development of stimulus equivalence. They suggest that stimulus equivalence may be just one instance of a general ability of humans to respond to relations between arbitrary stimuli. Responding to relations between stimuli is clearly shown in the transposition literature (Reese, 1968). A typical transposition problem would be to give subjects a history of responding to stimuli which differ from each other along some stimulus dimension (brighter-darker, longer-shorter, larger-smaller, etc.). Given a history of reinforcement for responding to one stimulus---for example, the larger of two squares---a new set of stimuli is presented such that the stimulus which had formerly been correct stands in a different relation to the other stimulus. In the previous example the square which had formerly been the largest is now paired with a square which is even larger. The results indicate control by the relation rather than the specific stimulus; the subject will choose the largest square. This sort of experimental finding demonstrates control by relations between the physical characteristics of stimuli. This is an example of control by a non-arbitrary relation between stimuli.

This stands in contrast to control by arbitrarily related stimuli such as those used in the arbitrary match to sample task. Hayes and Brownstein suggest that the general ability to respond to relations between arbitrary stimuli is the result of the development of "relational frames".

According to Hayes and Brownstein (1986), a relational frame exists when an arbitrary relation between two arbitrary stimuli comes to control responding. This control is not based on direct experience with the particular stimuli of interest. Neither is it based on non-arbitrary aspects of the stimuli or the relation between these non-arbitrary aspects. Rather, control by the frame emerges due to a history of responding in terms of the relation per se. Once a particular abstract relation has been acquired, in the presence of stimuli indicating that responding in terms of that relation would be reinforced, relational control is likely.

Applying this analysis to the stimulus equivalence literature, it is assumed that the arbitrary match to sample procedure results in the establishment of a relational frame of the form "___=___," with the sample and comparison stimuli (e.g., A and B) being related within the frame. The existence of the relational frame is inferred from the control of behavior by a relation between stimuli which is not based on previous training. The demonstration of symmetry and transitivity in stimulus equivalence is exactly this sort of untrained control.

Hayes and Brownstein think that the development of relational frames depends on a history with relations between arbitrary stimuli. It may be, for instance, that the ability to form stimulus equivalences depends on an extensive history of learning that one stimulus "is the same as" or "goes with" another stimulus. Examples of how this learning might occur would include the following: reinforcement for sorting two stimuli together, instruction that the two stimuli are the "same," explicit training that the two stimuli are interchangeable as sample and comparison, a history of reinforcement for symmetrical matching, and so on. It may be that phylogenetic contingencies give humans the general ability to respond to arbitrary relations, but Hayes and Brownstein think that an ontogenetic history is required. This is an empirical question which could possibly be answered by developmental studies.

Demonstration of the existence of relational frames. Hayes and Brownstein have defined criteria for demonstrating the existence of relational frames. First, train one part of a bidirectional relation and then test for a defined relation in the opposite direction. In a more formal sense, given A-R1-B, then the derived relation B-Rx-A must be specified. In equivalence this is the property of symmetry; if A occasions the selection of B, then B should elicit the selection of A. This same sort of test could be applied to other relations. For example, if training has established A as "greater than" B, then B should be responded to as "less than" A. Thus, the derived relation need not be identical to the trained relation (R1 need not equal Rx).

The second method for demonstrating relational frames is the establishment of networks of relations which then produce untrained control of behavior. In equivalence this is the property of transitivity. With relations other than equivalence, different sorts of network of control could be developed. For instance, if A is greater than B and training establishes B as greater than C, then A should be responded to as greater than C. More formally, if A-R1-B, and B-R1-C, then the derived relation A-Rw-C (and the symmetrical relation C-Rv-A) must be specified.

The third criterion is that arbitrary relations must be under explicit stimulus control, because the relation is not defined by the non-arbitrary stimulus environment. For example, presentation of a second-order conditional stimulus which controls selection of equivalent stimuli should result in the selection of the word "immense" when "huge" is the sample. But in the presence of a second-order conditional stimulus which controls the selection of opposites should result in the selection of the word "tiny" with "huge" as the sample.

Finally, relations must control multiple functions of stimuli. If, for example, one stimulus is given a conditioned reinforcer effect, then control by other stimuli in the relational class must be derivable from the relation. More formally, if $f(A) = q$, then $f(B) = Rz(q)$; if the function of A is q, then the function of B (a stimulus related to A) can be defined by the function of A and the nature of the relation between A and B.

Other open frame theories. The concept of the open frame has been used by other theorists in the analysis of verbal behavior. Skinner (1957) introduces the concept of the frame during a discussion of autoclitics, units of verbal behavior which are based upon or depend upon other verbal behavior and modify their effects on the listener. He suggests that partially conditioned autoclitic "frames" can combine with responses appropriate to a specific situation to produce novel verbal responses. His example is that if a person has acquired the responses the boy's gun, the boy's shoe, and the boy's hat, then the partial frame the boy's ________ is available for recombination with other responses (p.336).

Skinner makes further use of the concept of the frame in a discussion of definitions.

> Thus An amphora is a Greek vase with two handles has at least three effects upon the listener. As the result of having heard this response he may (1) say amphora when asked What is a Greek vase with two handles called?, (2) say A Greek vase having two handles when asked What is an amphora?, and (3) may point appropriately when asked Which of these is an amphora? (p.360)

Skinner says that these responses are a product of a long history of verbal conditioning. He then goes on to discuss the process of translating language and suggests that the autoclitic "________ means ________" controls responding (p.361). A definitional "frame" seems to be implied. Skinner's predictions about the effects of hearing a definition are very similar to the effects of establishing equivalence classes. He says that such a frame establishes the ability to use a new term as both a reader and a speaker. This is the symmetry of expressive and receptive behaviors discussed previously.

Skinner views the autoclitic frame as a complex discriminative stimulus. But his discussion seems very descriptive and sketchy; it is not at all clear what sort of "verbal conditioning" history would be required to produce the effects he predicts.

Zuriff (1985) applies the frame concept to the analysis of syntactic relations. He discusses the issue of syntactic dependencies between words which are separated in sequences and rejects analyses based on sequential control. He suggests that syntactic relations (such as agreement in number between subjects and verbs) may be controlled by an open frame, "a kind of discontinuous response" (p.135). He elaborates, "The open frame is a type of relational response, a pattern filled with different verbal material on different occasions." Zuriff provides the example of a frame, "The (plural noun) who (plural verb) (noun) are ________," which could result in the response, "The men who built the house are here." Again, there is no specification of the learning history necessary for the establishment of the frame. Zuriff's formulation, like Skinner's, seems to be a preliminary suggestion which needs elaboration and refinement.

It should be noted that Zuriff's use of the term "relational" is quite different from that of Hayes and Brownstein. For Zuriff the inclusion of elements in the frame is itself "relational", while Hayes and Brownstein would require much more for the use of the term. The words that would be placed into Zuriff's syntactic frame do not exert the features of stimulus control (bidirectionality, networks of relations, etc.) required for components of Hayes and Brownstein's relational frame.

Zuriff's formulation can be related to the processes discussed in Hayes and Brownstein's development of their relational frame hypothesis. He seems to be saying that the selection of words to be placed in the frame is under conditional control. For instance, words of the class "plural noun" can be inserted into the first opening in the frame. Zuriff's analysis only hints at the complexity of the conditional control necessary for the production of a grammatical sentence. Using his frame, additional sorts of necessary conditional control can be specified. For example, the use of the word "who" requires the plural noun to refer to persons, not objects. The last opening in the frame, which Zuriff left unspecified, would have to be filled by either a verb (e.g. , "The men who built the house are coming,") or a word which can modify the plural noun (e.g., "The men who built the house are sick"). The issue of complex conditional control is clearly involved in Zuriff's analysis and is addressed by the relational frame hypothesis.

Predictions of the relational frame theory. Hayes and Brownstein's (1986) formulation results in distinct experimental predictions. Seeing stimulus equivalence as the result of control by a relation between stimuli leads to the possibility that relations other than equivalence could come to control responding. It may be that a wide variety of conditional relations between stimuli can be taught in such a manner that untrained derived relations will also come to control behavior. Using appropriate training procedures and arrangements of contingencies, one should be able to develop networks of relations resulting in control by numerous untrained relations. If, for example, a subject has learned that A is the opposite of B and B is the same as C, then the relation "A is the opposite of C" should be available to control behavior. Humans seem to demonstrate this type of control often in their verbal behavior. If a child asks "What does 'frigid' mean?" and is told that 'frigid' is the opposite of 'hot,' then the child is likely to wear a coat when hearing a weather report describing "frigid" weather. The following list provides some examples of possible conditional relations which could enter into networks of relations: inequality (less than or greater than), opposition, serial order, negation, and hierarchical class membership.

Conditional Control of the Relations Same, Different and Opposite

The central hypothesis of the present study is that arbitrarily applicable relations can come to control responding. In particular, the present study assessed control by the relations "opposite," "different," and "same." The "productive" effects of control by relations were tested by training networks of relations and assessing control by derived relations that were not directly trained.

A critical question, then, is what criteria should be used to determine whether or not the relations "opposite" or "same" exist between two stimuli. Sidman & Tailby (1982) borrowed the definition of equivalence from logic and then had the fortunate outcome that the behavioral data fit the definition. To begin the development of the definition of "opposite" let us consider how the word is used in our everyday speech. The word "opposite" is applied to points along some continuum of a qualitative property. This property may relate to objective stimulus properties (e.g., "hot" and "cold") or abstract properties (e.g., "good" and "bad"). Words are opposites if they refer to conditions on opposite sides of an arbitrarily defined midpoint of the qualitative continuum. Let us consider the opposites "left" and "right". The qualitative continuum is one of physical location defined arbitrarily along a line determined by the position of a person.

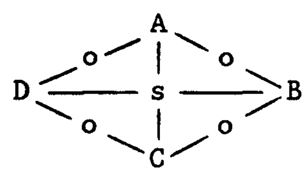
Words that are opposites usually refer to positions which are on opposite sides of the midpoint of the qualitative continuum and are equally far from the midpoint. Thus, the opposite of "warm" is not "cold," but "cool." The opposite of "worst" is "best," while "worse" and "better" are opposites.

Our use of "opposite" in natural language also involves properties of the "not" relation of formal logic, commonly symbolized by the tilde, $\sim$. (We will use the term "logical not" or the symbol, $\sim$, to refer to this relation to avoid confusion with the natural language word "not.") The following list illustrates the defining properties of the "logical not" relation:

1. $a = \sim\sim a$;
2. If $a = \sim b$, then $b = \sim a$;
3. If $a = \sim b$, and $b = \sim c$, then $a = c$.

In natural language if one is told that A is the opposite of B, and B is the opposite of C, one can conclude that A and C are the same. This relation expressed in terms of "opposites" is exactly equivalent to the third defining property of the "logical not" relation (above). When the relation of "opposite" is applied to totally arbitrary stimuli such as A, B, and C in the preceding example all reference to a qualitative or quantitative dimension is absent and the relation of opposition reduces to the "logical not" relation.

Following Sidman and Tailby's example, definitional properties for opposition can be borrowed from logic, and predictions can be made about the type of control that should be demonstrated if the relation is successfully established. The relation of opposition is irreflexive; A is not the opposite of A. The relation is symmetrical; if A is the opposite of B, then B is the opposite of A. Transitivity is not predicted; if A is the opposite of B and B is the opposite of C, then A is not the opposite of C. But another derived relation is present in the last case; A is the same as C. While transitivity in its usual sense is not observed, if the network of relations is extended, one can predict a relation which will be called "second order transitivity." This second order transitivity is demonstrated by the following set of relations: if A is the opposite of B, and B is the



o=opposite
s=same

Figure 8. Relations among sets of stimuli developed by relating sets as opposites.

opposite of C, and C is the opposite of D, then D is the opposite of A. This set of relations is demonstrated graphically in Figure 8. The relation "different," like the relation opposite is symmetrical. If A is different from B, then B is also different from A. The relation "different" is (like opposite) irreflexive. A is not different from A. Other than irreflexivity and symmetry the different relation allows for no predictions about networks of relations. If B is different from A, and C is different from A, then the relation of B to C is totally undefined. B and C could be the same, different, opposite, etc., so no predictions about transitivity or second-order transitivity are possible when stimuli are related as being different.

Predicted network of relations. Having developed an *a priori* definition of opposition which allows predictions about derived relations, the next task is to devise an objective way to train the opposite relation and test for derived control. Since many of the predictions about relations predict equivalence of stimuli as well as opposition, tests for both relations must be possible. This can be done by bringing sample-comparison choices under the conditional control of another stimulus which will signal whether the choice of comparisons is to be based on the relation of sameness or opposition. This procedure involves what Sidman (in press) has termed second-order conditional control. Figure 9 illustrates second-order conditional control using words as stimuli.

Second-Order Conditional Stimuli:	Same	Opposite
Samples:	"frigid"	"frigid"
	\	/
Comparisons:	"hot" "cold"	"hot" "cold"

Figure 9. Illustration of second-order conditional control over sample-comparison choices.

The final remaining problem is how to establish the second-order conditional stimulus as controlling the relations of "opposite" and "same". This was attempted in a pretraining session using the second-order conditional discrimination procedure. The second-order conditional stimuli were arbitrary visual stimuli. The sample and comparison stimuli were non-arbitrary visual stimuli. An example will help clarify the procedure. In the presence of the second-order conditional stimulus which is to control the selection of opposites and a sample which is a short line, selection of a long line was reinforced. (See Figure 10 for a diagramed example.) In the presence of the symbol for "same" and a sample which is a large square, selection of the comparison which is a large square was reinforced. After a number of exemplars, the arbitrary stimuli for "same" and "opposite" should come to control selections with novel samples and comparisons. Once this control is established with non-arbitrary stimuli, it should be possible to use the second-order stimuli to establish arbitrary stimuli as being opposite or the same.

The predicted pattern of responding derived from the logical relations must be tested with a set of unreinforced probes. Figures

10-12 outline a set of training trials which should result in the development of a network of relations and a series of probes which can test for the control of responding by the hypothesized network of relations. The letters "O" and "S" represent the arbitrary stimuli which were trained to control selection of comparisons which were the same as or opposite of the sample. All other letter and number combinations represent the arbitrary visual stimuli which served as samples and comparisons. All stimuli with the same numerical subscript are to be equivalent as a result of training or derived relations. If pairs of stimuli have different subscripts they are opposites.

