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Contextual Control of Stimulus Equivalence with Preschool Children

M. Regina Green
Utah State University

CONTEXTUAL CONTROL OF STIMULUS EQUIVALENCE
WITH PRESCHOOL CHILDREN

by

M. Regina Green

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Dedicated to my mother, Melvia Green, and

to the memory of Daniel Schindler

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Gina Green

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ABSTRACT

Contextual Control of Stimulus Equivalence
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by

M. Regina Green, Doctor of Philosophy

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Major Professor: J. Grayson Osborne

Department: Psychology

This research asked whether a contextual stimulus in a visual conditional discrimination task controlled membership in classes of stimuli related hierarchically. Six experiments with nonreading preschool children posed the following questions:

Does a stimulus juxtaposed with a conditional discrimination task control relations among the stimuli involved in the task? In Experiments I and II, printed instance or concept words were juxtaposed with conditional discrimination tasks involving symbols. Results for eight of nine children demonstrated neither conditional nor equivalence relations between words and symbols.

Would conditional discrimination training establish classes of visual stimuli composed of selectively nonequivalent subsets? In Experiment III, subjects from the first two experiments were taught conditional relations, then tested for stimulus class development. Printed words that could have been related transitively were not, apparently due to interference by identical letters in certain words, so no stimulus classes developed.

Would the equivalence relations sought in Experiment III develop without a history where printed words were unnecessary to conditional discrimination tasks? For Experiment IV-A, one experimentally naive child was taught the same conditional relations as Experiment III subjects. Two stimulus classes emerged, each containing two subsets that were selectively nonequivalent depending upon trial context.

Are direct or transitive stimulus relations more likely to control responding? In Experiment IV-B, the subject from Experiment IV-A expressed more direct than transitive relations on modified matching trials.

Would interference by identical elements in words be precluded by training conditional relations among words directly? One child in Experiment V was taught conditional relations between concept words and instance words, and instance words and symbols. Results suggested that stimulus class development, which would have answered the question affirrmatively, had begun but was incomplete.

Would providing auditory labels for some printed words preclude interference by identical elements, allowing nonidentical words to be related transitively? In Experiment VI, one child was taught auditory labels for selected printed words, followed by the same visual conditional discrimination training provided in Experiment III. Two stimulus classes developed, requiring transitive and symmetric relations among printed words.

(248 pages)

INTRODUCTION

Stimulus equivalence and mediated transfer are related constructs that are by no means new to psychology. Their origins can be traced to 19th century associationist philosophy, and attempts to develop empirical bases for both constructs were initiated nearly fifty years ago (Jenkins, 1963; Peters, 1935; Shipley, 1935; Wetherby, 1983). The past decade has witnessed a burgeoning interest in stimulus equivalence and mediated transfer among experimental and applied behavior analysts, concomitant redefinitions of both constructs, and delineation of several promising areas of research.

Historically, stimulus equivalence in its broadest sense described the observation that, under certain conditions, organisms behaved as if two or more stimuli were the same functionally, even though the stimuli did not necessarily share any obvious common attributes (Hull, 1939; Lawrence, 1963; Miller & Dollard, 1941; Shipley, 1935). Mediated transfer referred to the indirect association of two otherwise unrelated events via their common association with a third event (Hulse, Deese & Egeth, 1975; Jenkins, 1963; Peters, 1935).

Definitions have been modified over the years to better account for the accumulating data, and mediated transfer (renamed transitivity) has been described recently as just one of three properties defining stimulus equivalence (Sidman, Rauzin, Lazar, Cunningham, Tailby & Carrigan, 1982; Sidman & Tailby, 1982).

Operant researchers have relied primarily on match-to-sample procedures to study stimulus equivalence. In the standard procedure, a stimulus (called the sample) has been presented to a subject, then two or more stimuli (called comparisons) have been presented, usually in close temporal and physical proximity to the sample stimulus. A response to one of the comparisons, deemed by the experimenter a correct response to the sample, has been followed by reinforcement, while a response to the incorrect comparison has not been reinforced. Various relations among sets of stimuli have been trained in this manner. Typically, experiments have been arranged so that, for example, two sets of stimuli were never matched to each other but each independently was matched to another set of stimuli. Transitivity tests have been conducted in which stimuli from the two sets related only by their common relation with a third set have been presented in conditional discrimination problems (e.g., Sidman, 1971). Two additional tests for stimulus equivalence have been specified: generalized identity matching (reflexivity), wherein previously untrained, physically identical stimuli are related; and sample-comparison interchangeability (symmetry), which means that the subject relates one stimulus to another in match-to-sample problems regardless of whether each stimulus serves as sample or comparison (Sidman et al., 1982; Sidman & Tailby, 1982).

When the above-described procedures have been used with human subjects, investigators have reported evidence that large sets of stimuli were related after only a small proportion of possible conditional relations were trained directly (Dixon, 1978; Dixon & Spradlin, 1976; Fucini, 1983; Gast, VanBiervliet & Spradlin, 1979; Lazar, 1977; Lazar, Davis-Lang, & Sanchez, 1984; Lazar & Kotlarchyk, in press; McDonagh, McIlvane & Stoddard, 1984; Saunders & Spradlin, 1983; Sidman, 1971; Sidman & Cresson, 1973; Sidman, Cresson, & Willson-Morris, 1974; Sidman, Kirk, & Willson-Morris, 1985; Sidman et al.,1982; Sidman & Tailby, 1982; Sidman, Willson-Morris, & Kirk, in press; Spradlin, Cotter & Baxley, 1973; Spradlin & Dixon, 1976; Stromer & Osborne, 1982; VanBiervliet, 1977; Wetherby, Karlan & Spradlin, 1983). In addition to the great economy such procedures have afforded for training many important skills, such as reading (e.g., Sidman, 1971), arithmetic (e.g., Gast et al., 1979), and simple money manipulations (e.g., McDonagh et al., 1984), several writers have suggested using these procedures to investigate the complex stimulus control involved in language and concept formation (e.g., Dixon, 1978; Dixon & Spradlin, 1976; Sidman, in press; Sidman et al., 1982; Sidman & Tailby, 1982; Spradlin & Dixon, 1976; Spradlin & VanBiervliet, 1980; Wetherby, 1983; Wetherby et al., 1983). When humans emit behaviors that are described as linguistic or that demonstrate the use of "concepts," such behaviors are potentially under the control of a number of stimuli simultaneously present (Skinner, 1957; Wetherby, 1983). It is not sufficient to examine stimulus equivalence simply in terms of relations that involve only two stimuli, a sample and a comparison, on any given trial in a conditional discrimination task. Experimental approximations to human linguistic and conceptual behavior should be designed to permit analyses of stimulus equivalence under the control of multiple stimuli (Wetherby, 1983). Although the factors that produce stimulus equivalence are not yet well understood (Fields, Verhave, & Fath, 1984, 1985), the procedures are developed well enough that they can be applied to complex human behaviors.

STATEMENT OF THE PROBLEM

Numerous experiments have demonstrated that training a subset of all possible conditional relations among sets of nonidentical stimuli resulted in the emergence of untrained conditional relations (Dixon, 1978; Dixon & Spradlin, 1976; Fucini, 1983; Gast et al., 1979; Lazar, 1977; Lazar et al., 1984; Lazar & Kotlarchyk, in press; Mackay & Sidman, 1984; McDonagh et al., 1984; Saunders & Spradlin, 1983; Sidman, 1971; Sidman & Cresson, 1973; Sidman et al., 1974; Sidman et al., 1985; Sidman et al., 1982; Sidman & Tailby, 1982; Sidman et al., in press; Spradlin et al., 1973; Spradlin & Dixon, 1976; Stromer & Osborne, 1982; VanBiervliet, 1977; Wetherby et al., 1983). In most of these experiments, a trial consisted of presentation of a single sample stimulus and from one to eight comparison stimuli, one of which was designated correct (but see Lazar & Kotlarchyk, in press; McDonagh et al., 1984). With the exception of a few experiments that examined relations between both the sample and the correct comparison, and the sample and the incorrect comparison (e.g., Stromer & Osborne, 1982), the influence of other contextual stimuli on the matching relations developed via such procedures has received little experimental attention (but see Fucini, 1983; Lazar & Kotlarchyk, in press). Yet the potential importance of additional contextual stimuli to the control of behavior in many everyday situations has long been recognized. Skinner (1957) described situations in which the topography of a single response might be controlled by two or more discriminative stimuli simultaneously present. One such situation is the differential use of words to describe events that may be categorized in any of several ways, depending upon context (Sidman, in press; Skinner, 1957; Spradlin & Dixon, 1976; Wetherby, 1983; Wetherby et al., 1983).

The present research investigated the control of equivalence relations among stimuli by explicit contextual stimuli following each of several match-to-sample training procedures. It adds to the limited empirical evidence that complex linguistic behaviors, such as responding selectively to a stimulus as a member of a broad stimulus class or as a member of a subset of the larger class, may be the products of specifiable experiences wherein certain relations among stimuli are reinforced in the presence of particular contextual stimuli. Analyses of contextual control like those attempted in this research require shifting stimulus control research from its basic unit of analysis, the three-term contingency, to complex levels of investigation focusing on more than just a single discriminative stimulus, or even a conditional stimulus and a discriminative stimulus. Such a shift is necessary to enable clear demonstrations of the controlling relations involved in human language and conceptual behaviors.

REVIEW OF LITERATURE

The Problems of Stimulus Equivalence and Mediated Transfer in Traditional Psychology

The notion that two events can become associated via a third common event was first postulated by the British associationists Hume and Hartley. Hamilton (cited in Peters, 1935) coined the term "mediate association" to distinguish such associations from direct associations resulting from the contiguous occurrence of two events (Jenkins, 1963; Peters, 1935). For philosophers and early experimental psychologists, the events that entered into associations of either type were ideas. When two ideas, A and B, had never been associated directly but each independently was associated with a third idea, C, then A would be associated with B. The third term was considered to mediate the two previously unrelated ideas (Hulse et al., 1975; Jenkins, 1963; Peters, 1935).

From its inception, stimulus equivalence (e.g., Shipley, 1935) was a construct that was closely related to mediate association (or mediated transfer, as mediate association was later called). Both constructs represented attempts to explain how apparently unrelated events came to be connected. Converging lines of reasoning developed from neobehavioral conditioning work and verbal learning work, both stemming from the associationist tradition. Major empirical findings and theoretical discussions from each of those areas are summarized in the following two sections.

Neobehavioral Views of Stimulus Equivalence

The earliest use of the term "stimulus equivalence" was in Shipley's (1935) report of apparent indirect classical conditioning with human subjects. A light blow on the subject's cheek served as an unconditioned stimulus (US) eliciting an eyeblink, the unconditioned response (UR). This US was preceded on randomly alternating trials by a faint flash of light or the brief sound of a buzzer, until the light or buzzer independently produced the eyeblink, thereby functioning as conditioned stimuli (CS). One CS, the light, was then presented in a series of trials preceding a shock to the subject's index finger that elicited unconditioned finger withdrawal. Two test trials were conducted with the buzzer alone, and six of ten subjects produced finger withdrawals to that stimulus even though it had never been paired with the US (shock) for finger withdrawal.

Shipley (1935) suggested that two or more stimuli conditioned to the same response might become functionally equivalent, such that if one of those stimuli was conditioned to a new response the other stimulus would also tend to evoke the new response. However, this hypothesis did not explain two sets of results he obtained with some control subjects: first, some subjects who experienced only USs (e.g., blow to the cheek followed by shock) in training trials still gave finger withdrawals in response to a nominal CS (e.g., flash of light); and a significant proportion of subjects who underwent conditioning trials on which each CS preceded a different rather than a common response also produced a response to the CS with which that response had not been paired previously.

Despite Shipley's (1935) dismissal of the stimulus equivalence hypothesis, Hull (1939) considered stimulus equivalence an important problem for behavior theory. The problem was to explain how a stimulus could evoke a response with which it had never been associated. Hull postulated three forms of stimulus equivalence based on three different principles:

1. Equivalent responses could be evoked by stimuli that shared some element of physical identity.

2. Primary or physiological generalization described the observation that when a response was conditioned to a stimulus, other stimuli from the same stimulus continuum evoked the response with diminishing effectiveness as distance from the original stimulus increased.

3. Secondary generalization referred to the case where primary generalization along a stimulus continuum occurred as a result of conditioning one response to a stimulus on that continuum; then, when a new response was conditioned to one point along that same continuum, all other stimuli on the continuum also tended to evoke the new response (Hull, 1939, pp.11-12).

Hull noted that equivalent stimuli evoked qualitatively similar responses, although responses to stimuli other than the one to which the response was conditioned originally might be quantitatively different. He suggested that the three forms of stimulus equivalence combined in various ways depending upon situational variables, and that other forms of stimulus equivalence might exist.

Miller and Dollard (1941) also viewed occurrence of a common response as a necessary condition for dissimilar stimuli to acquire equivalence. According to their theory, through explicit training individuals learned to make a common verbal or nonverbal response to each of several different cues. The common response itself produced cues, and those (presumably internal) cues formed a set of common stimuli. The response-produced cues mediated between the external stimuli and subsequent new responses to the same stimuli. Transfer of responses to previously untrained stimuli also occurred when stimuli shared "innate similarities," but transfer based on response-produced cues was considered particularly important where social behavior was concerned (Miller & Dollard, 1941).