Following the initial training of A-B relations there are two probes which are critical to demonstration of control by the opposite relation. In the probes for reflexivity, a novel stimulus was used as one comparison and A1 was the sample and the other comparison. When the symbol for "opposite" is present, irreflexive choices should be made, and the subject should choose a novel stimulus with no reinforcement history.

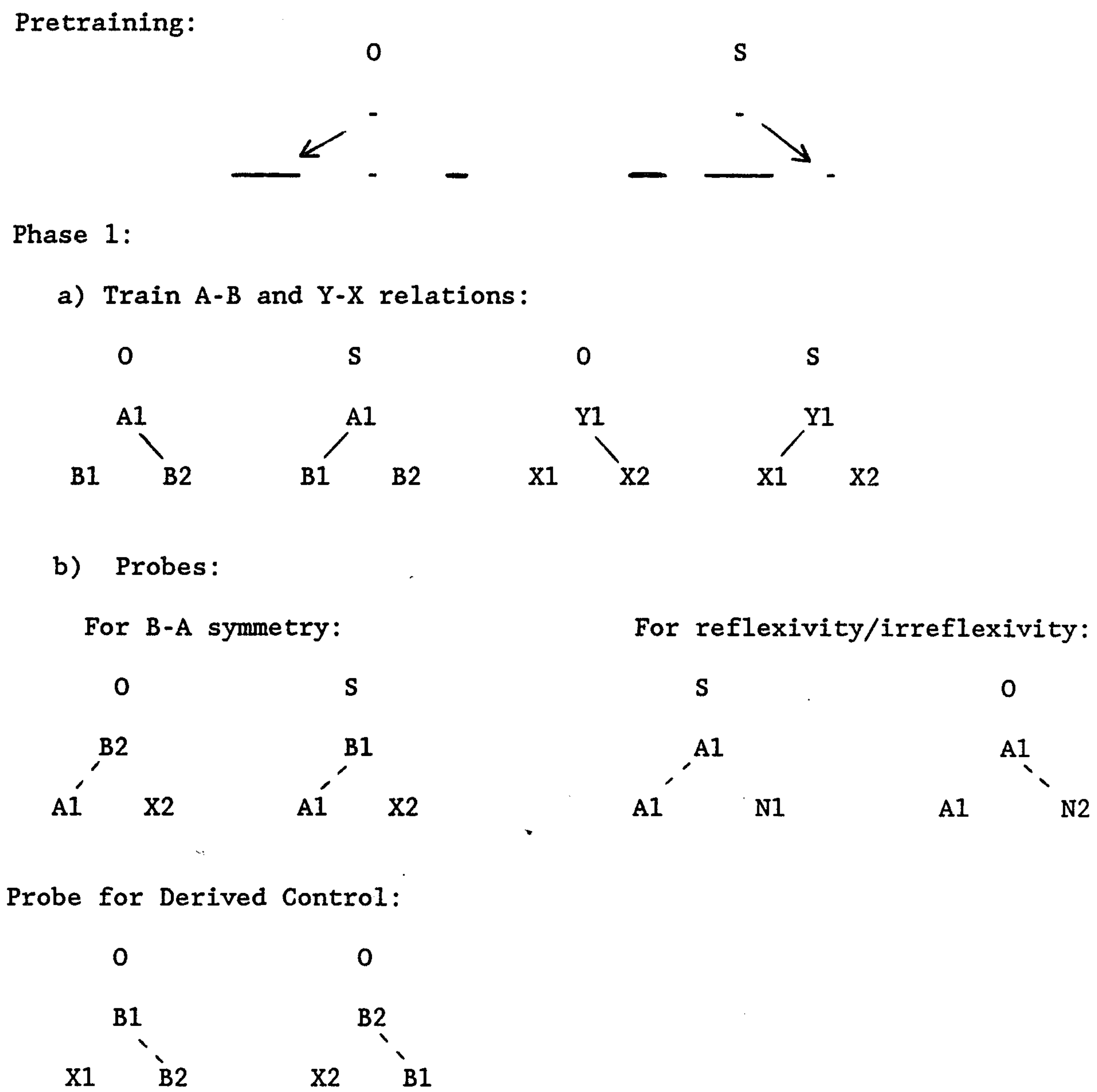
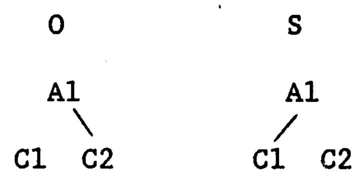


Figure 10. Outline of procedure for the first phase of training and testing.

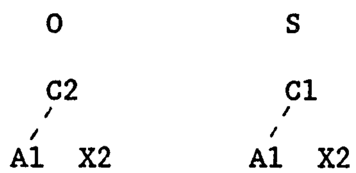
Phase 2:

a) Train A-C relations:



b) Probes:

For C-A symmetry:



For derived control:

Figure 11. Outline of further training and probe arrangements.

Phase 3:

a) Train C-D relations:

```
     O              S

     C2             C2
    /                 \
  D1   D2         D1   D2
```

b) Probes:

For D-C symmetry:

```
      O              S

      D1             D2
        \              \
    C1   C2        C1   C2
```

For derived control:

```
       O              S              O              S

       D1             D1             A1             A1
         \           /                 \           /
     B1   B2     B1   B2         D1   D2      D1   D2
```

Figure 12. Outline of further training and testing.

In the probes for derived control the fact that training establishes B1 as the same as A1, and B2 as the opposite of A2 should establish B1 and B2 as opposites. The X stimuli are used as comparisons in these probes to provide stimuli which have not yet been explicitly related to A or B stimuli, but which have had a history of reinforcement.

Following the training of A-C relations (see figure 11), derived relations between stimuli in sets B and C can be tested. In the presence of the "opposite" stimulus matches should be B1-C2 and C1-B2. Finally, after training the C-D relations (Figure 12), the presence of second order transitivity can be examined with sample-comparison combinations such as B2-D1. That relation comes about through a chain of opposite linkages (B2-A1-C2-D1). The demonstration of derived control would validate the prediction of Hayes and Brownstein that networks of relations can be established resulting in untrained control of responding consistent with the relations among stimuli.

<u>Second order conditional control</u>? A second hypothesis of the present study is that selection of comparisons on the basis of same or opposite relations can be brought under conditional control. If successful, this outcome would be relevant to the issue of whether or not to expand the unit of behavioral analysis to include more than one antecedent stimulus. The critical issue is explaining the function of the stimulus which signals which relation (same or opposite) is to control choices of comparisons.

This writer cannot develop a way to use the three-term contingency, even with mediation, to account for the predicted results. Perhaps the symmetry probes could be accounted for by saying that the second-order conditional stimulus, sample, and comparison stimuli (e.g. O, A1, B2) form a compound discriminative stimulus during training and that during testing (with the former correct comparison presented as a sample) the subject selects the stimulus that completes the compound. There does not, however, seem to be a feasible account for predicted irreflexive
choices and the derived control without resort to a four-term or even five-term unit of analysis. If the experimental hypotheses are supported by the results, the development of an explanation using the three-term unit of an analysis could, perhaps, best be attempted by a proponent of that viewpoint.

Other possible forms of stimulus control

It may be possible that consistent responding on some probe trials could result from some sort of stimulus control not explicitly related to the "same" or "opposite" relations.

Conditional equivalence classes. Some of the predicted responses on probe trials could come about through the development of conditional equivalence classes. Even without pretraining, a subject could learn during A-B training (1a), that with identical sample and comparison stimuli, one response is reinforced in the presence of one second-order conditional stimulus and the other response is reinforced in the presence of the other second-order conditional stimulus. No pretraining would be required to establish this sort of conditional responding; the training in phase 1a alone would be adequate.

With no pretraining, the training in phase 1a should result in the development of conditional equivalence classes. These classes are illustrated in Figure 13. In the presence of the first second-order conditional stimulus ("same" for pretrained subjects), A1, B1, and C1 should become equivalent stimuli and occasion the selection of each other. In the presence of the other second-order conditional stimulus ("opposite" for pretrained subjects), A1, B2, and C2 should become equivalent stimuli.

	S			O	
	A1			A1	
B1		C1	B2		C2

Figure 13. Conditional equivalence classes which should emerge as a result of the experimental training for subjects with no pretraining.

Without control by the opposite relation, there seems to be no reason to predict any pattern of consistent responding on the probe for irreflexivity. Similarly, without control by the relations of same and opposite there seems to be no reason to expect the pattern of derived control predicted for the probes in phase 1b.

The probes which follow A-C training are particularly important. If the conditional equivalence classes diagrammed in Figure 13 emerge, then the subjects who receive no pretraining could make the pattern of responses shown in Figure 14.

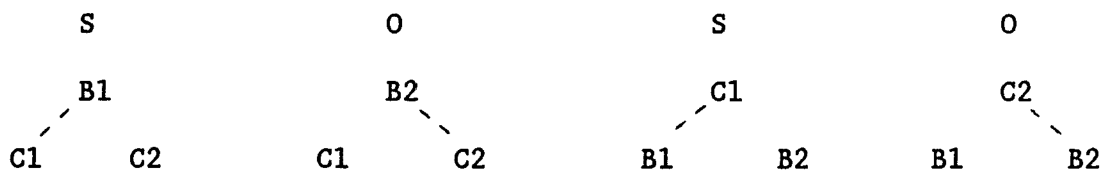


Figure 14. Probe response pattern which could be established by conditional equivalence classes.

The probes which are actually presented in Phase 2b do not fit this pattern. The first probe for derived control in this phase (S-C2-B2) is particularly important. This predicted response for pretrained subjects is inconsistent with conditional equivalence classes. Furthermore, the subjects will have no history of receiving reinforcement for selecting the comparison B2 in the presence of this second-order conditional stimulus ("same" for pretrained subjects). Subjects who do not receive pretraining should demonstrate inconsistent responding or patterns of responses other than that predicted for the experimental subjects.

<u>Selections based on conditional control of reflexive or irreflexive choices</u>. While subjects who receive no pretraining should not be able to respond in the same manner as those who receive pretraining, it is possible that a different type of pretraining could result in identical results. It may be that the pretraining previously described does not establish control by the opposite and same relations, but rather that the "same" stimulus comes to control making reflexive choices (identity matching), and the "opposite" stimulus comes to control making irreflexive choices (selecting the comparison which is different from the sample).

Three subjects were given a different pretraining procedure in which two different arbitrary stimuli signaled differential reinforcement of the selection of comparisons which were the same as (reflexive choices) or different from (irreflexive choices) the sample. It seemed possible that the pattern of responding demonstrated by these subjects would be similar to that of the experimental subjects. If so, this would support the analysis that once the relation of "opposite" is applied to arbitrary stimuli it reduces to the "logical not" relation. This analysis would clarify our understanding of the opposite relation in natural language.

Testing for the existence of a relational frame.

Hayes and Brownstein (1986) suggested that one step in testing for the existence of a relational frame is to look for bi-directionality of the relation. This is exactly what the probes for symmetry in this experiment examine. The second criterion for the existence of the relational frame was the establishment of a network of relations which results in predictable control of untrained behavior. This criterion is examined by the probes for derived control. The third criterion proposed was bringing the application of the relational frame under explicit stimulus control. This entire experiment is based on the premise that explicit stimulus control (by second-order conditional stimuli) of relations (same, different, and opposite) can be developed and applied differentially to the same sets of sample and comparison stimuli. The present experiment does not give any of the stimuli a further function (such as conditioned reinforcer), so Hayes and Brownstein's fourth criterion is not examined.

The hypothesis of the present study is that all three of these criteria for the existence of a relational frame will be met by the responses of subjects who are taught to make "same" and "opposite" choices in pretraining. This hypothesis will be supported if the experimental subjects make the predicted responses on probe trials following A-B and A-C training (phases 1b & 2b). Failure to observe the predicted responses to the probes following C-D training (phase 3b) would not lead to a negative conclusion. It could be argued that more extensive training would be required to establish the extended network of relations.

If subjects who received no pretraining showed the predicted pattern of responses on the probe trials, the experiment would have demonstrated second-order conditional control, but the main hypothesis would not be supported. The findings would, however, be relevant to the issue of whether or not to extend our unit of behavioral analysis to a four- or five-term contingency.

CHAPTER II

EXPERIMENT 1

Method

Subjects

Subjects were youths from 13 to 17 years of age who were recruited through personal contacts for paid participation. Respective ages and sexes of the subjects were as follows: TE, 16, M; HE, 13, F; RA, 17, M; JO, 16, M; KE, 17, M; KI, 17, F; BR, 16, M; DA, 16, M; and LA, 17, F. Youths were in the college preparatory curriculum in school, so it can probably be assumed that all subjects were of average or above average intelligence. Youths were paid at a mutually agreed upon rate based on their usual rate of compensation for part time work such as baby-sitting. No youth was paid less than $2.00 per hour. For all subjects below the age of 18, the informed consent of their parents was obtained before their participation.

Apparatus and Stimuli

Subjects were seated at a table in a large room. A computer monitor and a joystick, used as the response device, were placed on the table directly in front of the subject. The monitor and joystick were connected to a microcomputer which was also on the table. The experimental stimuli were figures displayed on the computer screen using high resolution graphics. The second-order conditional stimulus was presented in the center of the top third of the screen. The sample stimulus was presented in the center of the middle third of the screen. The comparison stimuli were presented at the bottom of the screen.

Same/opposite pretraining. During pretraining for the establishment control over the selection of same and opposite comparisons, it was possible to relate the sample and comparison stimuli on the basis of their physical properties, and three comparison stimuli were presented. Stimuli which vary on some physical dimension were used. These sets of stimuli included the following:

1) short to long lines,
2) small to large squares,
3) sets of few to many dots,
4) sets of closely spaced to distantly spaced lines,
5) a scale with a cursor which is located at the top, bottom, or middle,
6) a scale with a cursor which is located at the left, right, or center,
7) figures drawn with very thick to thin lines,
8) tall to short lines.

Each set was presented with the sample drawn from either end of the range of differences. This made possible the presentation of 16 different sets of sample and comparison stimuli.

During the pretraining designed to establish control over selection of "same" or "different" comparisons all stimuli were arbitrary figures. Two comparison stimuli, one of which was identical to the sample, were presented. The second-order conditional stimulus used to control selecting the "same" comparison during same/opposite pretraining was also used to signal selection of the "same" comparison during this type of pretraining.

For all other phases of the experiment only two comparison stimuli were presented and the stimuli were arbitrary figures designed so that they did not resemble any letters, numerals, or mathematical symbols. Presentation of stimuli and recording of responses were controlled by the computer.

Responses were made by using the computer joystick. Moving the lever on the joystick from left to right resulted in the movement of a box on the monitor screen. The box moved in such a manner that it always surrounded one of the available comparison stimuli. Pressing a button switch on the joystick case "selected" the comparison stimulus currently inside the box on the screen.

Overview of the sequence of training

The training and testing sequences are presented diagrammatically in Figures 10-12. The letters "O" and "S" represent the second-order conditional stimuli which should control the selection of same or opposite stimuli. The other letter and numeral combinations represent sample and comparison stimuli. The sample stimulus is presented in the center of the arrangement. Solid lines indicate trained selections of comparisons, and dashed lines indicate predicted selections. Stimuli with the same numeric subscript are the "same" while stimuli with different subscripts are "opposite".

Some subjects were given pretraining designed to establish two arbitrary stimuli as controlling selection of comparisons which are the same as or opposite of the sample stimulus (same/opposite pretraining). These stimuli were then used in a match to sample procedure to establish arbitrary stimuli as being the same or opposite.

It was predicted that the sequence of training would establish the network of relations which is illustrated in Figure 15. The diagram indicates that A1 is the opposite of B2 and C2, and that C2 is the opposite of D1. The stimuli A1, B1, C1, and D1 are to be selected as

Figure 15. The network of relations to be established by training.

the same as each other. If appropriate derived control is developed, the subjects should make the responses to probe items indicated in Figure 12.

The use of so many stimuli runs the risk of overloading the subjects. For this reason some care was taken to use only the minimum number of sample and comparison stimuli necessary to support or disconfirm the experimental hypothesis. As a result, there was no A2 stimulus.

Procedure

All subjects were given individual sessions lasting up to two hours. At the start of the first session, subjects were given instructions about the general nature of the task. (See the appendix for the complete text.) Whenever possible, sessions were scheduled on consecutive days. At the start of each session the subject started at the very beginning of the sequence of tasks and reviewed all previously trained material.

On each trial, the second-order conditional stimulus was presented, and after a 2 second delay the sample stimulus would appear. Following another 2 second delay the comparison stimuli were presented in random positions (left, center, or right).

During training and reviews of previously trained relations, feedback was given. When the response was correct, two tones sounded and a message saying "correct" appeared on the screen. If a response was incorrect, a repetitive low-pitched tone sounded and a message saying "wrong" appeared.

Pretraining for same/opposite control. In this pretraining condition, conditional control of the selection of comparisons which are the same as or opposite of the sample (on a non-arbitrary physical dimension) was trained. For example, a sample was a short line and comparisons were three lines ranging from a short line of the same length as the sample to a much longer line. In the presence of the second-order conditional stimulus which is to control the choice of same stimuli, selection of the short line was reinforced. In the presence of the second-order conditional stimulus for "opposite," the selection of the longest line was reinforced. Feedback was given after each response.

Training was conducted in blocks of 20 trials with samples drawn from each end of the continuum and both second order conditional stimuli presented in a balanced fashion. For example, with comparisons which were long to short lines, the second-order conditional stimulus for opposite would be presented for 10 trials, 5 trials with the short line as sample and 5 trials as the long line as sample. On 10 trials in the same block, the second-order conditional stimulus for same would be presented, and again there would be 5 trials with the short line as sample and 5 trials with the long line as sample. Order of presentation was randomly determined.

The pretraining with feedback was conducted with three sets of stimuli---long to short lines, large to small squares, and tall to short lines. The subjects had to achieve a 90% accuracy rate on each set of stimuli before going on to the next set. Once responding on all three sets were at the 90% accuracy level, problems from the three sets were presented concurrently in one block of 32 trials.

After a 90% accuracy rate on the concurrent presentation of trained items was achieved, unreinforced probes were used to test for generalized control by the second-order condtional stimuli. Novel sets of stimuli were presented with the same procedure as used in training, except that no feedback was given. If a subject made any incorrect responses with a set of stimuli, responses to those stimuli were trained with feedback, and an additional set of novel stimuli was presented. The criterion for successful pretraining was errorless performance for six trials during the presentation of each of three novel sets of stimuli. Such a performance would indicate that the arbitrary second-order conditional stimuli had come to control the selection of comparison stimuli which are the same as or opposite of the sample stimulus.

Pretraining for same/different control. In this condition the pretraining stimuli were arbitrary visual stimuli. A sample was presented in the middle of the screen. Two comparisons were presented, one of which was identical to the sample. In the presence of the second-order conditional stimulus for "same," the selection of the comparison which was identical to the sample was reinforced. In the presence of the second-order conditional stimulus for "different," selection of the comparison which was not identical to the sample was reinforced.

Training was conducted in blocks of 20 trials---10 trials with the "same" stimulus and 10 trials with the "different" stimulus. Each block used one set of two arbitrary stimuli, and each stimulus in the set was used as the sample an equal number of times. All other aspects of the procedure (accuracy criteria, presentation of different sets of stimuli, probes without feedback, etc.) were identical to the procedure used in same/opposite pretraining.

Training. In all training blocks each problem was presented for 10 trials. Problems were presented in random order unless otherwise noted. In phase 1 the Y-X relations were trained only so that the X stimuli could be used in subsequent probes for symmetry and derived control. The selection of these stimuli (X1 and X2) was reinforced during training, so failure to select them during probes would be the result of conditional control and not merely the result of differences in frequency of previous reinforcement.

Following the additional training sets (A-C and C-D relations) in phases two and three. All of the trained relations were reviewed concurrently with feedback given on each trial. This was done to make sure that all trained responses were at full strength. To advance to the next phase of the study a subject had to make accurate responses on 80% of the trials for each problem with a 90% accuracy rate for the whole block. Failure to achieve the 90% criterion resulted in a return to the same training block.

Probe blocks. Two to four different probes were presented in blocks of trials. Previously trained problems, presented in extinction, alternated with the probes. In any block all previously trained problems were presented an equal number of times, all probes were presented for an equal number of times, and the number of probes and the number of previously trained problems presented in extinction were equal. Each probe was presented a minimum of 8 times in each block. Order of problems and probes within the blocks was randomly determined. These constraints dictated the number of trials in a given block. For example, if a block was to contain 6 previously trained problems presented in extinction and 4 probes, each probe would be presented on 9 trials for a total of 36 probe trials and each trained problem would be presented on 6 trials for a total of 36 extinction trials. Each block of trials was planned for the smallest number of trials which would meet the criteria above.

The criterion for mastery was an 80% accuracy rate for each individual probe and an overall accuracy rate of 90% for all probes in a block. Usually, when a subject failed to achieve these accuracy rates, s/he was given a review of all previously trained problems followed by a return to the same block of probes where difficulty was encountered. Repeated reviews might provide the subject with feedback about inaccuracy. So if three reviews did not produce accurate responding on a given probe block, other problems were presented before returning to the set of probes where difficulty was encountered.

Use of expanded probe sets. Sometimes a subject would fail to show the expected pattern of responding after reviewing trained relations a number of times. Because we had chosen to use an abbreviated set of all possible probes, it was possible to give subjects additional, related probes. This was done without providing any feedback about current or previous responses. This procedure was used with control subjects as well as with subjects in the main experimental group.

Debriefing subjects. At the end of the experiment each subject was asked if s/he had labels for the second-order conditional stimuli. Sometimes control subjects were asked why they responded in a particular way on some problems. The purpose of the study was explained to all subjects.

Results

Subjects Who Received Same/Opposite Pretraining

Pretraining. Pretraining was accomplished in the following number of training blocks for each subject: TE, 8 blocks; HE 15 blocks; RA, 8 blocks; and JO 8 blocks. Subject HE was the only subject to experience substantial difficulty with the training process. The procedure was modified slightly so that she was repeatedly given the same pretraining problem until she mastered it. Then the next problem was presented, and then previously mastered problems were presented concurrently. All other subjects had multiple problems presented concurrently, and experienced no difficulty mastering the pretraining task.

Training. All of the subjects who received same/opposite pretraining achieved a 90% accuracy rate for A-B relations in the first block of 40 training trials. They also were better than 90% accurate in the first 20-trial block of A-C training.

Responses to Probes. Subject TE (see Table 3) showed the predicted pattern of responses on 100% of all probes following A-B and A-C training. (In the tables and in the text, problems and probes are described using abbreviations. The second-order conditional stimulus is given first, S for same and O for opposite, followed by the sample, and then the predicted comparison choice.) After C-D training TE showed control by symmetry of the D-C relations on only 75% of the trials. An error in the computer program allowed progress to the next set of probes, and TE showed the predicted pattern of responding on the probes which tested for D-B relations. After a brief review of C-D

Table 3

Percentage of Accurate Responses on Training Problems and Probes for Subject TE

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	92.5
Probe for symmetry of (B-A) relations	100
Probe for reflexivity/irreflexivity	100
Probe for derived control O-B1-B2 and O-B2-B1	100
Train A-C relations	95
Review A-C, A-B, and Y-X relations with feedback	100
Probe for C-A symmetry	100
Probe for derived control S-C2-B2, O-C1-C2, O-C1-B2, O-B1-C2	100
------------------Break between sessions------------------	
Review A-B and A-C relations with feedback	100
Probe for derived control (C-B & B-C relations)	95.8
Train C-D relations	100
Review A-B, A-C, & C-D relations with feedback	98
Probe for symmetry of D-C relations	75
Probe for derived control, D-B relations	100
Train C-D relations (5 trials each)	100
Probe for symmetry of D-C relations	100
Probe for derived control, D-B relations	100

training, responses to probes for symmetry were 100% accurate. The probes for D-B relations were repeated, and responses were again 100% accurate.

After initial training of the A-B relations, subject HE (see Table 4) failed to show control of responding by symmetry of the trained same relation. Even after repeated review of the trained A-B relations control by symmetry was not demonstrated. At this point the procedure was altered (alteration of procedure is indicated in the tables with an asterisk, *) to provide additional probes for symmetry of the same relations. Originally this probe presented the second-order conditional stimulus for selection of "same" comparisons, B1 as the sample, and A1 and X2 as comparisons. The additional probes used X1 and B2 as incorrect comparisons. This procedure resulted in 100% accurate responses to probes for symmetry.

Following the training of A-C relations, HE responded accurately to all probes for derived control, except she could not relate C2 and B2 as being the same. Review of trained relations did not produce the expected pattern of responding. Again, the procedure was altered to provide for additional probes (see Table 4 for details) for derived control by the same relation (transitivity of equivalence). This produced 100% accurate responding immediately. At this point subject HE was demonstrating the expected pattern of responding on all of the probes originally planned for this phase. She chose to withdraw from the experiment at this point.

With the use of expanded probes, HE demonstrated the predicted pattern of responding for relating the A, B, and C sets of stimuli. This is sufficient to support the experimental hyptheses. The other subjects went on to add the D set of stimuli to the network of relations, but the essential features of control by the opposite and same relations are demonstrated without the D stimuli.

Subject RA (see Table 5) made correct responses at or above the 90% rate on all blocks of training and probes until phase 3 of the experiment. After C-D training, RA's responses to probes for control by D-B relations were above 50% accurate, but failed to reach criterion levels. This subject was immediately given probes for the intermediate A-D relations and met the criterion level for these probes. A repetition of the D-B probes resulted in 100% accuracy.

Table 4

Percentage of Accurate Responses on Training Problems and Probes for Subject HE

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	100
/Probe for symmetry O-B2-A1	40
\Probe for symmetry S-B1-A1	60
Review A-B and Y-X relations with feedback	95.8
/Probe for symmetry O-B2-A1	100
\Probe for symmetry S-B1-A1	0
Review A-B and Y-X relations with feedback	100
/Probe for symmetry O-B2-A1	100
\Probe for symmetry S-B1-A1	0
/Probe for symmetry O-B2-A1	100
\Probe for symmetry S-B1-A1	0
--------Break between sessions--------	
Train A-B and Y-X relations	92.5
/Probe for symmetry O-B2-A1	100
\Probe for symmetry S-B1-A1	0
Review A-B and Y-X relations	100
/*Probe for symmetry S-B1-A1 (X1 as other comparison)	100
*Probe for symmetry S-B1-A1 (B2 as other comparison)	100
Probe for reflexivity/irreflexivity	100
Probe for derived control O-B1-B2 and O-B2-B1	95
Train A-C relations	95
Review A-B, Y-X, and A-C relations with feedback	100
Probe for symmetry O-C2-A1 and S-C1-A1	100
/Probe for derived control S-C2-B2	0
\Probe for derived control O-C1-C2	100
Review A-B, Y-X, and A-C relations with feedback	100
/*Probe for derived control S-B2-C2	100
\ Probe for symmetry S-C1-A1	100
/Probe for derived control S-C2-B2	100
\Probe for derived control O-C1-C2	100
/Probe for derived control O-C1-B2	0
\Probe for derived control O-B1-C2	0
/Probe for derived control O-C1-B2	0
\Probe for derived control O-B1-C2	0
--------Break in sessions. Program modified at this point.--------	
Review A-B, A-C, and Y-X relations with feedback	100
Probe for symmetry of C-A relations	100
/ Probe for derived control S-C2-B2 (other comparison B1)	100
*Probe for derived control S-B2-C2 (other comparison C1)	100
*Probe for derived control S-B1-C1 (other comparison C2)	100
*Probe for derived control S-C1-B1 (other comparison B2)	100
/ Probe for derived control O-C1-C2	100
Probe for derived control O-C1-B2	100
\ Probe for derived control O-B1-C2	100

Table 5

Percentage of Accurate Responses on Training Problems and Probes for Subject RA

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	90
Probe for symmetry of opposite and same relations (B-A)	100
Probe for reflexivity/irreflexivity	100
Probe for derived control O-B1-B2 and O-B2-B1	100
Train A-C relations	95
Review A-C, A-B, and Y-X relations	100
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	100
\Probe for derived control O-C1-C2	100
Break between sessions.	
Train A-B and Y-X relations	95
Probe for symmetry of opposite and same relations (B-A)	95
Probes for reflexivity/irreflexivity	90
Probe for derived control O-B1-B2 and O-B2-B1	100
Train A-C relations	95
Review A-C, A-B, and Y-X relations	100
Probe for C-A symmetry	100
Probe for derived control S-C2-B2 and O-C1-C2	100
Probe for derived control O-C1-B2 and O-B1-C2	100
Train C-D relations	90
Review A-B, Y-X, A-C, & C-D relations with feedback	100
Probe for symmetry of D-C relations	93.8
/Probe for derived control O-D1-B2	87.5
\Probe for derived control S-D1-B1	62.5
/Probe for derived control O-A1-D2	87.5
\Probe for derived control S-A1-D1	100
/Probe for derived control O-D1-B2	100
\Probe for derived control S-D1-B1	100

The visual stimuli were reassigned to different functions in the experiment for JO's training and probes. This was done to make sure that some incidental feature of the stimuli had not produced the pattern of control observed with the first three subjects. Subject JO mastered the trained relations quickly, and then demonstrated the predicted pattern of responding for the probes in phase 1. After A-C training, JO failed to show the predicted pattern of responding to the probe S-C2-B2. In this case, no modification of the procedure was necessary. In the next experimental session previously trained relations were reviewed and at that point JO demonstrated the predicted pattern of responding to probes in phases one and two.