Lawrence (1963) proposed an explanation of acquired equivalence of stimuli similar to the Miller and Dollard hypothesis. The organism was assumed to code every sensory input. The implicit coding response produced a stimulus, called the "stimulus-as-coded" (s-a-c), which in turn elicited directly an overt response. When the same coding response was associated with a series of sensory inputs, an ordered series of s-a-c was produced. One s-a-c could then be substituted for another, depending upon their juxtaposition in the hypothesized series of s-a-c, to elicit the same overt response. The original overt stimuli as well as the covert s-a-c were considered to have acquired similarity, the overt stimuli because they all produced similar implicit coding responses, and the covert s-a-c because they all elicited similar overt responses (Lawrence, 1963).

Mediated Transfer in Verbal Learning

Peters (1935) initiated a research tradition using paired-associate problems for studying mediation phenomena. In paired-associate problems, subjects learned two different lists of paired items (e.g., nonsense syllables) with one set of items in common. For example, in a list designated A-C, A items were words and C items were letters of the alphabet in one of Peters' experiments. The second list consisted of B items (numbers) and C items (letters). Subjects were presented with pairs of items, then with the first item of each pair to which they were to produce the corresponding second item, until they could name the second item of each pair correctly three times through the list. After they learned the A-C and B-C lists, they were given a list of A items and instructed to name the B items that went with them. This final step in the procedure constituted a test for mediated associations, since A and B should only be associated indirectly via their former direct association with the common C items. In three of four experiments employing variations on the basic design, subjects produced significantly more "correct" B items in response to A items than would have occurred by chance, from which the presence of mediated associations was inferred. Other experiments reported in the same paper, but using different methods, obtained mixed results (Peters, 1935).

Nearly 30 years of research on mediated associations using paired-associate methods ensued. The experimental paradigms and findings were distilled in comprehensive reviews by Jenkins (1963) and Jenkins and Palermo (1964). In general, in this research subjects learned lists of pairs of items, typically words or nonsense syllables. The first item in a pair was considered the stimulus, the second was considered the response. Tests for mediation required subjects to learn a new list composed of previously unrelated items. Performances of experimental subjects on the third list were compared to performances of control subjects who did not learn the first lists. The simplest paradigms consisted of various combinations of three "elements" (Jenkins' term to replace "ideas") arranged so that two elements were associated with a third. These were called three-stage mediation paradigms, and Jenkins (1963) grouped them into three principal types: chaining (e.g., learn A-B and B-C, test for A-C); stimulus equivalence (e.g., learn A-B and C-B, test for A-C); and response equivalence (e.g., learn B-A and B-C, test for A-C). All possible arrangements of three sets of elements were tested by several different investigators, and all produced evidence of mediated associations, which occurred in the third (test) stage (Hulse et al., 1975; Jenkins, 1963).

A logical extension of the mediated association model was the addition of a fourth element, which allowed further tests to determine whether elements that were only associated indirectly would function as equivalent stimuli or responses, i.e., whether they would elicit a common response or be produced in response to a common stimulus. These four-stage paradigms were categorized similarly to their three-stage counterparts, with the addition of a fourth element, as follows: chaining (e.g., learn A-B, B-C, and A-D, test for C-D); stimulus equivalence (e.g., learn A-B, C-B, and A-D, test for C-D); and response equivalence (e.g., learn B-A, B-C, and D-A, test for D-C). Experiments with all possible four-stage combinations initially failed to find any mediation effects (Jenkins, 1963); the sole evidence for four-stage mediation in paired-associate work came from experiments in which an explicit mediating response was required, or in which natural language materials were used and the task was structured such that occurrence of a covert mediating response (e.g., a verbal categorical label) was made very likely (Jenkins & Palermo, 1964).

A critical assumption underlying inferences that mediated associations developed in either the three- or four-stage models was that an implicit, covert response occurred in the test stage. That response was also assumed to have stimulus properties sufficient to elicit an overt response that would otherwise not be elicited by the stimulus presented to the subject. For instance, in the simple chaining case, once A-B and B-C were learned, when A was presented alone the covert B response presumably occurred and served as the implicit stimulus for the C response. Hence the implicit B was said to mediate, or provide the link between, the previously unrelated A and C items (Jenkins, 1963; Jenkins & Palermo, 1964). The role of the implicit mediating response was originally suggested by Hull (1939) and was essentially accepted, with some modifications, by paired-associate researchers. However, failure to find mediation effects under all conditions in which they were expected to occur, especially in the four-stage paradigm, led Jenkins (1963) to conclude that the mediating response did not occur automatically, was differentially aroused by the demands of various tasks, and was susceptible to the influence of variables such as reinforcement, extinction, and interference by competing responses.

Jenkins and others were particularly interested in the four-stage mediation paradigms for two reasons: the paradigms offered a means to analyze both stimulus equivalence and response equivalence; and they were analogous to natural language models in that previously learned elements appeared in new combinations with elements that had been learned in a different context. In the standard example, subjects learned A-B and C-B in the first two stages. This was assumed to make A and C functionally equivalent stimuli. In the third stage, A-D, a new response to A was learned, making it likely that the D response would occur to C stimuli in the test stage because A and C were equivalent. Presumably in the last two stages the A-D and C-D associations were mediated by the implicit occurrence of B, the original common response to A and C. It was then possible to change the positions of functionally equivalent items in training and testing sequences. That is, once subjects went through the sequence

Learn A-B
C-B
A-D

Test C-D

the third and fourth stages could be changed to D-A and D-C. If subjects performed the final two tasks with relative ease, then equivalent stimuli would have become equivalent responses, a result analogous to a simple linguistic transformation (Jenkins, 1963). Further, groups of equivalent stimuli and responses were hypothesized to form classes of substitutable words, so that new utterances theoretically could occur by substituting various words from equivalent classes (Jenkins, 1963; Jenkins & Palermo, 1964). Jenkins and Palermo (1964) speculated further that first language learning proceeded from simple S-R associations to the formation of large and complex stimulus and response classes through a combination of imitation, differential reinforcement, and implicit mediating responses that served to establish new relations among elements of existing classes. They also suggested that syntax, or the sequencing of classes of verbal utterances, was acquired in similar fashion (Jenkins & Palermo, 1964).

Stimulus Equivalence and Mediated Transfer in the Operant Framework

Transfer, Concept Formation, and Language

Skinner (1935, 1938, 1957) rejected the emphasis placed on hypothetical covert mediating responses and implicit response-produced stimuli by S-R psychologists, instead seeking to base a science of behavior primarily on functional relations among well-defined environmental events and observable behaviors. That stance left radical behaviorists vulnerable to criticism that the behavioral approach could not explain such complex behaviors as transfer, concept formation, and language (e.g., Chomsky, 1959; Royer, 1979). In recent years radical behaviorists have devoted increasing effort to answering that criticism. However, psychology in general has offered several different views of transfer, concept formation, and language. An attempt is made here to describe the logical and empirical relations among these three categories of complex behaviors and to outline briefly the role behavior analysis might play in clarifying them.

Transfer may be defined as observed change in the performance of a particular task that occurs as a function of some specifiable prior experience (Hulse et al., 1975; Spradlin & VanBiervliet, 1980). There may be several types of transfer. For example, Spradlin and VanBiervliet (1980) suggested these:

1. Primary stimulus generalization: When a specific response is conditioned to one stimulus, other stimuli that are physically similar to the original stimulus will also control that response, to a degree (cf. Hull, 1939).

2. Abstraction: A particular property or cluster of properties of a class of stimuli controls a common response to all members of the stimulus class.

3. Dimensional transfer: Individuals learn a new discrimination more quickly if the new task involves the

same stimulus dimension as a previously trained discrimination than when the new discrimination involves a new stimulus dimension.

4. Stimulus-response classes: If two or more stimuli, or units of stimulus-response chains, are established as members of a class, conditioning a new response to one member of that class may result in other members of the class also controlling the new response.

Recent research on stimulus equivalence has focused on the development of stimulus classes, and the role of stimulus classes in transfer. The stimulus class construct is important as an explanatory tool to counteract claims that the operant approach cannot explain complex behaviors.

The term "concept" has been used to explain how transfer occurs, especially the transfer presumably occurring in complex recombinations of behavior. Traditionally a concept was defined in terms of common properties among stimuli (e.g.,Bruner, Goodnow & Austin, 1956; Hunt, 1962) or as a set of stimuli controlling similar responses (e.g., Kendler, 1961; Osgood, 1953). Such definitions often invoked the existence of some mediational process, usually covert, that served to link stimuli together. Goldiamond (1962), following Skinner (1935), suggested that two or more stimuli could function interchangeably as occasioners of similar responses, even when neither the stimuli nor the responses had similar physical characteristics. Thus Goldiamond (1962) defined a stimulus class as a set of stimuli that were functionally equivalent with respect to the prevailing reinforcement contingencies. This definition was adopted by operant researchers because it connoted fewer unobservable variables than did any of the existing definitions of "concept" while describing essentially the same behaviors subsumed under that term (Dixon & Spradlin, 1976; Lazar, 1977; Spradlin et al., 1973; Spradlin & Dixon, 1976). In fact, Spradlin and Dixon (1976) redefined "concept" as stimuli or events that were substitutable for one another in a given context, i.e., a stimulus class. By definition, any variable that affected one member of a class of stimuli affected all members of the class, thereby extending the influence of such variables as reinforcement, and providing a plausible explanation for the occurrence of seemingly novel behaviors, such as problem-solving or the "generative" aspects of language (Sidman & Tailby, 1982; Spradlin & Dixon, 1976).

The operational definition of stimulus class was further expanded by Sidman and his colleagues (Sidman et al., 1982; Sidman & Tailby, 1982). A stimulus class necessitated the development of equivalence relations among the member stimuli. Although match-to-sample procedures were assumed to generate classes of equivalent stimuli, that assumption was unwarranted without specific empirical tests of equivalence. The typical match-to-sample procedure presents the subject with a stimulus, designated the sample, and two or more discriminative stimuli, called comparisons. According to rules established by the experimenter, a response to one comparison stimulus is followed by reinforcement; a response to the other comparison(s) is not reinforced. The task for the subject is a conditional discrimination, defined as an "if...then..." relation between sample and comparison (e.g., if the sample is green, select green comparison). When accurate performance on such a task is called "matching," it implies that the stimuli involved comprise a class of equivalent stimuli, and therefore that considerably more than conditional relations among stimuli have developed. Such an inference, according to Sidman et al., requires demonstration that equivalence relations in fact exist. An equivalence relation must possess the following three properties:

1. Reflexivity: Each stimulus must bear a conditional relation to itself, that is, "If A, then A" must be true; identity matching must occur. Generalized identity matching is proof of reflexivity.

2. Symmetry: The conditional relation between two stimuli must be bidirectional: each must function as both sample and comparison (i.e., as stimulus and response) for the other. For example, if B is the correct comparison stimulus when A is the sample, then when B is the sample A must be selected as the correct comparison.

3. Transitivity: Once two conditional relations have been established in which the comparison from the first served as the sample in the second, a third conditional relation between the sample from the first relation and the comparison from the second must result without direct training or instruction. This defines an emergent relation (Sidman & Tailby, 1982) and is equivalent to mediated association.

When conditional relations meet all these criteria, the stimuli involved are equivalent members of a class. Only then can the performance be correctly labelled "matching" (Sidman & Tailby, 1982). Relations other than equivalence relations among stimuli -- e.g., larger than, shorter than, etc. -- may be involved in so-called transitive inferences (Thayer & Collier, 1978), but they are explicitly excluded from considerations of stimulus equivalence because they are unidirectional and therefore logically cannot meet the conditions for symmetry described above.

The Sidman definition equates stimulus class with "true" equivalence, going beyond Goldiamond's (1962) definition of stimulus class to specify the evidence necessary for a conclusion of functional equivalence among stimuli. Sidman and his colleagues (Sidman et al., 1982; Sidman & Tailby, 1982) further suggested that their equivalence paradigm provided tests for whether a conditional discrimination involves semantic relations. If equivalence was demonstrated between, say, certain printed words and objects, it would allow us to describe the words as "symbols" for the objects, or the objects as the "meanings" of the words, without making high-level inferences. This supposition placed stimulus equivalence research squarely in the realm of language, providing a potentially powerful paradigm for exploring aspects of language that operant analyses had previously only touched upon.