Following C-D training JO failed to respond correctly to probes for D-B relations. He was immediately given probes for the intermediate A-D relations and made 100% accurate responses. A return to the probes for B-D relations resulted in demonstration of the predicted pattern of responding. These results indicate that the pattern of responding is due to control by the network of relations, not some incidental aspect of the experimental stimuli.

Table 6

Percentage of Accurate Responses on Training Problems and Probes for Subject JO

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	95
Probe for symmetry of opposite and same relations (B-A)	100
Probe for reflexivity/irreflexivity	95
Probe for derived control O-B1-B2 and O-B2-B1	100
Train A-C relations	100
Review A-C, A-B, and Y-X relations	100
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	0
\Probe for derived control O-C1-C2	92
--------Break between sessions.--------	
Review A-B and Y-X relations with feedback	92
Probe for symmetry of opposite and same relations (B-A)	100
Probes for reflexivity/irreflexivity	100
Probe for derived control O-B1-B2 and O-B2-B1	100

Table 6 (continued)

Train A-C relations	100
Review A-C, A-B, and Y-X relations	93
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	83
\Probe for derived control O-C1-C2	100
/Probe for derived control O-C1-B2	92
\Probe for derived control O-B1-C2	100
Train C-D relations	95
Review A-B, Y-X, A-C, & C-D relations with feedback	100
Probe for symmetry of D-C relations	100
/Probe for derived control O-D1-B2	12.5
\Probe for derived control S-D1-B1	0
/Probe for derived control O-A1-D2	100
\Probe for derived control S-A1-D1	75
Review A-B, Y-X, A-C, & C-D relations with feedback	95.8
/Probe for derived control O-A1-D2	100
\Probe for derived control S-A1-D1	100
/Probe for derived control O-D1-B2	87.5
\Probe for derived control S-D1-B1	87.5
/Probe for derived control O-A1-D2	100
\Probe for derived control S-A1-D1	100
/Probe for derived control O-D1-B2	100
\Probe for derived control S-D1-B1	100

Latency of responding. Fields and his colleagues (1984) suggested that the number of nodes required to relate two stimuli might be an indication of "associative distance." Increasing associative distance might result in increased response latencies. In the present study, the fact that two relations were used to control responding complicates the issue. Difficulty of the problems may have been increased in those probes in which the subject had to consider two relations "same" and "opposite" in arriving at a choice. The concept of stages developed by Sidman and his colleagues (Sidman & Tailby, 1982; Sidman et al., 1985)---instead of the nodal distance construct--- was applied to the probes. The number of stages and the number of relations involved in the derived control were used to make an a priori prediction about the difficulty of the probes. An example will help to clarify this process. The probe S-A1-D1 is a two-stage (A-C and C-D) relation and initially appears to only involve a single relation, "same." But D1 was brought into the network of trained relations through the training O-C2-D1, so both the "same" and "opposite" relation entered into the development of the control for this probe. Probes were divided into six groups. The latency data from subjects TE, RA, and JO were analyzed. These subjects were selected because they had relatively uncomplicated training histories. (Subject HE was given an expanded probe set and had many repetitions of phases of the experiment.) The groups of probes, rationale for determining groups, and average latencies are given in Table 7. The response latencies

Table 7

Average Latency of Response for Probes of Different Complexity in Seconds

Group	Description of Group	Mean Latency in Sec.'s
A	Probes for symmetry & probes for reflexivity/irreflexivity 1 stage, 1 relation	1.8
B	Probes for comparisons in the same set being related as opposite (e.g. O-B1-B2)- 1 stage, 2 relations	2.4
C	Probes for derived control- 2 stage, 2 relations (e.g. O-C1-B2, O-A1-D2, S-A1-D1, & S-C2-B2	3.4
D	Probes for D-B control- 3 stage, 2 relations (O-D1-B2 & S-D1-B1)	4.1

were analyzed with a single-factor analysis of variance, and a statistically significant effect ($p<.0001$) was found (F (3, 830)=10.83, MS=664552.9). Differences between groups were examined using Tukey's studentized range (HSD) test. Latencies of type A were significantly shorter than those of types C and D. Latencies of type B differed significantly only from those of type D. Latencies for probes in group C were significantly longer than those in group A, and those in group D differed significantly only from those in group A.

Labeling second-order conditional stimuli. Subjects HE, RA, and JO correctly labeled the second-order conditional stimuli as "same" and "opposite." Subject TE used the appropriate designations "synonym" and "antonym."

Subjects who Received No Pretraining

Trained relations. Subject KE (see Table 8) had difficulty mastering the initial training of A-B and Y-X training. After four 40-trial blocks, he was responding at chance levels. At that point the procedure was modified so that only A-B relations were trained until a criterion level of mastery was reached. Then Y-X training was conducted, followed by a concurrent review of A-B and Y-X problems presented concurrently. It took 328 trials to demonstrate mastery of these trained discriminations.

For subject KI (see Table 9) the initial training procedure was modified so that A-B relations were trained first, followed by the training of Y-X relations and then concurrent presentation of both sets of problems. KI made accurate response on more than 90% of all trials, so the original procedure might have been sufficient for her.

Probes for reflexivity and irreflexivity. Following A-B training, both KE and KI showed control by symmetry. But on the probes for reflexivity and irreflexivity they both showed a consistent pattern of responding which was quite different from that of the pretrained subjects; they selected the novel stimulus instead of A1 in the probe for reflexivity and the probe for irreflexivity. Review of the trained relations did not produce a change in response pattern for either subject.

When pretrained subjects did not show the predicted pattern of responding, they were given an expanded set of relevant probes. This same tactic was tried with KI. She was given two probes for reflexivity, S-A1-A1 with N1 as the wrong comparison in one problem and N2 as the wrong comparison in the other problem. Two similar probes for irreflexivity (O-A1-N1 and O-A1-N2) were also given, but the pattern of responding was like that of the pretrained subjects on only 50% of the trials.

Table 8

Percentage of Accurate Responses on Training Problems and Probes for Subject KE

Problem or Probe	Percentage Correct
Train A-B & Y-X relations 40 trials	62.6
Train A-B & Y-X relations 40 trials	57.5
Train A-B & Y-X relations 40 trials	60
Train A-B & Y-X relations 40 trials	50
Train A-B relations only 40 trials	82.5
Train A-B relations only, 40 trials	100
Train Y-X relations only, 40 trials	92.5
Train A-B & Y-X relations 24 trials	62.5

Table 8 (continued)

Train A-B & Y-X relations 24 trials	100
Probe for symmetry of opposite and same relations (B-A)	100
Probes for reflexivity/irreflexivity	55
Review A-B and Y-X relations with feedback	100
Probes for reflexivity/irreflexivity	50
Review A-B and Y-X relations with feedback	100
Probes for reflexivity/irreflexivity	50
--------Break between sessions.--------	
Review A-B and Y-X relations with feedback	100
Probes for symmetry of B-A relations	100
Probes for reflexivity/irreflexivity	50
Review A-B and Y-X relations with feedback	100
Probes for derived control (B1-B2)	50
Review A-B and Y-X relations with feedback	100
Probe for reflexivity/irreflexivity	50
Review A-B and Y-X relations	100
Probe for derived control (B1-B2)	50
Train A-C relations	95
Train A-C relations & previously trained A-B relations	100
/Probe for symmetry O-C2-A1	66.7
\Probe for symmetry S-C1-A1	100
Review A-B,A-C,and Y-X relations	100
/Probe for symmetry O-C2-A1	45.8
\Probe for symmetry S-C1-A1	91.7
Train A-C relations	95
/Probe for symmetry O-C2-A1	0
\Probe for symmetry S-C1-A1	100
--------Program modified to provide different wrong comparison.--------	
/Probe for symmetry O-C2-A1 (with X1 as other comparison)	100
\Probe for symmetry S-C1-A1	100
/Probe for derived control S-C2-B2	0
Probe for derived control O-C1-C2	100
Probe for derived control O-C1-B2	100
\Probe for derived control O-B1-C2	100
--------Break between sessions--------	
Train A-B and Y-X relations	100
/Probe for symmetry O-B2-A1	60
\Probe for symmetry S-B1-A1	100
Review A-B and Y-X relations with feedback	100
/Probe for symmetry O-B2-A1	70
\Probe for symmetry S-B1-A1	100
Review A-B and Y-X relations with feedback	95.8
/Probe for symmetry O-B2-A1	100
\Probe for symmetry S-B1-A1	100
Train A-C relations	100
/Probe for symmetry O-C2-A1 (X1 as other comparison)	100
Probe for symmetry O-C2-A1 (X2 as other comparison)	100
Probe for symmetry S-C1-A1 (X1 as other comparison)	100
\Probe for symmetry S-C1-A1 (X2 as other comparison)	100

Table 8 (continued)

*Train S-A1-B1, S-A1-C1, and S-Y1-X1	100
/Probe for symmetry, S-B1-A1 (X2 as other comparison)	100
Probe for symmetry, S-C1-A1 (X2 as other comparison)	87.5
Probe for symmetry, S-B1-A1 (X1 as other comparison)	100
\Probe for symmetry, S-C1-A1 (X1 as other comparison)	87.5
/Probe for transitivity, S-B1-C1	100
\Probe for transitivity, S-C1-B1	100
*Train O-A1-B2, O-A1-C2, and O-Y1-X2	100
/Probe for symmetry, O-B2-A1 (X2 as other comparison)	87.5
Probe for symmetry, O-C2-A1 (X2 as other comparison)	75
Probe for symmetry, O-B2-A1 (X1 as other comparison)	87.5
\Probe for symmetry, O-C2-A1 (X1 as other comparison)	100
*Train O-A1-B2, O-A1-C2, and O-Y1-X2	95.8
/Probe for symmetry, O-B2-A1 (X2 as other comparison)	100
Probe for symmetry, O-C2-A1 (X2 as other comparison)	100
Probe for symmetry, O-B2-A1 (X1 as other comparison)	100
\Probe for symmetry, O-C2-A1 (X1 as other comparison)	100
*Probe for pattern predicted by conditional equivalence classes. The selections O-C2-B2 and O-B2-C2 were observed	100
/Probe for derived control O-B1-B2	100
\Probe for derived control O-B2-B1	0
/Probe for derived control S-C2-B2	0
Probe for derived control O-C1-C2	100
Probe for derived control O-C1-B2	100
\Probe for derived control O-B1-C2	100
/Probe for reflexivity S-A1-A1	0
\Probe for irreflexivity O-A1-N2	100
/Probe for derived control O-B1-B2	100
\Probe for derived control O-B2-B1	0
/Probe for derived control S-C2-B2	0
Probe for derived control O-C1-C2	100
Probe for derived control O-C1-B2	100
\Probe for derived control O-B1-C2	100

Table 9

Percentage of Accurate Responses on Training Problems and Probes for Subject KI

Problem or Probe	Percentage Correct
Train S-A1-B1 and O-A1-B2	95
Train S-Y1-X1 and O-Y1-X2	95
Train all A-B and Y-X relations	100
Probe for B-A symmetry	100
/Probe for reflexivity	0
\Probe for irreflexivity	100

Table 9 (continued)

Review A-B and Y-X relations with feedback	100
Probe for derived control O-B1-B2 and O-B2-B1	95
Probe for B-A symmetry	100
/Probe for reflexivity	0
\Probe for irreflexivity	100
Train A-C relations	100
Review A-B, Y-X, and A-C relations with feedback	100
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	0
Probe for derived control O-C1-C2	100
Probe for derived control O-C1-B2	100
\Probe for derived control O-B1-C2	100
Review A-B, Y-X, and A-C relations with feedback	100
Probe for derived control O-C1-B2 and O-B1-C2	100
Break Between Sessions	
Review A-B and Y-X relations with feedback	100
Probe for B-A symmetry	100
/ Probe for reflexivity S-A1-A1 (with N1 as other comparison)	0
Probe for irreflexivity O-A1-N2	100
*Probe for reflexivity S-A1-A1 (with N2 as other comparison)	100
*Probe for irreflexivity O-A1-N1	0
Review A-B and Y-X relations with feedback	100
/Probe for derived control O-B1-B2	100
\Probe for derived control O-B2-B1	0
Review A-B and Y-X relations with feedback	100
/Probe for derived control O-B1-B2	100
\Probe for derived control O-B2-B1	0
Train A-C relations	95
Review A-B, Y-X, and A-B relations	100
Probe for symmetry of C-A relations	100
/Probe for derived control S-C2-B2	0
Probe for transitivity S-C1-B1	100
Probe for transitivity S-B1-C1	100
\Probe for derived control S-B2-C2	0
Review A-B, Y-X, and A-B relations	100
/Probe for derived control S-C2-B2	0
Probe for derived control O-C1-C2	100
Probe for derived control O-C1-B2	100
\Probe for derived control O-B1-C2	0
/Probe for derived control S-C2-C2	0
\Probe for derived control O-C1-C2	100
/Probe for derived control O-C1-B2	100
\Probe for derived control O-B1-C2	100

Probes for symmetry. Subject KI responded correctly to all probes for symmetrical control of responding. KE initially showed symmetrical control of B-A relations, but failed to demonstrate symmetry of C-A relations. Presentation of an expanded set of probes resulted in C-A control of responding.

Derived relation of comparisons in the same set. Pretrained subjects can learn that B1 is the same as A1, while B2 is the opposite of A1. They can then respond consistently to the probe O-B1-B2. KE initially failed to show this pattern of control for B1 and B2, but this pattern of responding was observed in later sessions. KI did, however, respond to these probes in a fashion which was identical to the pretrained subjects.

Derived control across stimulus sets. Following A-C training, subjects were given three probes (S-C2-B2, O-C1-B2, and O-B1-C2) which test for derived control. Even though trained relations were repeatedly reviewed and expanded probe sets were given, KI and KE consistently responded to the probe S-C2 by selecting the comparison C1. On the latter two probes for derived control, their pattern of responding came to be like that of the pretrained subjects.

Conditional equivalence classes? It was hypothesized that the experimental procedure should develop conditional equivalence classes for the subjects who received no pretraining. In the presence of the first second-order conditional stimulus ("same" for pretrained subjects) A1, B1, and C1 should all become equivalent stimuli. In the presence of the second second-order conditional stimulus ("opposite") A1, B2, and C2 should be equivalent stimuli. Subject KE was given probes to test for the presence of conditional equivalence classes. He immediately responded at a 100% level given the probes O-C2-B2 and O-B2-C2. This pattern demonstrates conditional transitivity (since the patterns S-B1-C1 and S-C1-B1) are also observed. Symmetry had already been observed, so the only criterion for equivalence which was lacking was reflexivity.

Summary. The subjects who had not received pretraining did not show patterns of responding to the probes for reflexivity and irreflexivity which were similar to the pretrained subjects. While KI and KE responded to some of the probes for derived control in a manner similar to that of the pretrained subjects, neither of them responded to the probe S-C2 by selecting B2, the comparison chosen by pretrained subjects. There is evidence from KE's pattern of responding for the symmetrical control of conditional relations and conditional transitivity. Given the absence of reflexivity, one might not want to apply the term "conditional equivalence" to his performance.

Subjects Who Received Same/Different Pretraining

Pretraining. The subjects who received same/different pretraining required the following number of 40-trial blocks to reach the criterion level of performance: subject BR, 11; subject DA, 9; and subject LA, 8.

Subject BR. The performance of subject BR was totally unlike that of any other subject (see Table 10). Following pretraining, the initial A-B and Y-X training was accomplished in two blocks of trials, and probes for B-A symmetry were at the criterion level. On the first probe for reflexivity or irreflexivity, BR failed to show control by the second-order conditional stimuli for the same and different relations. Reviewing the same/different pretraining and reviewing the initial A-B training failed to produce consistent responding on these probes. Finally, the problems S-A1-A1 and D-A1-N2 were explicitly trained using feedback. Even after reflexive and irreflexive choices were made reliably, BR failed to show control by any of the derived relations in phase 1. He should have been able to respond correctly to the probes D-B1-B2 and D-B2-B1 if the second-order conditional stimuli had come to control making same and different choices.

Even though he failed to show the expected pattern of responding A-C training was begun. BR mastered A-C relations with one block of 20 trials, reviewed all trained relations, and then responded with 100% accuracy to probes for C-A symmetry. But even with reviews of trained relations and expanded probe sets, BR failed to show control by derived relations. During debriefing BR was asked to label the second-order conditional stimuli. He said that they meant different things at different times. He went on to describe an elaborate system he had used to remember the trained relations. This system was involved finding some detail of the stimuli which could be related to each other. In the presence of one second-order conditional stimulus one detail of the sample and comparison stimuli would be used. When the other second-order conditional stimulus was presented, he focused on a different detail of the stimuli. When asked about the role of the second-order conditional stimuli during pretraining, he said that the first second-order conditional stimulus meant "choose the same one," while the other second-order conditional stimulus meant "choose the other one." It seems that BR's attention to irrelevant (for the design of the study) details of the arbitrary stimuli resulted in stimulus control by these details instead of stimulus control by the second-order conditional and sample stimuli.

Table 10

Percentage of Accurate Responses on Training Problems and Probes for Subject BR

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	80
Train A-B and Y-X relations	100
Probe for symmetry of B-A relations	75
Review A-B and Y-X relations with feedback	100
Probe for symmetry of B-A relations	95
Probe for reflexivity/irreflexivity	0
*Review pretraining block for same/different control	95
Probe for reflexivity/irreflexivity	0
Review A-B and Y-X relations with feedback	95.8
Probe for reflexivity/irreflexivity	0
*Review a pretraining block for same/different control	83.3
*Review a pretraining block for same/different control	100
*Probe for reflexivity/irreflexivity with symbols from main exp.	100
Train A-B and Y-X relations	95
Probe for B-A symmetry	95
Probe for reflexivity/irreflexivity	0
*Review a pretraining block for same/different control	95.8
Probe for reflexivity/irreflexivity	0
*Review a pretraining block for same/different control	95.8
Probe for reflexivity/irreflexivity	0
*Review a pretraining block for same/different control	95.8
Probe for reflexivity/irreflexivity	0
*Explicitly train reflexive/irreflexive choices using the experimental stimuli	93.8
Probe for symmetry of B-A relations	100
Probe for reflexivity/irreflexivity	0
*Train reflexivity/irreflexivity with experimental stimuli	70
Probe for reflexivity/irreflexivity	85
Probe for derived control D-B1-B2 and D-B2-B1	0

Table 10 (continued)

Review A-B and Y-X relations with feedback	100
Probe for derived control D-B1-B2 and D-B2-B1	0
*Train reflexivity/irreflexivity with experimental stimuli	91.7
*Train reflexivity/irreflexivity with experimental stimuli	100
Probe for reflexivity/irreflexivity	100
Probe for derived control D-B1-B2 and D-B2-B1	0
Train A-C relations	100
Review A-B, Y-X, and A-C relations with feedback	100
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	0
\Probe for derived control D-C1-C2	8.3
Review A-B, Y-X, and A-C relations with feedback	100
/Probe for derived control S-C2-B2	0
\Probe for derived control D-C1-C2	0
/Probe for derived control S-C2-B2	16.7
Probe for derived control S-B2-C2	0
Probe for derived control S-B1-C1	50
\Probe for derived control S-C1-B1	0
Review A-B, Y-X, and A-C relations with feedback	100
/Probe for derived control S-C2-B2	0
Probe for derived control S-B2-C2	0
Probe for derived control S-B1-C1	0
\Probe for derived control S-C1-B1	0

Phase 1, subjects DA and LA. Both DA (see Table 11) and LA (see Table 12) showed rapid mastery of A-B training. On probes for symmetry, reflexivity/irreflexivity, and derived control (D-B1-B2 and D-B2-B1), both subjects demonstrated a criterion-level performance on the initial block of trials.

Phase 2, subjects DA and LA. LA and DA showed rapid mastery of A-C training and control by C-A symmetry. LA went on to respond with 100% accuracy to all of the phase 2 probes for derived control. DA failed to show control by the derived relations, so he was given an expanded set of probes. He quickly showed control by the derived relations. The patterns of responding predicted for phase 2 were sufficient to support the experimental hypothesis, so it was not necessary to give LA and DA the phase 3 training and probes. These subjects were not debriefed at this point, instead they returned to begin Experiment 2 in their next session.

Summary. Two of the three subjects who received same/different pretraining showed the same pattern of responding as the subjects who received same/opposite pretraining. Subject BR did not show the pattern of responding predicted for control by the relations same and different. He apparently used an idiosyncratic approach to the task, focusing on irrelevant details of the experimental stimuli.

Table 11
Percentage of Accurate Responses on Training Problems and Probes for Subject DA, Experiment 1

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	87.5
Train A-B and Y-X relations	97.5
Probe for B-A symmetry	100
Probe for reflexivity/irreflexivity	95
Probe for derived control D-B1-B2 and D-B2-B1	100
Train A-C relations	90
Review A-B, Y-X, and A-C relations with feedback	100
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	83.3
\Probe for derived control D-C1-C2	100
/Probe for derived control D-C1-B2	8.3
\Probe for derived control D-B1-C2	8.3
Review A-B, Y-X, and A-C relations with feedback	100
/Probe for derived control D-C1-B2	66.7
\Probe for derived control D-B1-C2	91.7
Review A-B, Y-X, and A-C relations with feedback	100
/Probe for derived control S-C2-B2	100
Probe for derived control S-B2-C2	83.3
Probe for derived control S-B1-C1	100
\Probe for derived control S-C1-B1	83.3
/Probe for derived control D-C1-C2	100
Probe for derived control D-C1-B2	100
\Probe for derived control D-B1-C2	70

Table 11 (continued)

/Probe for derived control D-C1-C2	100
Probe for derived control D-C1-B2	100
\Probe for derived control D-B1-C2	90

Table 12
Percentage of Accurate Responses on Training Problems and Probes for Subject LA, Experiment 1

Problem or Probe	Percentage Correct
Train A-B and Y-X relations	100
Probe for B-A symmetry	97.5
Probe for reflexivity/irreflexivity	100
Probe for derived control D-B1-B2 and D-B2-B1	100
Train A-C relations	100
Review A-B, Y-X, and A-C relations with feedback	100
Probe for C-A symmetry	100
/Probe for derived control S-C2-B2	100
\Probe for derived control D-C1-C2	100
/Probe for derived control D-C1-B2	100
\Probe for derived control D-B1-C2	100

Discussion

The performance of the pretrained subjects TE, RA, JO, DA, and LA provides some evidence for control of responding by relational frames. The pattern of responding on probes for symmetry indicates bi-directional control by the relations. The results demonstrate the existence of an extended network of relations which exerted predictable control over novel responses.

Since the subjects who received same/different pretraining showed the same pattern of responding as the subjects who received the same/opposite pretraining, it is not clear that conditional control of the relations opposite and different was developed.

The difficulty in interpreting the data comes from the fact that only two second-order conditional stimuli and two comparisons were used in this experiment. The probe for derived control S-B2-C2 (with C1 as the incorrect comparison) could have resulted in differential responding for the two groups of pretrained subjects. If it is known that B2 is the opposite of A1, and C2 is the opposite of A1, then one can directly conclude that B2 and C2 are the same. The subjects who received same/different pretraining had been trained to select B2 and C2 as being different from A1. This leaves the relationship between B2 and C2 as undefined; they are both different from A1, but they could be either the same as or different from the other. The fact that there were only two comparisons made another source of control possible. If C1 is the same as A1, and B2 is different from A1, then B2 and C1 cannot be the same. The subjects with same/different pretraining were forced to choose C2 as being the same as B2, because C1 could not be the same as B2. A different experimental design is needed to show distinct control by the different and opposite relations.

The results of Experiment 1 provide limited support for the relational frame theory. These results could be interpreted as being due to conditional application of equivalence. It could be argued that the pretraining establishes the following control over responding: in the presence of one second-order conditional stimulus ("same") make choices based on equivalence relations; in the presence of the other second-order conditional stimulus ("opposite" or "different") choose the comparison which is not equivalent to the sample. Clear evidence for control of responding by relational frames would require explicit control of the relations different and opposite with the application of these relations producing distinctly different response patterns.

The pattern of responses to the probes for reflexivity and irreflexivity demonstrated by the subjects who received no pretraining is somewhat puzzling. The training procedure should have resulted in the development of conditional equivalence classes. KE demonstrated the pattern of responding on probes for symmetry and transitivity which would be expected after the development of conditional stimulus classes. But it seems that after the development of conditional equivalence classes a stimulus should be chosen as equivalent to itself in the presence of any second-order conditional stimulus. In other words, no matter what second-order conditional stimulus is present, sample-comparison identity matching should be observed. What KE and KI both did, with high consistency, was avoid choosing the comparison which was identical to the sample. Their pattern of responding is presented in Figure 16. KI developed a consistent pattern of

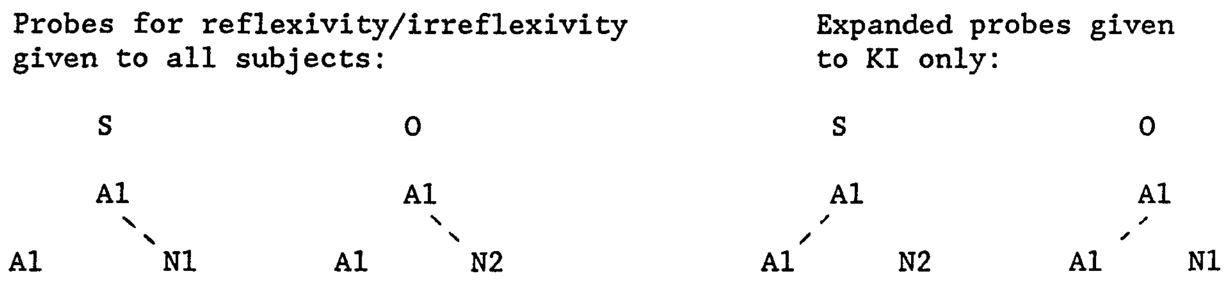


Figure 16. Pattern of responding to probes for reflexivity/ irreflexivity by subjects who received no pretraining.

responding which resulted in making four different responses to the four probes, only two of which were identity matching.

The failure of KE and KI to show reflexive responding may have been due to a number of factors. In the previous studies of equivalence tests of reflexivity were not made using novel stimuli as comparisons. Experiment 3 was conducted to test for the possibility that reflexive responding was disrupted by the use of novel stimuli as comparisons.

CHAPTER III

EXPERIMENT 2

The intent of Experiment 2 was to bring three relations---same, opposite, and different---under stimulus control. If successful, there would be evidence for a type of stimulus control which goes beyond equivalence. Both same and different are irreflexive relations, but have different implications for a network of relations. This is illustrated in Figure 17. If B and C are both opposite of A, then B

Figure 17. Networks of relations developed by opposite and different relations.

and C are the same. If B and C are both different from A, then the B-C relation is undefined. B and C could be the same or they could be different.