Control of Learned Behavior by Contextual Stimuli

The role of contextual stimuli in the control of learned behavior has been the subject of numerous laboratory investigations with animals, many aimed at testing predictions about the amount of conditioning that accrues to contextual stimuli based upon a mathematical model developed by Rescorla and Wagner (1972). Following a precedent set by Rescorla and Wagner, the typical approach was to conduct classical conditioning procedures in the presence of a defined but often pervasive contextual stimulus (e.g., light or sound) and then measure the effect of the contextual stimulus on an established baseline of instrumental responding (e.g., Patterson & Overmier, 1981). Other experiments, however, examined the effects of contextual stimuli on instrumental responding by less circuitous means. In a series of recent studies by Thomas and his associates (Mah, McKelvie & Thomas, 1983; Thomas, McKelvie, Ranney & Moye, 1981; Thomas & McKelvie, 1982), for example, pigeons were trained on a simple discrimination in one context (e.g., houselight and tone) and the reverse discrimination in a different context (e.g., no houselight and white noise). Generalization tests conducted in contexts that were the same as, or different from, the original training context revealed clear relations between discriminated responses and their contexts. That is, when the generalization test was conducted in the first context, the peak of the generalization gradient occurred at the S+ for that context, and similar results obtained for tests conducted in the other context.

Findings such as these verified that contextual stimuli exercise measurable control over simple discriminated operants, and suggested possibilities for similar research into the control of more complex conditional discriminations by contextual stimuli. The operant stimulus equivalence paradigm lends itself particularly well to such investigations. For humans, the composition of equivalent stimulus classes must change rapidly and often depending upon the presence of various contextual cues. A major source of cues that determine differential responding to environmental events is verbal behavior (Skinner, 1957; Spradlin & Dixon, 1976; Wetherby, 1983). Experimental analogues to common but poorly understood situations, such as responding to the same stimulus as a member of two different classes depending upon context, would allow investigation of equivalence relations among all the attendant stimuli. To date, only two such studies have been reported (Fucini, 1983; Lazar & Kotlarchyk, in press). It may also be the case that a complex form of transfer occurs across multiple stimulus classes in instances that appear to be examples of novel or spontaneous behaviors. For example, a response to one conditional cue, once learned, might transfer to another conditional cue concurrently available (Thomas & McKelvie, 1982). This possibility could also be examined in the operant stimulus equivalence paradigm.

Operant Analyses of Stimulus Equivalence in Humans

The first attempt to provide an operant account of stimulus equivalence with humans was reported by Sidman (1971). Reasoning that reading involves specifiable sets of stimulus-response relations, Sidman established an experimental paradigm that allowed precise assessment of the presence of each relation in a subject's repertoire, and the interdependency of those relations in the complex set of behaviors that constitute reading. Oral reading was characterized as oral naming of printed words; reading comprehension involved matching printed words to pictures; and auditory receptive reading required selection of the corresponding printed word in response to a spoken word. The major question Sidman raised was whether oral reading and reading comprehension required prior learning that auditory stimuli (spoken words) and visual stimuli (printed words and pictures) bear an equivalent relation to one another.

The subject was a severely retarded adolescent boy who could accurately select a picture in response to a spoken word and name pictures, but could not match pictures to printed words, name printed words, or match printed words to spoken word samples. The experiment was designed to determine whether teaching the subject one auditory-visual equivalence relation -- spoken words to printed words -- would establish equivalence among all of the stimuli involved, i.e., whether the subject would then be able to demonstrate the matching and naming performances that were absent from his preexperimental repertoire. The stimuli and conditional relations that concerned Sidman are represented schematically in Figure 1, adapted from the original paper. Borrowing conventions employed in subsequent research, each set of stimuli is designated by a letter; those letters are used in later discussions as shorthand notations for the stimulus sets. Established conditional relations are indicated by solid lines and arrows, and broken lines and arrows signify untrained relations.

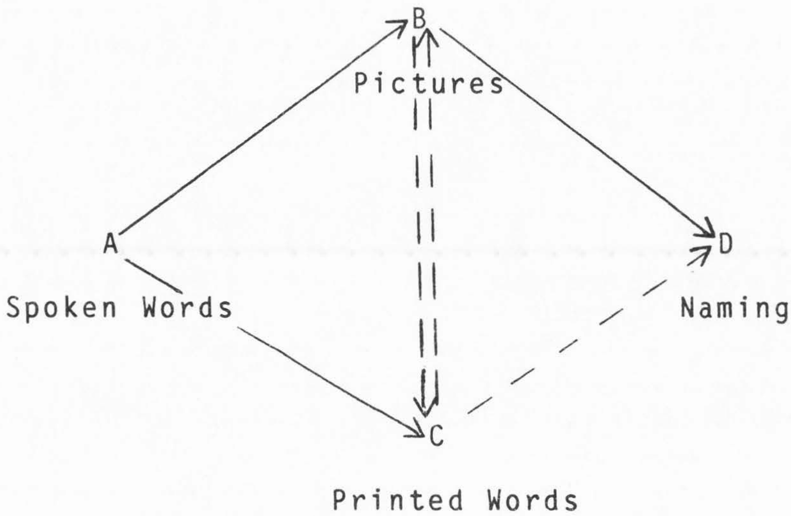

Figure 1. Trained relations (solid lines) and untrained relations (broken lines) among stimuli (from Sidman, 1971).

To reiterate, the subject entered the experiment demonstrating proficiency in AB and BD relations as diagrammed in Figure 1. The AC relation was trained, and the remaining relations (BC, CB, and CD) were tested (Sidman, 1971) via match-to-sample procedures. Stimuli were 20 three-letter words (spoken or printed) and corresponding pictures (e.g., axe, bed, boy, dog).

The teaching procedures consisted of AC matching; that is, samples were spoken words and choices were printed words for six sets of trials . Correct responses were consequated with tokens and the sound of chimes. Training continued until the subject demonstrated 80% matching accuracy. Thus, training established the AC matching performance (see Figure 1) in addition to the AB and BD performances that were demonstrated in pretesting.

Finally the subject was tested without reinforcement on BC, CB, and CD matching performances, none of which were trained directly in the experiment or existed prior to training. BC, CB and CD matching performances were highly accurate (at least 75%). Sidman concluded that training one auditory-visual relation, spoken to printed words (AC), in combination with the existing relations between spoken words and pictures (AB) and ability to name pictures (BD), was sufficient to produce the remaining three relations.

In this paper, Sidman (1971) described experimental procedures that provided operant researchers with a powerful tool for conducting functional analyses of complex stimulus-response relations with a variety of species using a wide range of tasks. This initial effort also raised a number of empirical questions. Sidman suggested, for example, that similar emergent relations might develop among sets of purely visual stimuli as they did among auditory and visual stimuli in his experiment. He also questioned the role of overt or covert naming of stimuli in mediating equivalence relations, and noted that oral reading (the CD relation in Figure 1) may not be a necessary product of auditory-visual word matching (AC) (Sidman, 1971). Some of these questions were answered by subsequent research, but the importance of the initial work is gauged by the research that has followed directly from it and by the important theoretical and empirical questions generated by studies conducted in the framework Sidman established. That research is the topic of the remainder of this section.

Auditory-Visual Equivalences

Several investigators studied equivalence relations between auditory and visual stimuli in the manner suggested by Sidman (1971). Sidman and Cresson (1973) essentially replicated the previous study with two severely retarded subjects by training auditory-visual relations (AB and AC; see Figure 1) and demonstrating the emergence of untrained matching performances with visual stimuli (BC, CB) as well as oral naming of visual stimuli (CD).

A question raised by the first two studies (Sidman, 1971; Sidman & Cresson, 1973) was whether BC and CB equivalence was mediated by words spoken to the subject (AB or AC) or by the names produced by the subject in BD or CD naming tasks. Sidman et al. (1974) precluded any direct association between spoken and printed words by first training two severely retarded subjects to associate pictures to spoken words (AB) and printed words to pictures (BC). Then they tested for emergence of the remaining relations. Training on one leg of the receptive triangle (the left side of Figure 1) did not result in the emergence of any untrained matching in either subject, but following BC training both subjects demonstrated transfer to other tasks (CB, AC, or CD performances). Sidman et al. concluded that response mediation, i.e., naming, was not necessary for auditory-visual transfer, but receptive training was sufficient for the development of untrained relations and may have facilitated oral naming.

Dixon and Spradlin (1976) and Spradlin and Dixon (1976) trained mentally retarded adolescents to match nonidentical forms with each visual stimulus serving as both sample and correct choice for every other stimulus in a set, thereby establishing classes of visual stimuli. Selecting one member of a set in response to an arbitrary auditory sample (e.g., "la" or "voo") was then reinforced. Dixon and Spradlin (1976) found that for three of six subjects, control by the auditory sample transferred to the untrained members of the visual stimulus class almost immediately on probe trials, but such transfer did not occur with the other subjects until they were trained on a second or third set of visual stimuli. Similarly, Spradlin and Dixon (1976) found it necessary to train their mentally retarded subjects to select two members of a class of visual stimuli in response to an auditory sample before transfer to the remaining two members occurred; no transfer was evident after auditory-visual matching that involved just one member of the visual stimulus class.

Two experiments reported by Dixon (1978) explored auditory-visual equivalences in a slightly different way. Six mentally retarded adolescents were first trained to select one of two forms in response to a spoken nonsense syllable. Two sets of four forms each served as choices. After this training, visual matching probe trials were inserted in which a form from one set served as the sample, a different form from the same set was the correct choice, and the remaining choice was from the other set of forms. If equivalence was established among the members of each set of stimuli by virtue of their having been correct responses to the same auditory stimulus, then subjects should have matched set members to one another on the purely visual matching probes. That was the case with nine of 12 subjects in the two experiments (Dixon, 1978).

Another analysis of equivalences among auditory and visual stimuli was conducted by Sidman and Tailby (1982). Previous studies established classes that consisted of three sets of stimuli (spoken words, pictures, and printed words; or spoken words and two sets of visual forms); Sidman and Tailby added a third set of visual stimuli. All stimuli were printed Greek letters and their spoken names. Spoken letter names were designated set A, and the three sets of printed letters were designated B, C, and D. Eight nonretarded 5-to-7-year-old children were trained on the AB, AC, and DC relations and then demonstrated all remaining matching relations (BC, CB, CD, BD, DB, AD) as well as oral naming of all visual stimuli. Sidman and Tailby concluded that this behavior indicated the development of two classes of three stimulus sets (ABC and ACD) and one four-stimulus class (ABCD). Six untrained relations were derived from three trained relations.

Sidman et al. (1985) used conditional discrimination procedures with children and adults to establish two groups of three classes of equivalent stimuli containing three members each. One group was established by training subjects to select visual comparisons (Greek letters) from stimulus Sets B and C conditionally upon auditory samples (dictated Greek letter names) from Set A, then demonstrating that relations among stimuli from all three sets were symmetric and transitive. A second group of three stimulus classes was established similarly using three sets of visual stimuli, English script letters (Set D) and two sets of Greek letters (Sets E and

F). The two groups of stimuli were then linked by training subjects to relate stimuli from Set C to stimuli from Set E, and tests demonstrated that five of eight subjects in Experiments I and II combined the two groups into one group of three classes, each containing six equivalent stimuli. In a third experiment, three children demonstrated formation of three six-member stimulus classes when each class was enlarged one member at a time. These subjects were trained on only 15 conditional relations, and 60 untrained relations emerged. Additionally, of the eight subjects whose performance demonstrated equivalence, six gave the same name for all class members on oral naming tests. Two subjects were inconsistent in the names they applied to stimuli after training, but their performance nonetheless demonstrated nearly perfect class formation.

A study designed to investigate the role of oral naming in mediating stimulus equivalence was reported by Sidman et al. (in press). Two normal five-year-old children and four retarded males, 19-25 years of age, were trained to select three Greek letters from Set B and Set C in response to dictated Greek letter names (Set A). They were also taught conditional relations between three script English letters in Set D and other Greek letters making up Sets E and F. That is, auditory-visual relations AB and AC, and visual-visual relations DE and DF were trained. Subjects were tested first for the transitive and symmetric relations BC, CB, EF, and FE; all subjects demonstrated that those relations had emerged. Next the symmetric relations between the visual stimuli ED and FD were tested, and all but one of the retarded subjects showed those relations. Thus, six classes of equivalent stimuli had formed, three that each contained three ABC elements, and three that each contained three DEF elements. Finally, subjects were asked to name all the B, C, D, E, and F stimuli. Four subjects gave the name of the auditory Set A stimulus for the B and C elements in each ABC class, but two subjects did not apply a common name to the B and C elements. In the all-visual DEF classes, one subject produced names for the DEF stimuli that were taken from the auditory stimuli (Set A) in the other class. None of the other subjects provided consistent oral names for the DEF stimuli, but the names they did produce were taken from Set A. The authors concluded that oral naming was neither necessary nor sufficient for stimulus equivalence to develop.

Visual-Visual Equivalences

Spradlin et al. (1973) examined Sidman's (1971) proposition that untrained equivalence relations might emerge when purely visual stimuli were involved as they did when relations between auditory and visual stimuli were developed. Mentally retarded adolescents received reinforcement for matching nonidentical forms from two stimulus sets (e.g., AB or AC). Next they were trained either to match new comparisons to the same sample (e.g., AD) or to match in the presence of a sample that was previously a comparison (BC). Probes tested for the emergence of the untrained relation BD. Seven of nine subjects in the three experiments taken together demonstrated considerable accuracy on the untrained BD matching task, leading the authors to conclude that if two stimuli control the same response, and a new response is conditioned to one of those stimuli, the remaining stimulus will also control the new response.