The procedure used in Experiment 2 was designed to use the differences in these networks of relations to explicitly demonstrate differential control by the relations same, opposite, and different. The plan for the training and probes are given in Figures 18 and 19. The first four sets of probes provide no advance over the results of

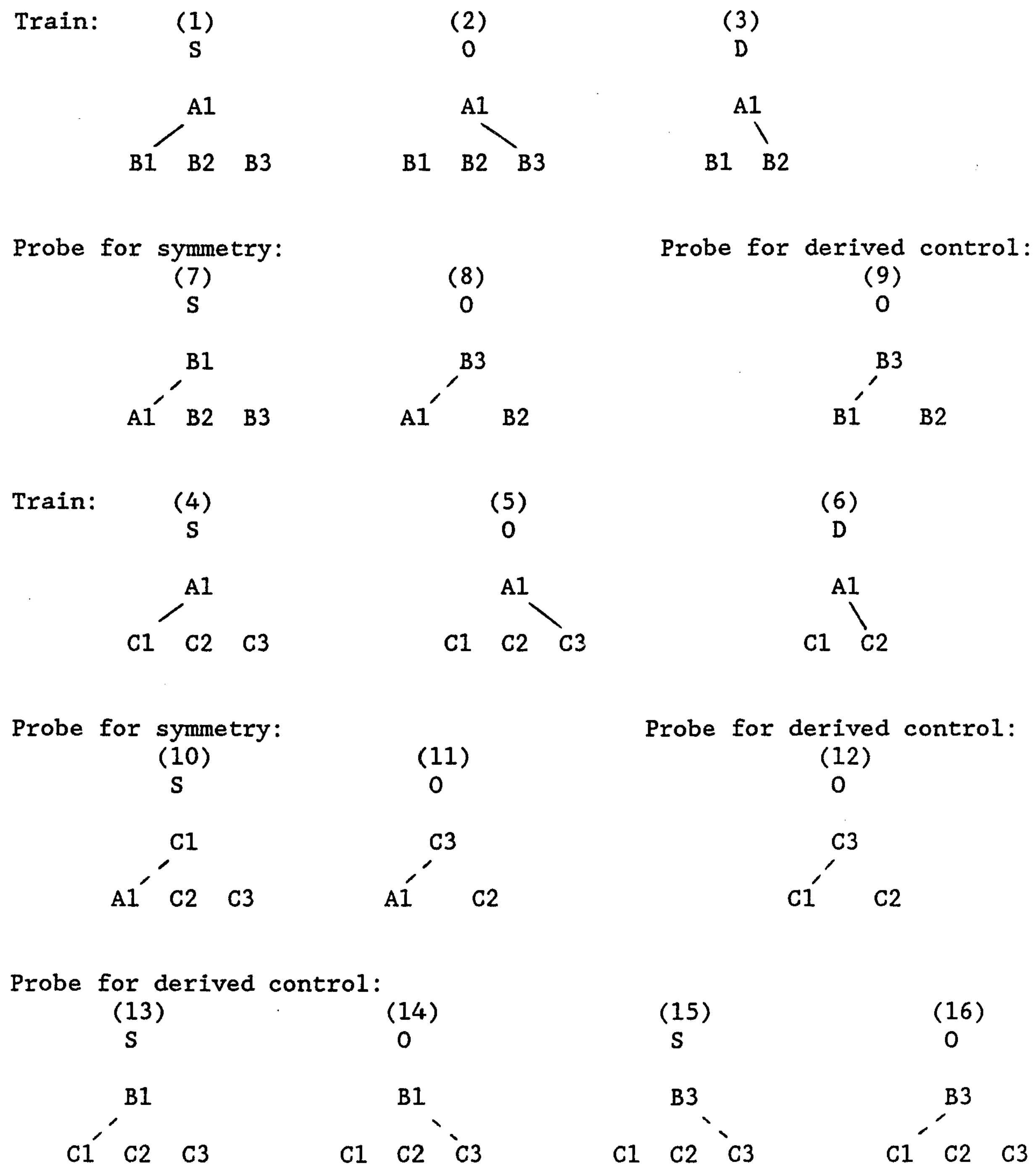


Figure 18. Initial training and probe arrangements for Experiment 2.

Probe for derived control:

(17)	(18)	(19)
S	D	O
C1 / B1 B2 N3 (C1–B1)	C1 / B1 B2 N3 (C1–B2)	C1 / B1 B2 N3 (C1–N3)

Figure 19. Critical predicted responses for Experiment 2.

Experiment 1. The crucial evidence can be provided by the last set of probes (17-19). The subject is presented with two familiar comparisons(B1 and B2) and a novel stimulus (N3) as a comparison. The predicted response S-C1-B1 comes from transitivity of equivalence. The control predicted in probe 18 comes from derived control. If B2 is different from A1, and C1 is the same as A1, then B2 is different from C1. The prediction of responding in probe 19 is based on the premise that the subject will choose the novel stimulus, because neither B1 or B2 can be a correct choice. Given that C1 and A1 are the same and that B2 is different from A1, but not the opposite of A1, B2 cannot be the opposite of C1. The only choice left is the novel stimulus. If the subjects respond in the predicted pattern, three different types of stimulus control will have been demonstrated.

Method

Subjects

The subjects for this experiment were DA and LA who had just completed Experiment 1 in which they had received same/different pretraining and had had training which developed conditional relationships among arbitrary stimuli which were consistent with the training to be provided in this experiment.

Apparatus and Stimuli

The apparatus and stimuli were the same as in Experiment 1 except that provision was now made to present three different conditional stimuli and two or three comparisons.

Procedure

DA and LA were first given same/opposite pretraining identical to that used with other subjects in Experiment 1. Then they were given a review of the same/different pretraining which they had received in the first experiment. Then the training and probe procedure presented in Figures 18 and 19 was followed. As in Experiment 1 probe blocks consisted of equal numbers of probe items and previously trained problems presented in extinction. Order of the probes was randomized with one exception which will be noted below. On each trial the placement of comparisons (left, center, or right) was randomly determined.

A-B training was given in blocks of 27 trials (nine for each problem). The probes for symmetry and the probe for derived control (problems 7-9) were presented in blocks of 27 probes combined with 27 trials in which the trained A-C problems were presented in extinction. A-C training was conducted in blocks of 27 trials, and then A-B and A-C training was reviewed with each problem presented three times. Problems 10-12 were presented in a probe block. Problems 12-14 were presented in a probe block, and problems 15 and 16 were presented in a probe block.

For the crucial set of probes (17-19) the order of presentation was not randomized. These probes were arranged so that the subject would have responded to probes 17 and 18 at least three times each before being exposed to probe 19. This was done so that the subject would have had an opportunity to respond to some of the C-B probes before being forced to deal with the novel stimulus.

Additional Probes for LA. If subjects did make the forced choice of N3 in Probe 19, then N3 might enter into the network of relations. Subject LA was given an additional probe for symmetry (O-N3-C1) and a probe for derived control (S-N3-C3) to see if N3 had entered into the network of relations.

Results

Subject DA

After same/opposite pretraining and a review of same/different pretraining, DA (see Table 13) mastered the A-B relations in one block of 30 trials. There was some initial problems with probes for symmetry and derived control, but after four blocks of probes responding was at criterion levels.

Training A-C relations required only one block of 20 trials, but DA failed to show derived control of responding with probe 14 (O-B1-C3). Review of trained relations and further probe trials failed to develop the predicted pattern of responding to probe 14 in the first or second session. Finally, in the third session, the experimenter noticed a clue to DA's failure to respond correctly on probe 14. When the previously trained relations were presented in extinction , DA sometimes made erroneous responses to the probe O-A1-C3. A set of probes which included O-A1-C3, S-B1-A1, and O-B1-C3. Immediate increase in correct responding to probe 14 was observed, and after two blocks of these probes, responses to probe 14 were 100% in the trained direction.

The critical set of probes (17-19) was presented in DA's sessions even before correct responding to probe 14 was established. He responded at criterion levels on the first presentation. On the second presentation of these probes he selected comparison N3 when given probe 18 (D-C1-B2). It should be noted that in terms of control by arbitrary relations this is not an incorrect response. If the previous exposure to N3 established it as the opposite of C1, then N3 is also different from C1. On two further exposures to this set of probes DA made only one response which differed from the predicted pattern.

At the end of the experiment DA was asked to name the conditional stimuli. The S stimulus was labeled "same," but DA could not provide labels for the other two conditional stimuli. Testing with a few examples showed that he could identify the function of the D and O stimuli in pretraining, but he said that he was not sure that they had the same function in the main experiment.

<u>Summary</u>. DA showed the predicted pattern of responding at criterion levels on three of four presentations of the critical set of probes. His initial difficulty with probe 14 was overcome by reviewing lower order relations in the network. On the last two presentations of all blocks of probes, DA responded in the predicted manner at criterion levels.

Table 13

Percentage of Accurate Responses to Training and Probe Trials for Subject DA, Experiment 2

Problem or Probe	Percentage Correct
Train A-B relations (with same, different, & opposite conditional stimuli)	96.7
/Probe for symmetry S-B1-A1	100
\Probe for derived control O-B3-B1	33.3
Review A-B relations with feedback	100
/Probe for symmetry S-B1-A1	100
\Probe for derived control O-B3-B1	0
Review A-B relations with feedback	100
/Probe for symmetry S-B1-A1	100
Probe for derived control O-B3-B1	100
\Probe for symmetry O-B3-A1 (B2 as other comparison)	77.8
Review A-B relations with feedback	100
/Probe for symmetry S-B1-A1	100
Probe for derived control O-B3-B1	100
\Probe for symmetry O-B3-A1 (B2 as other comparison)	100
Train A-C relations	96.7
Review A-B and A-C relations with feedback	100
/Probe for symmetry S-C1-A1	100
\Probe for symmetry O-C3-A1	100
/Probe for derived control O-C1-B3	11
\Probe for derived control S-C3-B3	100
Review A-B and A-C relations with feedback	100
/Probe for symmetry O-C3-A1 (B2 as other comparison)	89
\Probe for derived control O-C3-C1 (C2 as other comparison)	100
/Probe for derived control O-C1-B3	0
\Probe for derived control S-C3-B3	100
Review A-B and A-C relations with feedback	100
/Probe for derived control O-C1-B3	0
\Probe for derived control S-C3-B3	100
--------Break between sessions.--------	
Review pretraining for same, different, & opposite conditional stimuli	100
Train A-B relations	100
/Probe for symmetry S-B1-A1	100
Probe for symmetry O-B3-A1	88.9
\Probe for derived control O-B3-B1	100
Train A-C relations	100
Review A-B & A-C relations with feedback	100
/Probe for symmetry S-C1-A1	100
Probe for symmetry O-C3-A1	100
\Probe for derived control O-C3-C1	100
/Probe for derived control S-B1-C1	88.9
\Probe for derived control O-B1-C3	0

Table 13 (continued)

Review A-B & A-C relations with feedback	100
/Probe for derived control S-B1-C1	88.9
\Probe for derived control O-B1-C3	0
/Probe for derived control S-B3-C3	88.9
\Probe for derived control O-B3-C1	44.4
Review A-B & A-C relations with feedback	100
/Probe for derived control S-B3-C3	88.9
\Probe for derived control O-B3-C1	88.9
/Probe for derived control S-B3-C3	88.9
\Probe for derived control O-B3-C1	100
/Probe for derived control S-C1-B1	87.5
Probe for derived control D-C1-B2	75
\Probe for derived control O-C1-N3	87.5
Review A-B & A-C relations with feedback	100
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	87.5
\Probe for derived control O-C1-N3	100
/Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	11.1
Review A-B relations with feedback	100
/Probe for symmetry S-B1-A1	100
Probe for symmetry O-B3-A1	100
\Probe for derived control O-B3-B1	100
Train A-C relations	100
/Probe for symmetry S-C1-A1	100
Probe for symmetry O-C3-A1	100
\Probe for derived control O-C3-C1	100
/Probe for derived control O-C3-C1	100
Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	0
/Probe for derived control S-B3-C3	100
\Probe for derived control O-B3-C1	100
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	50
\Probe for derived control O-C1-N3	100
Review A-B & A-C relations with feedback	100
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	100
\Probe for derived control O-C1-N3	100
/Probe for symmetry S-B1-A1	100
Probe for symmetry O-B3-A1	100
\Probe for derived control O-B3-B1	100
/Probe for symmetry S-C1-A1	87.5
Probe for symmetry O-C3-A1	100
\Probe for derived control O-C3-C1	100
/Probe for derived control O-C3-C1	100
Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	0

Table 13 (continued)

/Probe for derived control O-C3-C1	100
Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	0
/Probe for derived control S-B3-C3	100
\Probe for derived control O-B3-C1	88.9
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	100
\Probe for derived control O-C1-N3	100
/Probe for symmetry S-B1-A1	100
Probe for symmetry O-B3-A1	100
\Probe for derived control O-B3-B1	100
/Probe previously trained relation O-A1-C3	100
Probe for symmetry S-B1-A1	100
\Probe for derived control O-B1-C3	88.9
/Probe for derived control O-C3-C1	100
Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	100
/Probe for derived control S-B3-C3	100
\Probe for derived control O-B3-C1	88.9
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	100
\Probe for derived control O-C1-N3	88.9

Subject LA

Subject LA's performance was characterized by extremely accurate responding (see Table 14). After same/opposite pretraining and a review of the same/different pretraining, A-B training was accomplished with only one wrong response. A-C training was also accomplished with only one wrong response. Responses to all probes were 100% according to the predicted pattern. The critical set of probes (17-19) was given to LA three times even though she was 100% accurate on the first presentation. Sidman (1987) has described situations in which it is possible to falsely conlude that relational control has been established. One possible way to make an erroneous judgment is to have the subject work at the experimental task until the expected pattern is observed and then stop. If the subject has not achieved a stable performance, an accidental variation in responding which happens to be the expected pattern could be interpreted as relational control. With LA responding at a 100% accurate rate for 3 different blocks of trials, a false interpretation is ruled out.

Subject LA was given the two additional probes to see if N3 entered into the network of relations, and again all responses were consistent with the predicted pattern.

At the conclusion of the experiment LA was asked to name the conditional stimuli. The S stimulus was labeled "same," the D stimulus was labeled "opposite," and the O stimulus was labeled "extreme opposite."

Table 14

Percentage of Accurate Responses on Training Problems and Probes for Subject LA, Experiment 2

Problem or Probe	Percentage Correct
Train A-B relations (with same, different, & opposite conditional stimuli)	96.7
/Probe for symmetry S-B1-A1	100
Probe for derived control O-B3-A1	100
\Probe for derived control O-B3-B1	100
Train A-C relations	96.7
Review A-B and A-C relations with feedback	100
--------Break between sessions.--------	
Review same/different pretraining for 24 trials.	
Review same/opposite pretraining for 24 trials.	
Review A-B relations (with same, different, & opposite conditional stimuli)	100
/Probe for symmetry S-B1-A1	100
Probe for derived control O-B3-A1	100
\Probe for derived control O-B3-B1	100
Train A-C relations	100
Review A-B and A-C relations with feedback	100

Table 14 (continued)

/Probe for symmetry S-C1-A1	100
Probe for symmetry O-C3-A1	100
\Probe for derived control O-C3-C1	100
/Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	100
/Probe for derived control S-B3-C3	100
\Probe for derived control O-B3-C1	100
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	100
\Probe for derived control O-C1-N3	100
/Probe for symmetry S-C1-A1	100
Probe for symmetry O-C3-A1	100
\Probe for derived control O-C3-C1	100
/Probe for derived control S-B1-C1	100
\Probe for derived control O-B1-C3	100
/Probe for derived control S-B3-C3	100
\Probe for derived control O-B3-C1	100
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	100
\Probe for derived control O-C1-N3	100
/Probe for derived control S-C1-B1	100
Probe for derived control D-C1-B2	100
\Probe for derived control O-C1-N3	100
/*Probe for derived control S-N3-C3	100
*Probe for derived control O-N3-C1	100

Discussion

Both LA and Da showed differential responding to the three second-order conditional stimuli on probes 17-19. This seems to indicate control of responding by three different relations. There is, however, another interpretation possible. It could be argued that the differential responding is due to reinforcement history. The selection of B1 has been reinforced only in the presence of the second-order conditional stimulus for "same," and the selection of B2 has been reinforced only in the presence of the second-order conditional stimulus for "different." Perhaps the differential responding on probes 17-19 be due to direct control by the second-order conditional stimuli.