Sidman et al. (1982) failed to obtain symmetry in conditional relations among visual stimuli with rhesus monkeys and baboons, and then employed the same procedures in an experiment with children. Subjects were trained to match physically identical hues and lines, and then to select a hue comparison in the presence of a line sample (e.g., horizontal-red, vertical-green). Symmetry probes assessed sample-comparison reversibility of each line-hue pair. Unlike the other primates, four of six children matched correctly when samples and comparisons were interchanged relative to their trained positions (i.e., symmetry), and the remaining two subjects did so after retraining with slightly different procedures. No other tests for equivalence were conducted.

In two experiments with mentally retarded adolescents, Stromer and Osborne (1982) explored equivalence as well as sample-comparison relations in match-to-sample tasks with sets of figures. Training in Experiment I consisted of reinforcement for selecting a particular comparison stimulus from one set in response to a sample from another stimulus set. Tests included various combinations of familiar samples with familiar and novel comparisons designed to determine the existence of positive and negative sample-comparison relations. Three tests also evaluated symmetry, i.e., interchangeability of samples and comparisons. All four subjects demonstrated nearly perfect performance on symmetry probes. In Experiment II each of three groups of mentally retarded subjects was trained on two conditional relations, each relation having one element in common with the other (AC, CB; AB, AC; AB, BC). These training procedures were identical to the stimulus equivalence, response equivalence, and chaining paradigms employed in earlier verbal learning research (Jenkins, 1963). Tests evaluated the symmetry of each conditional relation (e.g., AB, BA; CB, BC) and transitivity, or the emergence of relations between the two sets of stimuli that previously shared a common element (e.g., AB, CB, AC). The symmetric case of the transitive or derived relation (e.g., AB, CB, CA) was also tested. Most of the 12 subjects' performances demonstrated both symmetry and transitivity in these derived relations. One subject in Group 1 failed to provide evidence of either equivalence relation, and one subject in Group 3 showed symmetry but not transitivity.

Recently Wetherby et al. (1983) added to the evidence that it is necessary only to train a small subset of all possible conditional relations among sets of stimuli in order for all remaining relations to develop. They trained seven preschool children to match various combinations of stimuli from four different sets of abstract designs (e.g., AC, BC, AD) and then tested for the emergence of untrained transitive relations (e.g., BD) as well as matching with samples and comparisons reversed (symmetry; e.g., CA, CB, DA, DB). All subjects performed with nearly 100% accuracy on all tests, regardless of the order in which the underlying relations were trained.

Saunders and Spradlin (1983) took a slightly different approach to the evaluation of stimulus equivalence. Two mentally retarded adolescents were first trained to perform a simple (two-choice) discrimination involving four pairs of nonidentical figures. Conditional discrimination probes presented a sample and one comparison from the set of positive stimuli and another comparison from the set of negative stimuli from the simple discrimination training. Initially there was no evidence that the simple discrimination training resulted in formation of a class of equivalent stimuli. After conditional discrimination trials with two of the four sets of stimuli were reinforced, probe trials were inserted to test for symmetry among the stimuli in the reinforced conditional discriminations, and the transfer of matching performance to the untrained conditional discriminations. Both subjects gave clear evidence of symmetry with trained stimuli, but one subject performed with 80% accuracy on untrained conditional discrimination trials while the other subject's performance was near baseline level. The authors concluded that training a two-choice simultaneous discrimination did not result in the development of stimulus classes.

In another study using only visual stimuli, stimulus class expansion occurred as a result of training sets of conditional relations and then testing for the additional equivalence relations made possible by that training (Lazar et al., 1984). Stimuli were line drawings of Greek and Hebrew letters in five sets, labelled A, B, C, D, and E. There were three letters in each set. Children aged 5-7 years were taught various conditional relations with match-to-sample procedures. Initially they learned the AD and DC relations; that is, stimuli from Set A were samples with Set D stimuli as correct comparisons, and then Set D stimuli served as samples on trials where correct comparisons were from Set C. On subsequent tests all subjects demonstrated AC and CA, transitive and symmetric relations that followed from the initial training. Three classes of equivalent stimuli were formed, each consisting of one element from each of the sets A, C, and D (e.g., A1C1D1, A2C2D2). Next subjects were taught the ED relation and tested for the transitive and symmetric relations AE, EA, EC, and CE that should have been established with the addition of the ED relation. All subjects' test performances demonstrated the emergence of those transitive and symmetric relations, which indicated that each of the previously established stimulus classes had been expanded by the addition of a Set E element. The next conditional relation trained was CB, followed by tests for the transitive and symmetric relations AB, BA, EB, BE, DB, and BD. These tests were performed successfully by two subjects immediately after CB training. Two other subjects eventually demonstrated that all of these equivalence relations had developed, but only after a series of further tests and retraining. By the end of the experiment three classes of equivalent stimuli had formed, each of which contained one element from each of the five original sets. Once the initial classes of three elements (ACD) were established, membership in the classes was expanded sequentially by linking one new stimulus to just one of the three existing class members, which in turn set up further class expansion by virtue of the transitive and symmetric relations made possible by adding that link. A phenomenon that had been suggested by earlier findings was demonstrated clearly in this study: equivalence relations formed in part during testing for those relations, despite the fact that they were not reinforced. The authors also conducted oral naming tests after tests for visual equivalences, and found that no subject assigned the same label to all the stimuli that had been demonstrated to be members of the same class. They concluded that oral naming is neither necessary nor sufficient for the formation of classes of equivalent stimuli (cf. Sidman et al., 1974; Sidman et al., 1985).

Other Equivalence Research

The experiments described thus far all involved one- or two-syllable auditory stimuli, two-dimensional visual stimuli, or both. Subjects were required to touch stimuli on panels or cards, or in some cases to produce oral names of stimuli. A few experiments expanded the original Sidman (1971) paradigm to include stimuli and subject responses that fit none of the above categories. These experiments are reviewed in this section.

VanBiervliet (1977) noted that nonverbal communication training with language-deficient individuals required establishing functional equivalence among several sets of dissimilar stimuli: manual signs, objects, and spoken words. He trained six mentally retarded subjects with limited speech using as stimuli five spoken nonsense words, five junk objects, and five nonsense manual signs. Stimulus sets were : A - spoken words; B - objects; C - manual signs; D - oral names. Subjects were trained via match-to-sample procedures on the relations AD (word-name), BB (object-object), CC (sign-sign), BC (object-sign), and AC (word-sign). They were then tested on the AB (word-object) and BA (object-word) relations, which constituted tests for transitivity and symmetry (Sidman et al., 1982; Sidman & Tailby, 1982). In addition, the first three sessions of CB (sign-object) and CA (sign-word) matching served as symmetry probes. All subjects performed AB, BA and CB tasks accurately, but they did not fare well on CA probes that required them to produce spoken words in response to manual signs.

An experiment by Gast et al., (1979) sought to establish equivalences among the four types of stimuli involved in numeral identification and counting: spoken numbers (A), printed numerals (B), printed number words (C), and sets of objects or events (D). In addition to touching or pointing to visual comparison stimuli on matching tasks, subjects were required to count objects (E) and produce oral names of stimuli (F). Three mentally retarded and four preschool nonretarded children entered the experiment with the following relations established: AB (spoken number-numeral), AE (spoken number-counting objects), BE (printed numeral-counting objects), BD (numeral-set), BF (numeral-oral name), and DE (set-counting). After training on the AC relation (matching printed number word to spoken number) with one set of three number words, subjects' performances on CE (printed number word-counting) and BC (numeral-printed number word) probe trials improved over baseline but only with the trained set of printed number words; there was no transfer to the three untrained printed words. Following training with the second set of printed words, performances on all probes improved to high levels of accuracy, and there was no difference in the performance of retarded and nonretarded subjects. This experiment provided evidence of the emergence of two untrained transitive relations, but none of the trained or derived relations were tested for symmetry, and it was necesary to train the AC relation using all members of the set of comparison stimuli (printed number words) before those stimuli were included in the derived matching relations.

McDonagh et al. (1984) extended the operant stimulus equivalence methodology to include matching relations involving 18 different visual stimuli representing all combinations of coins and printed prices equalling five, ten, and fifteen cents. They reasoned that if a subject learned to match a nickel to a five-cent printed price and to match five pennies to the same printed price, then the ability to match a nickel to five pennies should emerge, and a class of three stimuli should result. Similarly, subjects could learn to match printed prices 10c and 5c5c to a dime as well as to the coin combinations of two nickels and two groups of five pennies, and the analogous stimuli for 15c values, resulting in the emergence of all possible relations among coins and printed prices representing 10 cents or 15 cents. This reasoning was supported by the data. A mentally retarded woman who entered the experiment with only two of the possible relations (matching a nickel and dime with their corresponding printed prices) demonstrated all 54 relations and their symmetric cases among combinations of coins and prices after being trained on only six relations with dissimilar sets of coins and printed prices (e.g., printed price 5c with five pennies; two nickels with two groups of five pennies; etc.). The subject also named each printed price and the values of all coins and coin combinations after training, where prior to the experiment she could only name single printed prices (e.g., 5c, 10c, and 15c as opposed to 5c5c or 10c5c) and state the value of individual coins. Further verification that large stimulus classes developed as a result of training a few matching relations was obtained from the subject's performance on a series of constructed response tests, where she was shown a sample price, coin, or coin combination and allowed to select from a pool of coins and printed prices all stimuli that corresponded to the sample.

An experiment by Lazar (1977) further expanded the methodology for investigating the formation of equivalent stimulus classes. Three subjects were taught to touch two stimuli (A1A2) in a particular sequence regardless of spatial position; training was repeated with three other pairs of stimuli (B1B2, C1C2, D1D2). The subjects were tested next with pairs such as A1B2 and B1A2. Results indicated the existence of a class of "first" and a class of "second" stimuli. Next, match-to-sample training was instituted with new stimuli (E1 and E2 or F1 and F2) serving as comparisons for the stimuli from sequence training. Responses to E1 or F1 when the sample was "first" (A1 or C1) and to E2 or F2 when the sample was "second" (A2 or C2) were reinforced. Subjects were then tested on match-to-sample trials with the same E and F stimuli as comparisons for two sets of trained samples (A and C) and two sets of untrained samples (B and D). If a class of "first" stimuli had developed that included, for instance, A1 and B1 by virtue of the sequence training, and E1 and F1 were added to that class because they were the reinforced choices to the A1 sample, then by transitivity the E1 or F1 choice should have been selected in response to samples B1, C1 and D1. Sequence posttests with E and F stimuli evaluated whether classes of "first" and "second" stimuli were extended to include E and F stimuli as a result of the match-to-sample training. Results indicated that none of the subjects transferred match-to-sample performance from one trained set of stimuli to two untrained sets, and transfer occurred for only one subject after training on two of three stimulus sets. However, two of three subjects gave evidence of transfer of sequence class membership on the final sequence tests with stimuli that had been comparisons on match-to-sample trials.

In another extension of stimulus equivalence procedures, Mackay and Sidman (1984) added two new modes for training and demonstrating equivalence, anagram naming and written naming. One experiment with a severely retarded teenage boy used five, six-element stimulus sets: dictated color names (A); colors (B); printed color names (C); oral color names (D); and anagram color names (E). The subject could already match dictated color names to colors (AB) and name the colors (BD). He was trained, through a sequence of fading steps, to construct color words from movable letters in response to dictated color names (AE), which the authors called anagram naming. Testing demonstrated the emergence of all other relations that were not already developed or trained: BE, AC, BC, CB, and CD. In a second experiment, three retarded boys who could already match dictated color names to colors (AB) and name colors (BD) were trained to produce anagram names in response to a set of visual stimuli, the colors (BE). All three subjects demonstrated the untrained AC, BC, CB, and CD relations on tests. Finally, the authors devised a self-study program to teach a severely retarded boy to produce written number names in response to written numerals. The stimulus sets involved were: dictated number names (A); numbers (B); printed number names (C); oral number names (D); and written number names (E). The subject could copy the numbers 1-10, match dictated names to numbers (AB), and name numbers orally (BD). He was trained on BE relations, which was accomplished by presenting a numeral as sample and having the subject initially copy the printed numeral name. Letters in the printed names were faded gradually until the subject produced entire printed names. Testing demonstrated that the untrained relations AC, BC, CB, and CD developed, though not completely, from this training.

Contextual Control of Stimulus Equivalence

Most stimulus equivalence studies have demonstrated stimulus class formation after subjects have learned a series of conditional discriminations. An interesting and important question is whether class membership, once established, can itself be brought under conditional stimulus control. A study by Lazar and Kotlarchyk (in press) suggests that it can.

Children were taught conditional relations between four Greek letters in Set A and a red sample stimulus, and between four other Greek letters in Set B and a green sample stimulus. Equivalence tests demonstrated that two stimulus classes had formed, one consisting of the hue red and stimuli A1-A4, the other consisting of the hue green and stimuli B1-B4. A second-order sequence training procedure was then implemented that employed two tones and the red and green hues. When Tone 1 sounded, subjects were reinforced for touching red first and then green. In the presence of Tone 2, a sequence of touching green first and then red was reinforced. Sequence tests were conducted with both tones and the comparison stimuli from the original conditional discriminations, A1-A4 and B1-B4, to determine whether subjects would respond first to stimuli related to the red hue and then to stimuli matched to the green hue (e.g., A1-B1) in the presence of Tone 1 and in the opposite sequence (e.g., B1-A1) in the presence of Tone 2. Results demonstrated that subjects responded in the predicted sequences, even though the tones and Greek letters had never been presented together in training. Class membership was controlled not only by the originally trained conditional stimuli, but also by higher-order or contextual stimuli (Lazar & Kotlarchyk, in press).