But this interpretation does not explain the subjects' responses on earlier probes. In Experiment 1, DA and LA selected B2 in the presence of the conditional stimulus for "same." In Experiment 2 both subjects selected B1 in the presence of the second-order conditional stimulus for "opposite" on probe 9. In probes 15 and 16 which come immediately before the presentation of 17-19, both subjects made choices inconsistent with direct control by the second-order conditional stimuli. And LA was given additional probes after 17-19 in which she made response inconsistent with control of responding by the second-order conditional stimuli. The performance of DA and LA on all probe items in Experiments 1 and 2 can best be explained by control by the separate relations same, different, and opposite.

EXPERIMENT 3

The subjects who received no pretraining in Experiment 1 (KE and KI) failed to make reflexive choices, but KE demonstrated all of the other features of control of responding---conditional symmetry and conditional transitivity---which would be predicted by conditional equivalence classes. It is possible that the presence of the second-order conditional stimuli disrupted reflexive responding. In the initial training in Experiment 1, a change in the second order conditional stimulus signalled a change in which comparison selection was reinforced. When these subjects were then given probes with different conditional stimuli, distributing their response to two different novel stimuli would be consistent with their training history. Making reflexive choices in the presence of both second-order conditional stimuli would contradict the type of control established during training. Wulfert and Hayes (1986) did not test for reflexive control, so it is possible that training procedures designed to develop conditional equivalence classes may not develop reflexive responding.

A second possible explanation is control of responding by the novel stimuli. Perhaps if novel stimuli were used in tests of reflexivity following simple equivalence training, subjects would select novel stimuli as well. So a test for reflexivity using novel stimuli after initial match to sample training would make clearer the reasons for the failure to observe reflexive choices in the subjects who received no pretraining in Experiment 1.

Method

Subjects

Subjects for this experiment were two youths and one adult. Respective ages and sexes were as follows: SH, 16, F; JU, 33, F; RO,15, M. The adolescents were enrolled in the college preparatory curriculum at their high school, and the adult is a college graduate.

Apparatus and Stimuli

The apparatus and stimuli were generally the same as in Experiments 1 and 2. Only in this experiment, no second-order conditional stimulus was used. The sample was presented in the center of the screen, and two comparisons were presented at the bottom.

Procedure

Subjects were given the series of training and probe trials outlined in Figure 19. A-B training was conducted for 20 trials, followed by probes for symmetry and reflexivity. A-C training was conducted for 20 trials, followed by probes for symmetry and transitivity. Each probe block consisted of 16 trials of probes and 16 trials in which trained problems were presented in extinction.

Results

Subjects JU and RO

JU required four blocks of A-B training to reach the 90% criterion, but RO was 90% accurate in the first block of training. Both subjects showed 100% accuracy on probes for B-A symmetry and reflexivity. RO mastered A-C training in one block, while JU required two. Both subjects were 100% accurate on probes for C-A symmetry and all probes for transitivity.

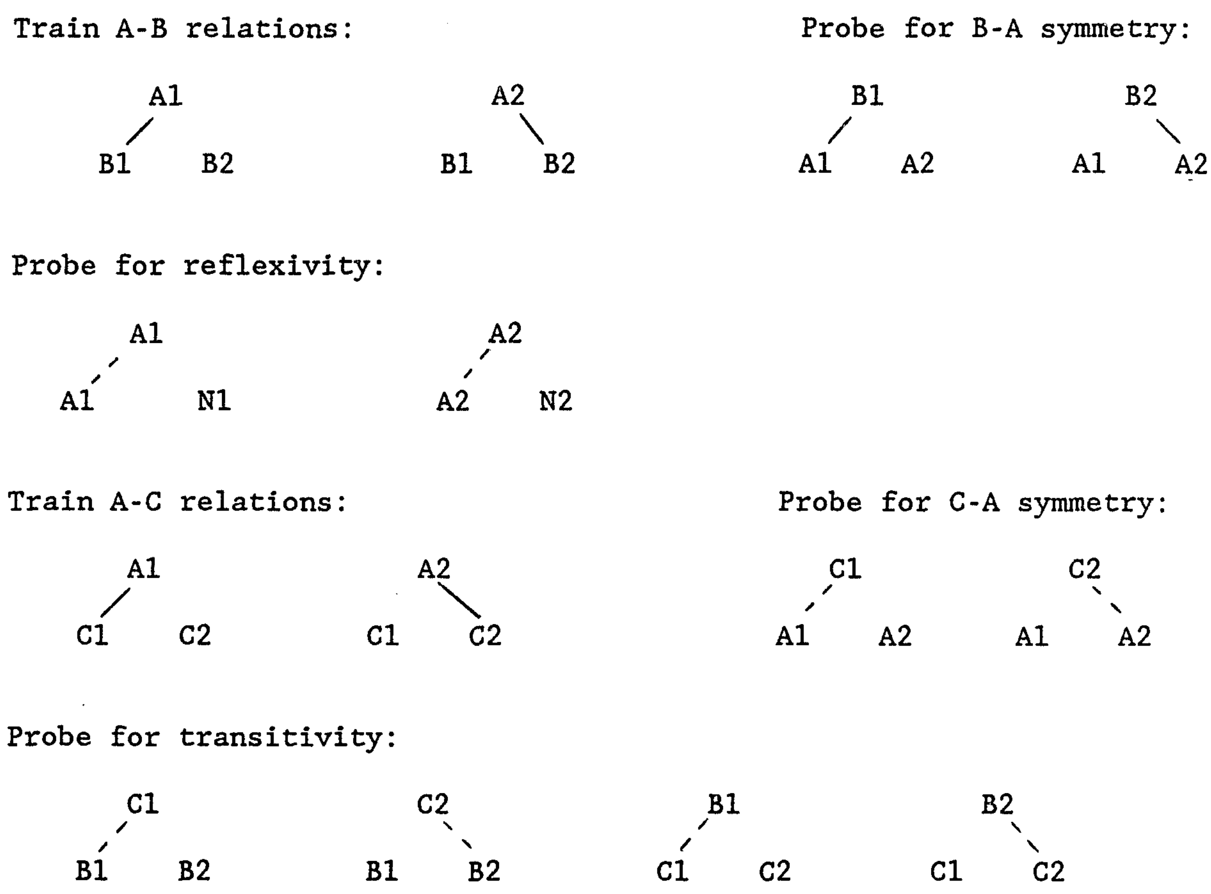


Figure 20. Training and probes for Experiment 3.

<u>Subject SH</u>

Subject SH had extreme difficulty in mastering A-B training. After twelve 20-trial blocks, accuracy of responding was still at chance levels. It was thought that she might be trying complicated hypotheses involving position of the comparison (left or right) and previous trials. So, she was told that each problem had nothing to do with previous problems and that which side of the screen (right or left) stimuli appeared in had nothing to do with which stimulus should be selected. After ten more blocks of training, she was still responding erratically. At that point she was told that the sample stimulus signals which comparison should be selected. SH said, "Oh, I should have known it was there for a reason." She completed the A-B training in two more blocks of trials.

SH demonstrated 100% accuracy on the probes for symmetry and 95% accuracy on the probes for reflexivity. After A-C training, responses to probes for symmetry were 100% accurate and responses to probes for transitivity were 95% accurate.

Discussion

On the probes for reflexivity with novel stimuli as the incorrect comparison, all subjects made reflexive responses. This indicates that the use of novel stimuli was not the reason for the irreflexive choices made by the subjects who received no pretraining in Experiment 1. It seems likely that the presence of the second-order conditional stimuli was the factor which resulted in the failure to make reflexive choices.

SH's difficulty mastering the initial A-B training seems puzzling. But one should remember that many of the previous studies of equivalence gave subjects identity matching pretraining (e.g., Sidman & Tailby, 1982; Sidman et al., 1985; Saunders et al., 1986; Lazar et al., 1984) or instructed the subjects to select the comparison which goes with the sample (Spradlin et al., 1973; Wetherby et al., 1983; Devany et al., 1986). For SH, the relevance of the sample stimulus had never been established. The identity matching pretraining or the verbal instructions to the subject may play a larger role in the development of equivalence classes than was previously thought.

CHAPTER IV

GENERAL DISCUSSION

In Experiment 1 performance on arbitrary match to sample problems was brought under conditional control. When subjects were given pretraining designed to establish control by the relations same and opposite, their performance on conditional match to sample probes was consistent with control by those relations. The same pattern of responding was observed in subjects who had been given pretraining designed to establish control by the relations same and different. Those subjects who received no pretraining in Experiment 1 showed consistent patterns of responding which were different from the pretrained subjects. Therefore, the responses of the pretrained subjects could not have been due to incidental features of the stimuli or procedure. Control of responding by forms of stimulus control unrelated to relations could have equally influenced the performance of the control subjects who received no pretraining. The consistency of responding exhibited by the subjects who received no pretraining seemed to result from other types of stimulus control. When subject KE was given probes consistent with the development of conditional equivalence classes, his responses were consistent with control by second-order conditional equivalence. This pattern of responding is different from that which was predicted for control by relations.

For pretrained subjects in Experiment 1, one second-order conditional stimulus reliably resulted in the choice of reflexive or equivalent sample-comparison selections. The other stimulus resulted in irreflexive or non-equivalent choices. The pretraining procedure clearly resulted in the second-order conditional stimuli exerting a type of stimulus control which did not appear in the absence of pretraining. Experiment 1 demonstrates the conditional control of equivalence and non-equivalence or exclusion. In the presence of one second-order conditional stimulus a given comparison would enter into an equivalence relationship with a sample. In the presence of the other second-order conditional stimulus, the same comparison would be excluded from the class of stimuli equivalent to that same sample.

This type of stimulus control goes beyond the conditional equivalence classes which were developed for KE. For pretrained subjects the comparison stimuli B2 and C2 enter into a defined relation of being different from or opposite of A1. For control subjects, B1 and C1 are equivalent to A1 in the presence of one second-order conditional stimulus (S), but in the presence of the other second-order conditional stimulus (O) B2 and C2 are equivalent to A1. When given the probe S-C2-B2 (with B1 as the other comparison), the subjects who received no pretraining are faced with an anomalous situation. B2 and C2 are both equivalent to A1 in the presence of the stimulus O, but there is no controlling relation between C2 and B2 in the presence of S. The other comparison does not provide any control over responding either. In the presence of S, B1 is equivalent to A1, but C2 is not equivalent to A1 in the presence of S. Pretrained subjects's responding is apparently controlled by two active relations: B1 is the same as A1, and C2 is different from or opposite to A1. So in the presence of the second-order conditional stimulus which controls the selection of equivalent stimuli, B1 cannot be selected as the same as C2. For pretrained subjects the second-order conditional stimulus signals which relation is to be used to relate sample and comparison stimuli. For control subjects the second-order conditional stimulus signals shifts in the application of a single relation, equivalence.

The performance of the pretrained subjects in Experiment 1 could be interpreted as demonstrating conditional control over equivalence and exclusion. The exclusion phenomenon, like equivalence, is observed in match to sample performances. Dixon (1977) trained mentally retarded adolescents to select one of two visual stimuli in response to a spoken word. When a novel word was spoken, the adolescents chose the comparison whose selection had not previously been reinforced. Apparently the control of responding was based on the exclusion of the trained choice in the presence of an untrained sample. Dixon and Dixon (1978) used a different procedure which also resulted in exclusion. Normal preschool-age children were trained to select a comparison which was identical to the sample. Then a novel stimulus was substituted for the comparison which was identical to the sample. The children selected the novel stimulus, apparently showing exclusion of the comparison whose selection had been unreinforced during training. It could be argued that the arbitrary match to sample procedure inherently induces equivalence or, alternatively, that the arbitrary match to sample procedure results in samples and their reinforced comparisons being related as being the same. Dixon and Dixon's observations indicate that at the same time the subjects learn that the sample and reinforced comparison are equivalent (or the same), they also learn that the sample and unreinforced stimulus are non-equivalent (or different). This is the sort of relational control which is invoked explicitly by the second-order conditional stimuli used in the present study.

In Experiment 1 the subjects who received no pretraining did develop consistent patterns of responding, some of which were the same as the pattern predicted by the network of relations. After A-B training, subject KI consistently responded correctly to the probes O-B1-B2 and O-B2-B1. She may have chosen to relate these two stimuli because they had been presented together as comparisons in the same problems during pretraining. After A-B and A-C training both KE's and KI's responses to the probes O-C1-B2 and O-B1-C2 were the same as the pretrained subjects. But given the probe S-C2 they always chose B1. What is the source of stimulus control which accounts for this consistency? A likely candidate is direct control of comparison selection by the second-order conditional stimulus. A careful analysis of the experimental procedure indicates that during initial A-B and Y-X training the presence of the sample was entirely superfluous. Given the comparisons B1 and B2, the second-order conditional stimuli signal which comparison selection is reinforced. On the probes which follow A-C training, KI and KE always selected the comparison with a history of reinforcement in the presence of the second-order conditional stimulus. For the pretrained subjects the relational control of the second-order conditional stimulus resulted in the relationship between the sample and the comparison controlling the response.

In Experiment 2, three second-order conditional stimuli were used to develop three different classes of stimuli. Stimuli in the first set were all equivalent to each other, opposite of all members of the third set, and different from members of the second set. Stimuli in the second set were all different from those in the first set, but their relations to other members of their set or members of the third set were unspecified. Members of the third set of stimuli were all equivalent with each other and opposite to members of the first set, but their relations with members of the second set were undefined. Patterns of subjects' responses could be reliably predicted from the network of relations.