Fucini (1983) conducted three experiments to examine conditional control of stimulus equivalence. In the first, five children and one adult were trained to select comparisons from each of two sets of Greek letters (designated B1 and B2 from Set B, X and C2 from Set C) in response to dictated Greek letter names, A1 and A2. They were also trained to select other Greek letters (D3 and X from Set D, F3 and F4 from Set F) given two different Greek letter names, E3 and E4. The result was the formation of two classes, A1B1X and E4D4X, with the common element X (Fucini called these intersecting classes), and two other classes, A2B2C2 and E3D3F3, that had no common element. Further testing with all combinations of the visual stimuli from both the ABC and the DEF groups demonstrated that the two intersecting classes had merged into one larger class of equivalent stimuli (e.g., A1B1E4F4X), while the classes without a common element did not merge. Although in training the stimulus X had appeared with one incorrect comparison when A1 was the sample, and with a different incorrect comparison when E4 was the sample, subjects apparently did not learn to discriminate those differences. They learned only that A1 and E4 were conditionally related to X and therefore related transitively to one another. The common stimulus was not treated selectively as a member of one class or the other depending upon the context, i.e., the sample and the incorrect comparison. A second experiment was conducted using a second-order conditional discrimination training procedure to teach four children to discriminate when the common element was to be selected in relation to the auditory samples A1 and E4. For example, a response to X was reinforced when A1 was the sample and stimulus O4 was the alternative comparison, but when A1 was the sample and stimulus M1 was the alternative comparison, responses to X were explicitly not reinforced. Similar rules applied when E4 was the sample. Following this training, three of the four subjects demonstrated selective stimulus equivalence on probe trials; that is, the two classes of stimuli that had the element X in common did not merge into one equivalence class. For the third experiment, four of the subjects from Experiment I who had demonstrated equivalence relations among all stimuli that had been related to the common stimulus X were given the second-order training used in Experiment II to see if the established equivalences between members of the intersecting classes could be broken down. Results indicated that equivalence deteriorated but did not break down completely for the three children; however, there was no evidence of deterioration for the adult subject. The author concluded that higher order conditional discriminations may change the boundaries of stimulus classes by modifying equivalences between elements of intersecting classes.

Summary

Operant analyses of stimulus equivalence using match-to-sample procedures have demonstrated the formation of sizeable classes of equivalent stimuli with minimal direct training. That is, when subjects have been trained to relate dissimilar stimuli to common stimuli, those stimuli have proven substitutable for one another as samples, comparisons, or both in conditional relations that were previously neither trained nor demonstrated by the subject. In most cases it has been necessary to establish only a small subset of all possible relations among various sets of stimuli to produce performance of all the remaining relations. Matching relations among a wide variety of stimuli have been demonstrated in this research. Untrained intramodal matching has been demonstrated with arbitrary visual stimuli (e.g., forms, figures, Greek letters) and visual stimuli that might be considered "natural" for humans, e.g., pictures, printed words, numerals, and objects. Visual stimuli used in these studies have included two-dimensional stimuli such as forms and printed letters and three-dimensional stimuli such as objects, coins, and manual signs. Auditory-visual equivalences that developed without direct training have included various combinations of the aforementioned visual stimuli matched with either arbitrary (e.g., nonsense syllables) or "natural" (e.g., English words) auditory stimuli.

Subjects have been required to demonstrate matching repertoires by: pointing to or touching visual stimuli; producing the oral, signed, or written name of a visually presented stimulus; counting a number of objects in response to a visual sample; and grouping visual stimuli that corresponded to a visual sample. Regardless of the nature of the stimuli employed or the response required of the subject, investigators from several different laboratories reached similar conclusions: large groups of initially unrelated stimuli have been made functionally equivalent as a result of relatively simple and expedient training procedures.

The practical significance of operant stimulus equivalence procedures was recognized almost immediately by Sidman and his associates (Sidman, 1971; Sidman & Cresson, 1973; Sidman et al., 1974) who pointed out their potential importance in teaching reading. Others (e.g., Gast et al., 1979; Mackay & Sidman, 1984; McDonagh et al., 1984; VanBiervliet, 1977) focused their research on such applied problems as teaching nonverbal communication, pre-arithmetic skills, and basic money management skills. As noted earlier, a number of writers also recognized that this approach held promise for answering difficult theoretical and practical questions about the complex behaviors involved in transfer, concept formation, and language (e.g., Dixon, 1978; Dixon & Spradlin, 1976; Sidman et al., 1974; Sidman et al., 1982; Sidman & Tailby, 1982; Spradlin & Dixon, 1976; Spradlin & VanBiervliet, 1980; Wetherby, 1983; Wetherby et al., 1983).

Spradlin and Dixon (1976) noted that it is not appropriate to treat all members of a class of stimuli as equivalent under all conditions. An important case in point is the observation that much of human language is arranged hierarchically, such that one stimulus or event is at one point characterized as belonging to a fairly constrained category (read: stimulus class), but at another point treated as a member of a broader category. To borrow an example from Wetherby (1983), a nickel could serve as a discriminative stimulus for the verbal responses, "nickel," "coin," or "money". The appropriate response is determined by the presence of one or more other contextual stimuli in addition to the nickel (Fucini, 1982; Sidman, in press; Wetherby, 1983; Wetherby et al., 1983).

GENERAL METHOD

Subjects

A total of twelve preschool children served as subjects. Eight attended the Child Development Lab School, College of Family Life, Utah State University. They were selected from the pool of children attending the lab school who were in the approximate age range 4 years to 5 years 6 months, could not read, and whose parents returned signed consent forms in response to a solicitation letter. One other subject was the child of personal friends of the investigator. Three subjects (ages 4 years 11 months, five years, and six years) participated because their parents responded to posters recruiting preschool children for the project that were placed in married students' housing facilities at Utah State University. The subjects' genders, chronological ages, and the experiment(s) in which they participated are listed in Table 1. Subjects were screened for participation in the study according to the pretest procedures described below. For subjects M.A., P.E., and A.M., English was a second language. Written parental consent for participation was obtained for every subject,

Table 1.

Subjects' Genders, Chronological Ages, and Experimental Assignments

Subject	Gender	Age(Yrs.-Mos.)	Experiment
L.L.	Female	4-2	I
H.N.	Male	3-11	I
F.N.	Male	5-2	II
M.D.	Male	4-11	I,III
B.S.	Male	4-11	II,III
A.A.	Female	4-5	I,III
B.B.	Male	4-10	II,III
J.C.	Male	4-11	I,III
T.B.	Male	4-10	II
M.A.	Female	6-0	IV
P.E.	Male	4-11	V
A.M.	Female	5-0	VI

and parents were apprised that they could withdraw their child from the study at any time.

Pretesting

All subjects were pretested on their abilities to sort, identify, and name stimuli used in the experiments. For the pretests, stimuli were presented on 4 in x 6 in cards. Three subtests were administered: a) In the sorting subtest, the prospective subject was given 18 cards in random order, on each of which was either: the color red, blue, green, or yellow (covering the entire surface of the card); a line drawing (black on white, 5 cm x 5 cm) of a circle, square, triangle, or cross; a printed word corresponding to each of the aforementioned colors and shapes; or the printed word "color" or "shape". The subject was instructed, "Put all the cards that belong together in three different piles." Three trials were allowed, and cards were shuffled between trials. If the subject did not sort the cards accurately on two of the three trials, the experimenter placed one card from each of the sorting categories (colors, shapes, words) in front of the subject, handed the remaining cards to the subject one at a time, and said "Where does this one go?" Criterion for passing was 100% correct sorting on two of three trials. b) For the identification subtest, stimuli were presented in five sets: colors, shapes, color instance words, shape instance words, and concept words. Each of the first four sets contained four stimuli, and the concept word set contained two stimuli (the words "color" and "shape"). The cards from one set were placed in random order before the subject, and the experimenter said, "Point to (show me) ____________" for each of the stimuli in the set. A trial was completed when all five sets had been presented. Three trials were allowed. The order in which sets were presented within and across trials and the order of stimulus presentation within sets were randomized. Passing criterion was correct identification of at least three of four stimuli in each of the first four sets and both concept words on two of three trials. c) A naming test was conducted by presenting the 18 stimulus cards to the subject one at a time and asking "What is this?". Three trials were conducted, with the order of stimulus presentation varied randomly from trial to trial and within trials. Criterion for passing was correct naming of at least 16 of 18 stimuli on two of three trials. Throughout pretesting there were no differential consequences for correct or incorrect responses, to preclude the development of relations among stimuli during this phase. The experimenter praised the subject for attending to task, trying hard, etc., and prospective subjects were given a small toy or sticker upon completion of the session.

Children who did not pass any pretests, or who passed only Pretest A, became eligible to serve as experimental subjects. Since a critical part of this research was establishing relations between printed words and other stimuli, it was necessary to select subjects for whom oral names for the printed words did not already exist. None of the 12 subjects listed in Table 1 passed subtest B or C. Their pretest results are summarized in Table 2. They varied in the extent to which they correctly sorted, identified, and named the stimuli to be used in the experiments. In general, the identification and naming tasks appeared to be easier for the subjects with the color stimuli, more difficult with the shapes, and most difficult when printed words were involved. Most importantly for purposes of this research, none of these subjects consistently identified or named the printed words.

Apparatus and Data Recording

All experimental tasks were nominally conditional discriminations that required subjects to select one of two comparison stimuli conditional upon either one or two preceding stimuli. Stimulus presentations were controlled

Table 2

Results for Two Trials of Each Pretest

PRETEST	SUBJECTS					
A. Sorting	L.L.	H.N.	F.N.	M.D.	B.S.	A.A.
Colors	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4
Shapes	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4
Words	10/10, 10/10	10/10, 10/10	10/10, 10/10	10/10, 10/10	10/10, 10/10	10/10, 10/10
	100%, 100%	100%, 100%	100%, 100%	100%, 100%	100%, 100%	100%, 100%
B. Identification						
Colors	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4
Shapes	4/4, 4/4	4/4, 4/4	3/4, 4/4	3/4, 3/4	2/4, 3/4	4/4, 4/4
Color Words	0/4, 0/4	1/4, 1/4	0/4, 1/4	0/4, 1/4	0/4, 0/4	1/4, 0/4
Shape Words	2/4, 0/4	1/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4
Concept Words	0/2, 0/2	0/2, 0/2	0/2, 1/2	0/2, 0/2	0/2, 0/2	0/2, 1/2
	56%, 44%	56%, 50%	39%, 56%	39%, 44%	33%, 39%	50%, 50%
C. Naming						
Colors	3/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4
Shapes	2/4, 3/4	2/4, 3/4	3/4, 3/4	3/4, 3/4	3/4, 3/4	3/4, 4/4
Color Words	0/4, 0/4	1/4, 1/4	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4
Shape Words	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4
Concept Words	0/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2
	28%, 39%	39%, 44%	39%, 39%	39%, 39%	39%, 39%	39%, 44%

(table continues)

PRETEST

	B.B.	J.C.	T.B.	M.A.	P.E.	A.M.
A. Sorting						
Colors	4/4, 4/4	2/4, 4/4	3/4, 4/4	4/4, 4/4	3/4, 4/4	4/4, 4/4
Shapes	4/4, 4/4	3/4, 4/4	4/4, 4/4	4/4, 4/4	3/4, 3/4	4/4, 4/4
Words	10/10, 10/10	3/10, 10/10	8/10, 10/10	10/10, 10/10	4/10, 6/10	10/10, 10/10
	100%, 100%	44%, 100%	83%, 100%	100%, 100%	56%, 72%	100%, 100%
B. Identification						
Colors	3/4, 3/4	4/4, 3/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 3/4
Shapes	4/4, 2/4	4/4, 4/4	3/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 2/4
Color Words	1/4, 1/4	0/4, 1/4	0/4, 0/4	2/4, 0/4	1/4, 1/4	1/4, 1/4
Shape Words	0/4, 2/4	1/4, 0/4	1/4, 0/4	0/4, 0/4	1/4, 0/4	0/4, 1/4
Concept Words	1/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2	1/2, 0/2	0/2, 0/2
	50%, 44%	50%, 44%	44%, 44%	56%, 44%	61%, 50%	50%, 39%
C. Naming						
Colors	3/4, 3/4	4/4, 3/4	4/4, 4/4	4/4, 4/4	4/4, 4/4	4/4, 4/4
Shapes	0/4, 0/4	4/4, 4/4	3/4, 3/4	3/4, 3/4	3/4, 3/4	2/4, 4/4
Color Words	0/4, 0/4	0/4, 0/4	0/4, 1/4	0/4, 0/4	0/4, 1/4	0/4, 0/4
Shape Words	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4	0/4, 0/4
Concept Words	0/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2	0/2, 0/2
	17%, 17%	44%, 39%	39%, 44%	39%, 39%	39%, 44%	33%, 44%