In Experiments 1 and 2 if predicted patterns of responding were not observed, extended use of probes provided a mechanism for the development of the predicted relational control. Subjects HE and DA needed expanded probe sets before they showed expected patterns of responding on some two-stage relations. In Experiment 2, DA did not show expected responses to one probe until the relations which seemed to be logically involved in deriving the pattern of control were all grouped in one probe block. Feedback about accuracy was not required, just careful selection of probes. This is similar to the Socratic dialogue; asking the right questions gets the right answers.

In Experiment 1, only TE was able to respond correctly on the first exposure of the probes for three-stage D-B relations. For RA and JO probes of the lower-order A-D relations resulted in subsequent correct responding to D-B probes.

The ability of probes to establish relational control has already been noted in the study of equivalence (Sidman, et al., 1974; Sidman et al., 1985; Spradlin, et al., 1973; Spradlin & Saunders, 1986). Sidman and his colleagues (1985) noted that failure of control by higher stage relations could be developed by testing lower order relations. The present study has replicated this finding, but with the opposite relation in addition to equivalence.

The mechanism by which probes seem to develop untrained repertoires remains unclear. The testing process may provide the context for forming the relations among stimuli. Sidman and his colleagues (1985) point out that equivalence classes could have been formed based on irrelevant dimensions of the stimuli used. Classes could be based on physical characteristics of stimuli, the subject's own reinforcement history, or the separation of the stimuli into "sample" or "comparison" classes. In Experiment 1, subject BR focused on irrelevant details which helped him remember how to make trained choices. When presented with probes where the irrelevant features provided no information about correct responding, his selection of comparisons was unrelated to the trained relations. Subject KI, who had no pretraining, responded in the same fashion as pretrained subjects to the probes O-B1-B2 and O-B2-B1. At debriefing she said that she related B1 and B2 to each other because they had appeared together as comparisons in the same problems. Presentation of probes which test for relational control may in effect "point out" the importance of the relation.

When probes are unrelated to the training experience, control by relations may not be developed. Devany and Hayes (1987) report that the presentation of irrelevant probe items can disrupt the formation of equivalence classes. In Experiment 1 the subjects who received no pretraining had no training history relevant to many of the probes. When they did develop consistent patterns of responding to those probes, their responses seemed to be based on the features of the problem which permitted a consistent type of control. Following A-C training in Experiment 1, KE and KI consistently showed direct control of comparison selection by the second-order conditional stimulus.

It is as if the subjects are generating hypotheses which will allow them to respond consistently to probe items and then testing these hypotheses during probe blocks. If this is the case, this would explain why close juxtaposition of relevant probes was helpful in developing DA's relational control in Experiment 2. Perhaps subjects come to the study with a history of being reinforced for consistent application of attempted solutions to new tasks.

The results from Experiments 1 and 2 provide clear evidence of second-order conditional control. One implication of these results along with the demonstration of conditional equivalence classes by Wulfert and Hayes (1987) is that a four- or five-term contingency may provide the simplest and most clear way to describe these results. Even if one accepts the proposition that selections of different comparisons are different responses, the role of the conditional stimulus and sample in the present study cannot be collapsed into a single stimulus function. A five-term contingency (second-order conditional stimulus, conditional stimulus, discriminative stimulus, response, and reinforcing stimulus) allows a clear description of the procedure and results of the present study. The five-term unit allows specific prediction of complex human behavior.

Those who would limit behavior analysis to a three-term unit are faced with two tasks. They must use a three-term unit of behavior analysis to explain the results of the present study. Then they must show that the explanatory scheme results in verifiable predictions of experimental outcome.

In Experiment 1 neither of the subjects who were not pretrained made reflexive choices when given an opportunity to select a comparison which was identical to the sample. Subject KE did, however, demonstrate all other aspects of relational control which one would expect following the development of conditional equivalence classes (i.e., conditional symmetry and conditional transitivity). The failure of these subjects to make reflexive choices was not due to the use of novel stimuli as comparisons in these probes. In Experiment 3 subjects were given basic match to sample training of the sort commonly used to develop equivalence classes. When tested with a probe procedure which also included novel stimuli as comparisons, these subjects made reflexive choices. So KE demonstrated conditional symmetry and conditional transitivity, but not reflexivity. In Wulfert and Hayes' (1987) study conditional symmetry and transitivity were also observed, but no test for reflexivity was ever made. These results can be interpreted by arguing that conditional equivalence classes were not developed in Experiment 1. Alternatively, it could be argued that reflexivity is not an essential feature of stimulus equivalence. Stimulus equivalence could be defined in the match to sample paradigm in the following way: Stimuli are equivalent when, as samples, they will occasion the selection of all other class members and, as comparisons, will be selected when any other class member is a sample.

Another alternative explanation is that the phenomenon which we are calling conditional equivalence is not equivalence at all. The hypothesized conditional equivalence class thought to be developed by KE's training took the following form: In the presence of one conditional stimulus (S), A1, B1, and C1 are equivalent stimuli; but in the presence of the other second-order conditional stimulus (O), A1, B2, and C2 are equivalent stimuli. Sidman and Tailby (1982) borrowed the definition of equivalence from number theory, but number theory will not allow conditional equality. A constant cannot be equal to one value at one time and another value at another time. The phenomenon which is observed is conditional membership in different classes of interchangeable stimuli, where that interchangeability is defined by symmetry and transitivity in match to sample performance. Perhaps we should re-label the phenomenon as "conditional membership of classes of interchangeable stimuli" instead of "conditional equivalence." In addition to the interchangeability of the stimuli in match to sample performance, if one of these stimuli is given a function in another learning task, all members of the class can interchangeably assume that function (Hayes et al., in press; Wulfert & Hayes, 1987).

The relational frame theory of Hayes and Brownstein (1986) is the only behavior analytic theory relevant to discussion of the results of the present study. The relational frames theory made very specific predictions about the pattern of responding which should have been observed using the procedure of the present study. Failure to observe this pattern of responding would not have decided in favor of another theory, but would have made the relational frames theory less plausible.

The results of Experiments 1 and 2 together are consistent with the predictions made by the theory of relational frames. Bi-directional control by the relations same, different, and opposite was observed. Extensive networks of relations were developed by second order conditional discrimination procedures. Responses to unreinforced probes were consistent with the predictions made by the network of relations. The patterns of responding demonstrated by the pretrained subjects meet three of the four criteria for the existence of relational frames put forward by Hayes and Brownstein. A possible interpretation of the experimental results is that sample and comparison stimuli are related within the relational frame which is invoked by the second-order conditional stimulus.

The response latencies of probes seemed to be related to the conceptual analysis of the source of stimulus control over responding. It was predicted that increasing the number of sets of stimuli related and the number of relations involved in deriving the control of responding would increase the response latency. In terms of the theory of relational frames, the analysis is that increasing the number of frames and the number of different types of frames should predict probe difficulty, and, therefore, response latency. The data would tend to support this hypothesis. Those probes which are conceptually most complex did result in longer latencies. These data must be interpreted cautiously, however, since there is a possible confounding variable. The design of the experiment was such that probe complexity typically increased as the session progressed. So the subject's fatigue could be a factor in the increased latencies.

Stimulus equivalence can be viewed as the application of one type of relational frame. It can be argued that in the previous studies of equivalence the match to sample format itself or the experimental procedure served as the second order conditional stimulus which signalled that the frame for the relation "same" was to be used. The match to sample procedure is widely used in the education of preschool children. There are many activities in which children are instructed to select an item which "is the same as" or "goes with" or "is like" a sample stimulus. So the match to sample format alone may be able to invoke the use of the frame for the relation "same" for the subjects with a history with this type of task.

Even if subjects did not have a learning history with match-to-sample tasks, the experimental procedure in many of the previous studies of equivalence established that the task involved identity matching or selecting items which went together. Some studies (e.g., Sidman & Tailby, 1982; Sidman et al., 1985; Saunders et al., 1986; Lazar et al., 1984) gave subjects an explicit history of identity matching with the experimental apparatus before beginning the training with the abstract stimuli. In other studies (Spradlin et al., 1973; Wetherby et al., 1983; Devany et al., 1986), subjects were explicitly instructed to choose the comparison which went with the sample. It could be argued that in all of the previous studies of equivalence a subject's prior history with match to sample tasks or the procedure of the experiments instructed the subject to relate sample and comparison stimuli as being the same. The importance of pretraining or verbal instructions in the development of equivalence classes is indicated by the difficulty which subject SH (in Experiment 3) experienced in learning conditional discriminations without pretraining or instructions.

The pretraining procedures used in these experiments provides only a model for how such complex stimulus control (or relational frames) might be initially developed. Since all of the subjects have very complete verbal repertoires, pretraining may have only alerted them to use skills which they had already been taught by the verbal community.

Verbal repertoires may have played a major role in the behavior of subjects in the present study. Of the six subjects who demonstrated extensive networks of relations, five were able to give the second-order conditional stimuli labels which related to the type of control developed in pretraining. If pretraining had been omitted and the words "same," "different," and "opposite" used as second-order conditional stimuli, the results would probably have been the same. It could be argued that the ability of people to respond based on the relations among arbitrary stimuli is simply the result of their verbal repertoire. But making this argument does not explain the history which develops the verbal repertoire.

Behavioral approaches to explaining the development of verbal behavior have been severely criticized. The following quotation, which refers to attempts by Skinner and Staats to explain language acquisition, is illustrative:

> Chomsky...so convincingly exposed the inadequacies of the neobehavioristic approach not only from the aspect of linguistic theory but also from the point of view of the theory and politics of scientific investigation that practically no one takes such a model seriously any longer. (Miller, 1979)

Staats (1974) provides the following summary of the principal criticisms of behavioral theories about language acquisition:

a) language acquisition is so rapid, and complete so early in life that it does not appear to be learned;

b) children with different language experiences can acquire essentially the same language; and

c) the process is systematic and productive in contrast to imitative or rote.

A judgment about the rapidity of children's acquisition of verbal behavior is really subjective. Children also show rapid acquisition of motor behavior. And while acquisition may be rapid, psycholinguists have documented progressive stages, and a role for experience is clearly indicated (McNeil, 1970).

The argument that children with different language experiences can acquire essentially the same language clearly has some outside limits. Children exposed to Spanish do not speak English, and it is not clear that children raised in Southern Appalachia speak the same language as children raised in New York City. But it is clear that all speakers of the "standard" version of a language show common patterns of usage.

Stimulus equivalence and the results of the present study provide a model for ways that behavioral processes can account for different experiences producing the same network of controlling relationships. Spradlin and Saunders (in press) were able to establish the same set of equivalence relationships using either a multiple sample or a multiple comparison procedure. In Experiment 1 of the present study, the D set of stimuli were added to the network of relations by relating them to C2. But the D stimuli could have been related in training problems to C1, B1, B2, or A1, and the same network of relations would have been developed. The key is not identical experience, but experience which is consistent with the network of relations.

Productivity has been an established feature of stimulus equivalence. Sidman and his colleagues (1985) developed six-member equivalence classes with the result that training 15 relations generated 60 new relations, a 4:1 ratio of emergent to trained relations. In Experiment 1, developing A-B, A-C, and C-D relations involved the explicit training of 6 relations. Not all possible probes were made. Sixteen untrained relations were demonstrated out of a possible set of 34. There is no reason to suspect that all 34 untrained relations (a 5:1 productivity ratio) would not have been observed if they had been tested.

In LA's performance in Experiment 2, six trained relations resulted in 15 novel relations and not all possible untrained relations were tested. A novel stimulus was added to the network of relations without any explicit training. A probe was presented in which the novel stimulus was the only possible correct selection. This forced choice brought the novel stimulus into the network of relations. This provides a model for how humans might be able to learn from context. People are often able to deduce the meaning of a new word from the context of its use. LA was apparently able to deduce the relational properties of the novel stimulus from its context in the probe.

Another feature of verbal behavior (discussed previously) is the symmetry between speaker and listener roles. This type of symmetry was not directly investigated. The presentation of a second-order conditional stimulus, a sample, and comparisons is, in effect, the same as the experimenter asking the subject, "Which of these comparisons is related to the sample in this way?" The experimenter names the relation. To test for the symmetry of speaker and listener roles, a different procedure would be required. The subject could be given the choice of selecting a second-order conditional stimulus in response to the presentation of a sample and a single comparison. This preparation is equivalent to the experimenter asking the subject, "How are these two stimuli related?" The subject, by selecting a second-order conditional stimulus would be naming the relation.

Behavior analytic investigation of relational control of responding is in its infancy. While there are indications that the phenomena observed in the study of stimulus equivalence could be related to language, the nature of that linkage is not clear. The methodology used to develop equivalence classes and the network of relations observed in the present study may or may not parallel the experience which develops verbal repertoires. Behavior analysts now have a theoretical framework (relational frames) and teaching procedures (conditional discriminations and second-order conditional discriminations) which will allow the exploration of complex human behavior which is sometimes described as "linguistic" or "cognitive."

The training and probe series used in the present study provides a methodology for determining whether or not control by the relations same, different, and opposite has been developed. As is the case with equivalence, the behavioral data are consistent with the pattern of control which is predicted by formal logic. This methodology can be used to investigate the learning history needed to establish control by relations. Developmental studies with children whose verbal repertoires do not include accurate use of "same," "different," and "opposite" would be relevant. Similarly, experiments with language-disordered individuals such as stroke patients might illuminate the connection between verbal behavior and the capacity for relations between arbitrary stimuli to control behavior.

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APPENDIX

Instructions to the Subjects

This is an experiment in learning. It is not a psychological test of any kind. We are interested in aspects of learning common to all people.

When the experiment begins, the screen in front of you will show some geometric figures. There will be either two or three figures at the bottom of the screen. Your task is to choose one of these figures by using the joystick. The joystick controls the movement of a box on the screen. Move the joystick until the box is around the figure you want to choose. Then press the button on the joystick. Sometimes there will be two figures in the bottom section of the screen and at other times there will be three. You make your choice the same way in either case.

Sometimes, after you press the button, a message on the screen will tell you whether or not you have made the correct choice. We want you to learn to make as many correct responses as possible. Try to make correct responses on all problems.

At first, the problems may be easy, but they will get harder. You will need to pay attention right from the start, because what you learn at first can be used later to make correct responses.

If you have any questions, ask them now. I cannot answer any questions after you start.