Note Number correct out of number of items is shown for each trial. Overall percentage correct for both trials of each student is shown within each subject's column.

by an Apple IIe microcomputer and BASIC programs, and were displayed on an Amdek high-resolution color monitor. Subjects viewed the stimuli through three or four plexiglas windows (depending on the experimental condition) inserted in a wood and aluminum panel placed directly in front of the monitor screen (see Figure 2). Each plexiglas window measured 5 cm x 5 cm. Windows were located as follows: The top edge of the first window was 9.5 cm below the top edge of the display panel, and its sides were inset 23 cm from the left and right sides of the panel. The second window was located 1.8 cm below the first in an identical alignment relative to the sides of the panel. The top edge of the third window was located 1.8 cm below the second, and its left edge was inset 19.5 cm from the left edge of the panel. The fourth window was 2.5 cm to the right of the third, with its right edge 19.5 cm from the right edge of the panel. A microswitch was mounted behind each window such that a press to the window closed the microswitch. Switch closures were detected by the input device of a Rayfield Equipment interface system (Rayfield, 1982; Rayfield & Carney, 1981) operated by the Apple IIe and were used by the BASIC program to make decisions regarding subsequent events in the experimental session. The BASIC program stored a numeric code for each event of interest in every session (onset of each stimulus, subject responses, trial

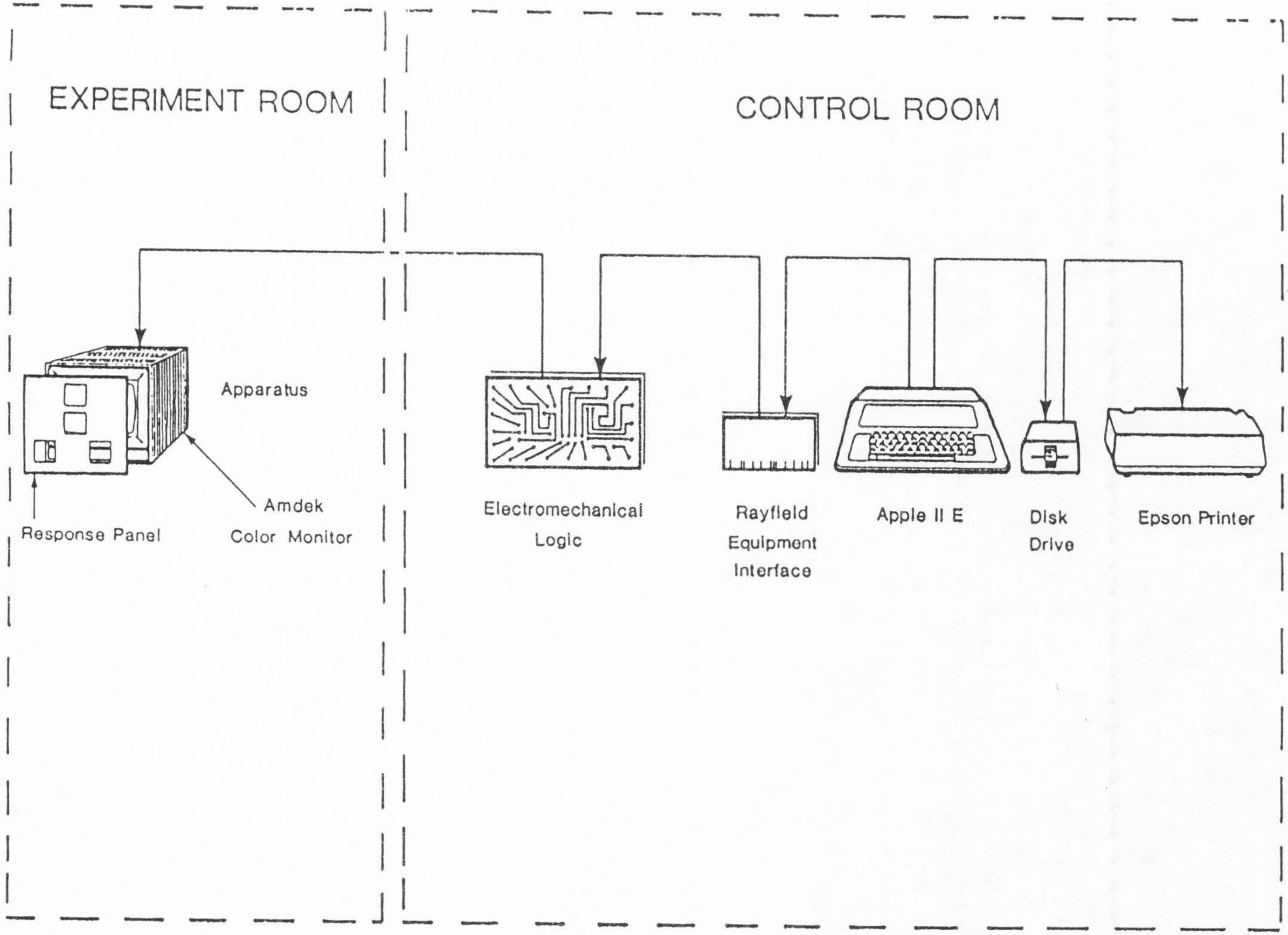

Figure 2. Experimental apparatus and control equipment.

type, stimulus type, consequences). At the end of each session all data were transferred from computer memory to floppy diskette for subsequent analysis.

Design

A probe design was used, with each subject responding to various stimulus configurations constituting a baseline of trained relations in which probes were inserted subsequently to assess the results of the preceding training. The training/testing cycle varied for each subject depending upon the experiment to which they were assigned and their performances, as described for each experiment in subsequent chapters.

General Experimental Procedures

This section describes procedures that applied to all experiments. Specific differences are noted in the descriptions of each experiment.

Setting

All experimental sessions were conducted in the Human Laboratory facilities of the Department of Psychology and the College of Family Life, Utah State University. The experimental room measured approximately 12 ft x 12 ft and contained an assortment of furniture and toys. Subjects were escorted individually to the experimental room by the investigator or a research assistant. The experimenter seated the child before the Amdek color monitor and response panel located on a low table. Sessions were monitored by the investigator and assistants from an adjacent control room, which contained the Apple IIe and a black-and-white monitor. The experimental room also had one-way windows to allow direct observation of subjects.

Training Procedures

All experimental tasks required the subject to press the plexiglas window in front of one of two comparison stimuli after having seen and responded similarly to one or two preceding stimuli, depending upon the condition. In some conditions the first stimulus was presented to the subject behind the topmost window on the response panel. A stimulus in this position was designated the superordinate stimulus (SS), except for Experiment IV-B in which it was designated ST1. A response to the SS was followed by onset of a stimulus behind the window immediately below the SS; that stimulus was designated the sample or standard (ST). Response to the ST resulted in simultaneous onset of two comparison (CO) stimuli behind the bottom two response windows while the SS and ST remained visible. One of the lower stimuli (S+) was designated the correct choice given the ST, the other

(S-) an incorrect choice, according to the programmed condition. For certain conditions no SS appeared; only a ST and two COs were presented.

Unless otherwise specified, all possible combinations of stimuli relevant to a condition were presented to subjects on an approximately equal number of trials and in random order during a condition or phase. That is, each stimulus appeared approximately the same number of times as SS (where applicable), ST, S+, and S-, and as a CO on the subject's left and right. The sequence of stimulus arrays presented in each session was randomized, and the left/right position of the S+ was randomized from trial to trial with the restriction that the S+ was not presented in the same position on more than three consecutive trials. Randomizations of stimulus selections, trial sequences, and S+ position were controlled by the BASIC program and the microcomputer.

During pretraining and training sessions, correct responses turned off the stimulus array and produced the sound of a chime (and, for some subjects, delivery of a token into a cup). These consequences are referred to as feedback for correct responses in subsequent discussions. The first stimulus for the next trial appeared 1.5 s later. Incorrect responses turned off the stimulus array, and 1.5 s later the first stimulus for the next trial appeared. Feedback followed every correct response in the initial phase of each training condition. When performance on a training condition reached a specified criterion (described below), the probability of feedback following correct responses was reduced in two steps from .60 to .20 in preparation for the insertion of unreinforced probe trials in a baseline of trained performances. Subjects selected colored stickers for completing each session. In some cases where a subject completed three consecutive training sessions with an accuracy score of no better than 60%, the subject was told that he or she would earn a token each time the chimes sounded, and if there were enough tokens earned by the end of the session, the subject could exchange them for a special sticker. The required number of tokens started at 20 (i.e., 67% correct in a 30-trial session), and the criterion shifted upward by two tokens per session when the preceding criterion was met, until performance met the criterion for changing conditions. The criterion was stated to the subject before the start of each session, and at the end of the session the experimenter and subject counted the tokens together. Tokens were exchanged for special stickers, i.e., some that appeared three-dimensional, depicted favorite cartoon characters, or were textured. If a subject failed to earn the required number of tokens, he or she still selected a more ordinary sticker for completing the session.

After the pretraining demonstrations and instructions (described below), the only verbal instructions given to subjects in training conditions were as follows: When chimes or chimes and token delivery followed every correct response, the subject was told, "It's time to play the game. Try to make the bell ring every time. Remember to use your pointing finger and only touch one picture at a time." For conditions where the probability of such consequences was reduced (including probe sessions) the instructions were modified to, "In this game the bell won't ring every time you get it right, but do your very best anyway."

For all pretraining and training phases, subjects had to demonstrate at least 90% correct matching performance in a session before proceeding to the next phase. When a subject successfully completed the prescribed sequence of training conditions for a particular experiment, baseline performance had to be maintained at 90% accuracy with the probability of feedback reduced; if it was not, the training sequence was repeated with that probability reset to 1.0, then gradually reduced to .20 until 90% accuracy was maintained.

Pretraining Procedures

All subjects underwent similar pretraining to familiarize them with the apparatus and with conditional discrimination tasks. The experimenter accompanied the subject into the experimental room and instructed the subject to watch while the experimenter "played a game." Five trials of three-key identity matching trials with nonexperimental hue stimuli were demonstrated, with the experimenter touching the ST window, then touching the correct CO. The subject was then seated in front of the response panel and instructed to try the game while the same five trials were repeated. If necessary the experimenter repeated the demonstration and allowed further practice until the subject selected the correct CO on five consecutive trials. Where appropriate to the experiment to which the subject was assigned, a similar demonstration was conducted with a four-key stimulus display, with stimuli presented in the SS, ST, and CO positions in sequence. The experimenter then instructed the subject to watch the windows and get ready to play more games, and left the room.

The next pretraining phases were designed to insure that subjects visually discriminated the experimental stimuli, performed identity matching, and responded to the three- or four-key displays in the correct sequence.

On all pretraining trials the SS (where applicable), ST, and correct CO stimuli were physically identical. Every correct response was followed by the sound of chimes. Subjects received at least one, 30-trial identity matching session with each of the following sets of stimuli: colors (red and blue); shapes (circle and triangle); printed color names (RED and BLUE); printed shape names (CIRCLE and TRIANGLE). If matching accuracy for any session with any set was less than 90%, sessions were repeated until the 90% criterion was met.

Probe Procedures

Certain phases of each experiment consisted of series of probe trials that tested for the presence of the specific relations between stimuli for the particular experiment. For conditions in which an SS had been involved in training, the four-key configuration was maintained on probe trials even though in some cases that meant that the SS and ST were identical. In probe conditions, a set of eight probe trials was interspersed randomly throughout a session consisting of a total of 30 trials. The remaining 22 trials were trained configurations; correct responses on these baseline trials were followed by chimes or chimes and a token with .20 probability. Where more than one probe configuration was presented, each configuration appeared an equal number of times in a session. All probe configurations appeared approximately an equal number of times in the SS, ST, S+, and S- positions over a full sequence of probe sessions. Responses on probe trials were never followed by feedback.

The number of probe sets given to each subject varied, depending in part upon time constraints and subject availability, but unless otherwise noted, each subject had at least one set (eight trials) of probes testing for the relations of interest at that phase in the experiment. If accuracy on any set of probes was out of the range of chance performance (0-1 or 7-8 correct) and time permitted, at least one additional set of the same probes was administered. Where possible, subjects received two or three sets of each type of probe. If baseline performance during a probe session fell below 90% accuracy, the preceding training condition generally was repeated until baseline performance recovered the 90% criterion, and then probes were readministered.

Binomial probabilities were used to define the range of chance performance on probes. In all cases (except on a few occasions when a program error cut a set of probes short by one trial), subjects received eight, 16, or 24 probes of a given type. The range of chance performance ($p > .05$) for each of those frequencies, with a .50

probability of success on any trial, was as follows: eight trials, 2-6 correct; 16 trials, 5-11 correct; 24 trials, 9-15 correct (Spurr & Bonini, 1967).

Although these probabilities define chance (and nonchance) responding statistically, accuracy on probe trials beyond the upper limits of chance may not be unequivocal evidence for the existence of controlling stimulus relations. There appears to be no consensus among stimulus equivalence researchers as to what constitutes acceptable test performance to support the inference that a subject has learned a symmetric or transitive relation. There is a tendency among some writers to set a stringent criterion (e.g., 22/24 correct, Lazar et al., 1984; 14/16 correct, Sidman et al., in press). For this research, only probe performances where the subject responded correctly on at least seven of eight trials (and multiples thereof, i.e., 14/16, 21/24) were taken as strong evidence for the presence of untrained conditional relations.

Experimental Sessions

Sessions consisted of 30 trials and lasted approximately 15 minutes each. They were conducted 3-5 days per week. For Experiments I, II, and III each subject completed one session per day in keeping with their preschool schedule. Subjects in Experiments IV, V, and VI generally completed two sessions per day, with a 15-minute play period between sessions. The number of sessions required to complete each condition varied unsystematically across subjects.

Stimuli

Stimuli used in Experiments I-V were selected from three sets (see Table 3): Set A (symbols) consisted of the colors red, blue, green, and yellow, and line drawings of a circle, triangle, square, and cross; Set B (printed instance words) consisted of printed word names for each of the first six elements of Set A; and Set C (printed concept words) had only two elements, the printed words COLOR and SHAPE. Four sets of stimuli were added for Experiment VI (see Table 4): Set D (dictated instance words) included dictated names corresponding to each of the first four symbols in Set A; Set E (named instance words) consisted of the same names produced orally by the subject; Set F (dictated concept words) consisted of the two concept words dictated by the experimenter; and Set G (named concept words) was made up of the subject's oral names for the concept words.

In discussions about the stimulus sets used in training and testing, individual stimuli are also referred to as _elements_ of a set. When results verify that three

Table 3.

Stimulus Sets, Experiments I-V

Set A: Symbols

A1: R	A5: G
A2: B	A6: Y
A3: ○	A7: □
A4: △	A8: +

Set B: Printed Instance Words

B1: RED

B2: BLUE

B3: CIRCLE

B4: TRIANGLE

B5: GREEN

B6: YELLOW

Set C: Printed Concept Words

C1: COLOR

C2: SHAPE

Notes. R = red, B = blue, G = green, Y = yellow (hues); ○ = circle, △ = triangle, □ = square, + = cross (line drawings). All other stimuli were printed words.

Table 4.

Stimulus Sets, Experiment VI

VISUAL STIMULI

Set A: Symbols

A1: R

A2: B

A3: ○

A4: △

A5: G

A6: Y

A7: □

A8: +

Set B: Printed Instance Words

B1: RED

B2: BLUE

B3: CIRCLE

B4: TRIANGLE

Set C: Printed Concept Words

C1: COLOR

C2: SHAPE

AUDITORY STIMULI

Set D: Dictated Instance Words

D1: "RED"

D2: "BLUE"

D3: "CIRCLE"

D4: "TRIANGLE"

Set E: Named Instance Words

E1: "red"

E2: "blue"

E3: "circle"

E4: "triangle"

Set F: Dictated Concept Words

F1: "COLOR"

F2: "SHAPE"

Set G: Named Concept Words

G1: "color"

G2: "shape"

Notes. R = red, B = blue, G = green, Y = yellow (hues); ○ = circle, △ = triangle, □ = square, + = cross (line drawings).

or more stimuli constitute a stimulus class, individual stimuli are referred to as <u>members</u> of a class. The following conventions are used when referring to elements of each of the stimulus sets in this narrative: symbols from Set A are written with lower case letters (e.g., red, triangle). Printed instance words from Sets B and C are all upper case letters (e.g., BLUE, SHAPE). Dictated words from Sets D and F are written with uppercase letters in quotation marks (e.g., "CIRCLE", "COLOR"). Oral names produced by a subject (Sets E and G) are written with lower case letters in quotation marks (e.g., "red", "shape")

EXPERIMENT I

The purpose of this experiment was to determine whether preschool children would relate explicit contextual stimuli to other physically identical stimuli that were related conditionally in their presence.

Method

Subjects

Subjects L.L., H.N., M.D., A.A., and J.C. participated in this experiment. The first two served as pilot subjects who tested the apparatus and the efficacy of the general procedures. Their results will be treated separately from those of the other three subjects.

Training and Probe Procedures

Stimuli selected from Sets A (symbols) and B (printed instance words) were used in this experiment (see Table 3). The conditional relations involved in each task and corresponding stimulus arrays are presented in Table 5. In pretraining, the SS, ST, and S+ were all physically

Table 5

Stimulus Configurations, Experiment I

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
PRETRAINING: AA,BB				
A1A1	R	R	R	B
A2A2	B	B	B	R
A3A3	○	○	○	△
A4A4	△	△	△	○
B1B1	RED	RED	RED	BLUE
B2B2	B	BLUE	B	RED
B3B3	CIRCLE	CIRCLE	CIRCLE	TRIANGLE
B4B4	TRIANGLE	TRIANGLE	TRIANGLE	CIRCLE
Mixed AA,BB	Random mixture of above configurations			
TRAINING: AA with B				
A1A1 with B1	RED	R	R	B
A2A2 with B2	BLUE	B	B	R
A3A3 with B4	CIRCLE	○	○	△
A4A4 with B4	TRIANGLE	△	△	○
Mixed AA with B	Random mixture of above configurations			
PROBES: AB/BA				
A1B1	R	R	RED	BLUE
B1A1	RED	RED	R	B
A2B2	B	B	BLUE	RED
B2A2	BLUE	BLUE	B	R
A3B3	○	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	CIRCLE	○	△
A4B4	△	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	TRIANGLE	△	○

Note. R=red, B=blue (hues); ○=circle, △ = triangle (line drawings). All other stimuli were printed words. The letters A and B denote stimulus sets (see Table 3) and numbers specify elements within sets.

identical while the S- was the nonidentical element representing the same concept (color or shape) as the S+. On training trials, the stimulus configurations were the same as in pretraining with the exception that the SS was the Set B element corresponding to the ST. That is, in training an identity match was reinforced after the subject first responded to a printed instance word. This type of training is referred to as "AA with B" in Table 5 and subsequently.

Probes assessed the presence of conditional and symmetric relations between Set A (symbols) and Set B (printed instance words) stimuli. On some probe trials, identical Set A stimuli appeared in the SS and ST positions; comparisons were Set B elements representing the same concept (color or shape) as the SS and ST. An equal number of probe trials per session had identical Set B elements in the SS and ST positions and Set A elements as comparisons (refer to Table 5).

Table 6 describes the sequence of pretraining, training, and probe conditions, and stimulus relations involved in each condition, for each subject. As this table indicates, L.L. and H.N. as pilot subjects proceeded through a sequence of pretraining, training, and probes. These two subjects were run concurrently. Subjects M.D., A.A., and J.C. were run in slightly different sequences based in part upon the pilot results.

Table 6

Sequence of Conditions for Subjects in Experiment I

L.L.

1. Pretraining: AA,BB
2. Training: AA with B
3. Probes: AB/BA

H.N.

1. Pretraining: AA,BB
2. Training: AA with B
3. Probes: AB/BA

M.D.

1. Pretraining: AA,BB
2. Probes: AB/BA
3. Training: AA with B
4. Probes: AB/BA

A.A.

1. Pretraining: AA,BB
2. Probes: AB/BA
3. Training: AA with B
4. Probes: AB/BA
5. Review: AA with B
6. Probes: AB/BA
7. Training: AA with B, zero delay
8. Probes: AB/BA

J.C.

1. Pretraining: AA,BB
2. Probes: AB/BA
3. Training: AA with B
4. Probes: AB/BA
5. Review: AA with B
6. Probes: AB/BA
7. Training: AA with B, zero delay
8. Probes: AB/BA

All three of these subjects received two sets of each type of AB/BA probe immediately following pretraining and prior to any training conditions, then completed training. After the first phase of post-training probes, all three of these subjects reviewed the training (AA with B) followed by another probe phase. Subjects A.A. and J.C. then completed several training sessions in which the matching procedure was changed to zero-delay: a response to the SS was followed by onset of the ST as usual, but a response to the ST resulted in its offset, leaving only the ST present when a comparison was selected. Probes were repeated following the zero-delay training.

Results

Subjects L.L. and H.N.

Pretraining

Both subjects performed color and shape identity matching with at least 90% accuracy, and H.N. did equally well when the task was to match identical Set B printed words. However, L.L.'s performance in sessions that required identity matching with only two printed color words was only 80% accurate for three sessions and fell to 69% in the fourth session. She was then given a session of 30 trials that included 10 color word identity matching trials with 10 trials each of the color and shape identity matching tasks, and matched color words correctly on all 10 trials. A similar session followed in which 10 shape word identity matching trials were substituted for the 10 color word identity matching trials, and she responded correctly on nine trials.

Training: AA with B

Following successful performance of all pretraining tasks, both subjects completed training sessions where AA (identity) matching responses were reinforced in the presence of corresponding Set B stimuli. In the first such session only two colors were presented, A1 and A2 (red and blue). Performance was 100% and 98% correct for L.L. and H.N. respectively. Subject L.L.'s second training session mixed A1-A4 and B1-B4; her performance in that session was 90% accurate, and in a session where the probability that chimes would be presented following correct responses was reduced to .60, she responded correctly on 93% of the trials. Subject H.N.'s next session involved just the two shapes, A3 and A4 (circle and triangle) and their corresponding Set B printed names in the SS position. When that session was completed with 98% accuracy, H.N. received a session that mixed A1-A4 and B1-B4 with chimes occurring after every correct response, and an identical session with the probability of chimes following correct responses reduced to .60.

Probes: AB/BA

Probes were administered in two sets, one set consisting of two configurations each of A1B1, B1A1, A2B2, and B2A2 (i.e., colors and color instance words) and a second set of the analogous configurations with A3, A4, B3, and B4 (i.e., shapes and shape instance words). Results for these two subjects are presented in the third and fourth columns of Table 7. Subject L.L.'s performance on the first set of probes suggested the existence of AB/BA relations, but she refused to attempt a second probe session. Her results were insufficient for concluding that all AB/BA relations had developed, but since she was a pilot subject, replicating the procedures with other subjects seemed warranted. Subject H.N.'s performances were at chance levels (Table 7). Baseline accuracy in sessions that included probes was 96% for L.L. but fell to 80% and 88% for H.N. Neither subject was available for further testing or training.

Subjects M.D., A.A., and J.C.

Pretraining

Pretraining results from the first two subjects suggested that it was possible to present mixed color, shape, and printed word identity matching trials in one

Table 7

Performances of Experiment I Subjects on Probes for Conditional Relations Between Set A and Set B Stimuli

		Results by Subject				
Condition	Relations	L.L.	H.N.	M.D.	A.A.	J.C.
Pre-training	A1B1/B1A1 A2B2/B2A2			9/16	5/16	10/16
	A3B3/B3A3 A4B4/B4A4			11/16	7/16	11/16
Post-training	A1B1/B1A1 A2B2/B2A2	7/8	4/8	6/16	3/8	4/8
	A3B3/B3A3 A4B4/B4A4		3/8	13/24	5/8	4/8
Post-review	A1B1/B1A1 A2B2/B2A2				18/24	15/24
	A3B3/B3A3 A4B4/B4A4				14/24	7/16
Post-zero delay training	A1B1/B1A1 A2B2/B2A2				3/8	7/16
	A3B3/B3A3 A4B4/B4A4				4/8	4/8

Note: Numbers in the body of the table represent number correct per number of opportunities to demonstrate each set of relations.

session rather than single sessions consisting entirely of one type of trial, without adversely affecting performance. For these three subjects, therefore, pretraining sessions consisted of 10 trials each of color, shape, and either printed color word or printed shape word identity matching, and accuracy on each trial type was recorded. Subjects A.A. and J.C. required only one or two sessions to demonstrate better than 90% accuracy on all three types of trials. Subject M.D. matched colors and shapes with better than 90% accuracy but had difficulty matching printed words. Three sessions with printed color words and two sessions with printed shape words were required to bring his performance on those two trial types up to the 90% criterion.

Probes: AB/BA

To determine whether there were preexisting relations between Set A and Set B elements, two sets of each type of probe described above were administered before training began. Results are summarized in Table 7. These three subjects' performances on the pretraining probes were within chance limits.

Training: AA with B

Training sessions for M.D., A.A., and J.C. consisted of approximately equal numbers of A1A1, A2A2, A3A3, and

A4A4 configurations with the corresponding Set B elements in the SS position. Each subject completed two such sessions with chimes presented after every correct response, and performances were uniformly at least 97% accurate. When the probability of chimes following correct responses was reduced to .60, performance remained at 97% correct for M.D. and A.A. and 93% for J.C. At .20 probability of chimes after correct responses, performances were 97%, 97%, and 90% for M.D., A.A., and J.C., respectively.

Probes: AB/BA

As shown in Table 7, M.D.'s performance on both types of AB/BA probes was within chance limits. Subjects A.A. and J.C. completed only one set of each type of probe before a school vacation period intervened; their performances were also at chance levels (Table 7, post-training).

Review and Probes: AB/BA

After a break of a few days, A.A. and J.C. were available for additional sessions. Each of them had two training review sessions (i.e., AA matching with SSs from Set B), one at .60 and one at .20 probability of chimes following correct responses. Both subjects' identity matching performances remained at least 90% correct for those two sessions. When probes were repeated, both A.A.

and J.C. responded correctly on more probe trials with colors and color words than with shapes and shape words, but only A.A.'s accuracy on color probes was above chance (see Table 7, post-review). It did not appear that subjects had learned to relate printed words from Set B to the Set A stimuli with which they had been presented in close physical and temporal contiguity over many trials.

Training: AA with B, Zero Delay

One possible reason for the subjects' failure to relate printed words that were in the SS position to stimuli that were in the ST position is that the SS was not necessary for solving the problem; the subject merely had to observe a color or shape ST and select the physically identical CO. A zero-delay training procedure was introduced to test the possibility that if the printed word SS remained on but the ST was not visible when a choice was made, subjects might refer to the SS and learn to relate it to the CO that was reinforced as a correct choice in its presence. In this procedure, trials began as usual with onset of the SS, which was always a Set B (printed instance word) element. A response to the SS was followed by onset of the ST, a Set A element (symbol), but a response to the ST resulted in its offset and simultaneous onset of the two comparison stimuli. That is, training trial configurations were exactly as described in Table 5, except that when a choice was made the SS but not the ST was visible to the subject. Subjects A.A. and J.C. received two, 30-trial sessions of zero-delay training, and accuracy for both subjects in both sessions was at least 90%.

Probes: AB/BA

Results of these probes are shown in the lower right of Table 7. Time constraints did not permit more extensive testing, but it appeared that neither subject's performance improved as a result of the additional training described above; in fact, A.A.'s deteriorated slightly.

Discussion

None of three preschool children in the extended experiment demonstrated conditional and symmetric relations between stimuli that were paired but not otherwise explicitly related in repeated presentations. One of two pilot subjects provided some evidence that such relations were learned. Even though a printed word was the first stimulus seen and responded to by the subject on each trial, and only one printed word was presented with each stimulus that subsequently appeared as ST, the task was simply matching on the basis of physical identity. Mere contiguity between Set A and Set B elements was not sufficient to establish conditional relations between them for most subjects. The subjects' propensity to perform identity matching with colors and shapes, as demonstrated in pretesting and pretraining, may have precluded the development of other stimulus relations while those identity relations continued to be reinforced. In retrospect, however, the tasks did not involve the printed words in any contingent relations with the remaining stimuli; thus it might not have been expected that such indirect training would establish stimulus control by the printed words.

EXPERIMENT II

Experiment II, which was run concurrently with Experiment I, was designed to determine if preschool children would relate contextual stimuli (in the form of printed words) to stimuli that were related either arbitrarily or on the basis of physical identity in the presence of the contextual stimuli.

Method

Subjects

Subject F.N. was a pilot subject for this experiment, and his results are presented as pilot data. Three other subjects participated in the extended experiment: B.S., B.B., and T.B. Subjects B.S. and B.B. underwent similar training and testing and their results were comparable, so they are treated together in this section. Procedures and results for T.B. differed slightly from those for B.S. and B.B., and are presented separately here.

Training and Probe Procedures

Stimuli used in this experiment came from Sets A (symbols), B (printed instance words), and C (printed concept words). The conditional relations trained or tested in each condition and corresponding stimulus configurations are presented in Table 8. Pretraining tasks were exactly as described for Experiment I, i.e., identity matching of colors, shapes, and printed instance words. In training sessions, one-half of the trials were identical to configurations used in Experiment I: the ST and S+ were physically identical, the S- was the nonidentical element representing the same concept as the S+, and the SS or contextual stimulus was the Set B printed word corresponding to the ST. On the other half of the trials in these training sessions, the SS was always the printed concept word COLOR or SHAPE. When the SS was the word COLOR (C1), the ST was either A1 or A2 (the color red or blue), the S+ was either A2 or A1, and the S- was A3 or A4 (circle or triangle). When the SS was the word SHAPE (C2), the ST was A3 or A4 (circle or triangle), the S+ was A4 or A3, and the S- was A1 or A2. In other words, when the SS was COLOR, a response to the colors red and blue as ST or S+ was reinforced; when the SS was SHAPE, a response that related the line drawings of the circle and triangle was correct. The combinations

Table 8

Stimulus Configurations, Experiment II

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
TRAINING: AA with B				
AA with C				
A1A1 with B1	RED	R	R	B
A2A2 with B2	BLUE	B	B	R
A3A3 with B3	CIRCLE	○	○	△
A4A4 with B4	TRIANGLE	△	△	○
A1A2 with C1	COLOR	R	B	○ or △
A2A1 with C1	COLOR	B	R	○ or △
A3A4 with C2	SHAPE	○	△	R or B
A4A3 with C2	SHAPE	△	○	R or B
Mixed AA with B and AA with C	Random mixture of above configurations			
PROBES:				
AC/CA				
A1C1	R	R	COLOR	SHAPE
C1A1	COLOR	COLOR	R	○ or △
A2C1	B	B	COLOR	SHAPE
C1A2	COLOR	COLOR	B	○ or △
A3C2	○	○	SHAPE	COLOR
C2A3	SHAPE	SHAPE	○	R or B
A4C2	△	△	SHAPE	COLOR
C2A4	SHAPE	SHAPE	△	R or B

(table continues)

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
AB/BA				
A1B1	R	R	RED	BLUE
B1A1	RED	RED	R	B
A2B2	B	B	BLUE	RED
B2A2	BLUE	BLUE	B	R
A3B3	○	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	CIRCLE	○	△
A4B4	△	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	TRIANGLE	△	○

Note: B=blue (hues); ○=circle, △=triangle (line drawings). All other stimuli were printed words. The letters A,B, and C denote stimulus sets (see Table 3) and numbers specify elements within sets.

of training trials just described are referred to as "mixed AA with B and AA with C" in Table 8 and in tables that follow.

Once subjects maintained trained performances at 90% accuracy or better with the probability of chimes or chimes and token presentation following correct responses reduced to .20, probe trials were inserted to test for the presence of conditional and symmetric relations between Set A and Set C stimuli, and between Set A and Set B stimuli. One subject (T.B.) received an additional set of probes to test for possible transitive relations between Set B and Set C stimuli.

The sequence of conditions for each subject is listed in Table 9. Pilot subject F.N. received two sets of AC/CA probes after completing training successfully, then two training review sessions and two more sets of the same probes. Subjects B.S., B.B., and T.B. all completed AC/CA and BC/CB probes prior to beginning training, and probes following training. Based on their performances on the first set of post-training probes, B.S. and B.B. then received two training review sessions, with more AC/CA probes inserted between review sessions and AB/BA probes following the final review session. The sequence for T.B. varied slightly: after training he had varying numbers of probe sessions for all three sets of relations, at which point he left the preschool and was

Table 9

Sequence of Conditions for Subjects in Experiment II

F.N.	B.S.	B.B.	T.B.
1. Pretraining: AA, BB	1. Pretraining: AA, BB	1. Pretraining: AA,BB	1. Pretraining: AA, BB
2. Training: AA with B, AA with C	2. Probes: AC/CA	2. Probes: AC/CA	2. Probes: AC/CA
3. Probes: AC/CA	3. Probes: BC/CB	3. Probes: BC/CB	3. Probes: BC/CB
4. Review: AA with B, AA with C	4. Training: AA with B, AA with C	4. Training: AA with B, AA with C	4. Training: AA with B, AA with C
5. Probes: AC/CA	5. Probes: AC/CA	5. Probes: AC/CA	5. Probes: AC/CA
	6. Review I: AA with B, AA with C	6. Review I: AA with B, AA with C	6. Probes: BC/CB
	7. Probes: AC/CA	7. Probes: AC/CA	7. Probes: AB/BA
	8. Review II: AA with B, AA with C	8. Review II: AA with B, AA with C	
	9. Probes: AB/BA	9. Probes: AB/BA	

no longer available as a subject.

Results

Subject F.N.

Pretraining

Subject F.N.'s identity matching performance with colors, shapes, and printed words was 100% correct for two sessions.

Training: AA with B, AA with C

This subject's performance on training tasks was 100% accurate in the first session and remained so through one additional session with chimes following every correct response, one session at .60 probability of chimes following correct responses, and one session at .20 probability.

Probes: AC/CA

Probe results are summarized in Table 10. Following training, F.N. correctly related stimuli from Set A to stimuli from Set C on a total of seven of 16 probes, which was within chance limits. Baseline performances remained 100% accurate.

Review

Two training review sessions were conducted, one

Table 10

Performances of Experiment II Subjects on Probes for Conditional Relations Between Set A, Set B, and Set C Stimuli

		Results by Subject			
Condition	Relations	F.N.	B.S.	B.B.	T.B.
	AC/CA				
Pre-training	A1C1/C1A1 A2C1/C1A2		9/16	7/16	4/16
	A3C2/C2A3 A4C2/C2A4		6/16	5/16	12/16
	BC/CB				
	B1C1/C1B1 B2C1/C1B2		1/8	1/8	4/8
	B3C2/C2B3 B4C2/C2B4		4/8	2/8	4/8
	AC/CA				
Post-training	A1C1/C1A1 A2C1/C1A2	5/8	3/8	4/8	14/16
	A3C2/C2A3 A4C2/C2A4	2/8	4/8	4/8	14/16
	BC/CB				
	B1C1/C1B1 B2C1/C1B2				10/24
	B3C2/C2B3 B4C2/C2B4				12/24

(table continues)

Condition	Relations	F.N.	B.S.	B.B.	T.B.
	AC/CA				
Pre-training	A1C1/C1A1		9/16	7/16	4/16
	A2C1/C1A2				
	A3C2/C2A3		6/16	5/16	12/16
	A4C2/C2A4				
	BC/CB				
	B1C1/C1B1		1/8	1/8	4/8
	B2C1/C1B2				
	B3C2/C2B3		4/8	2/8	4/8
	B4C2/C2B4				
	AC/CA				
Post-training	A1C1/C1A1	5/8	3/8	4/8	14/16
	A2C1/C1A2				
	A3C2/C2A3	2/8	4/8	4/8	14/16
	A4C2/C2A4				
	BC/CB				
	B1C1/C1B1				10/24
	B2C1/C1B2				

Results by Subject: F.N., B.S., B.B., T.B.

(table continues)

Condition	Relations	Results by Subject F.N.	B.S.	B.B.	T.B.
	AB/BA				
	A1B1/B1A1				2/8
	A2B2/B2A2				
	A3B3/B3A3				4/8
	A4B4/B4A4				
	AC/CA				
Post-review I	A1C1/C1A1	2/8	12/16	2/8	
	A2C1/C1A2				
	A3C2/C2A3	1/8		4/8	
	A4C2/C2A4				
	AB/BA				
Post-review II	A1B1/B1A1		14/24	7/16	
	A2B2/B2A2				
	A3B3/B3A3		7/16	9/16	
	A4B4/B4A4				

Note. Numbers in the body of the table represent number correct per number of opportunities to demonstrate each set of relations.

with .60 probability of chimes occurring after correct responses, and one with .20 probability of such feedback. The subject's performances were 97% and 100% accurate.

Probes: AC/CA

After review, F.N. related stimuli A1 and A2 to C1 (COLOR) on only two probe trials, and related A3 and A4 to C2 (SHAPE) on just one of eight probe trials (post-review I, Table 10). These below-chance accuracy levels suggested that this subject might have been relating stimuli on some systematic basis other than that expected from the training. An additional probe session was conducted in which the experimenter sat beside the subject and on each probe trial, before the subject responded to a CO, asked "Which one (indicating the COs) are you going to pick?" When the subject responded the experimenter asked "Why?" and recorded the subject's reply. During this probe/debriefing session, when the SS and ST were the word SHAPE the subject consistently selected A1 or A2 (a color) rather than A3 or A4 (a shape), and when the SS and ST were A1 or A2 the CO selected was the word SHAPE rather than the word COLOR. The subject's answers to questions about his choices indicated that he labelled the colors as "square" (the response windows through which stimuli were viewed were square in shape), he recognized the letter "S" in SHAPE, and since he knew that "square" started with "S" he selected the colored squares in response to the sample SHAPE and vice versa.

Subjects B.S. and B.B

Pretraining

Neither subject had any difficulty performing identity matching tasks with colors and shapes, but B.S. required five sessions of pretraining before he matched printed words with at least 90% accuracy for two consecutive sessions. For B.B., performance on trials where the task was to match identical printed words was only 54% correct in the first session but rose to 100% for the second and third sessions.

Probes: AC/CA, BC/CB

All probe data are summarized in Table 10. Prior to training, performances on AC/CA probes were within chance limits for both of these subjects. On BC/CB probes with color words (RED, BLUE, COLOR), however, performances for both were below chance. Examination of their responses on those probe trials revealed that errors were evenly distributed among the possible incorrect COs; no patterns that might have indicated a particular source of systematic stimulus control were readily apparent.

Training: AA with B, AA with C

Subject B.S. required seven sessions with chimes occurring after each correct choice to establish and maintain at least 90% accuracy on training trials. In the session that was to have been his first with chimes presentation reduced to .60 probability, an equipment failure resulted in his completing the session with no feedback for correct responses; his accuracy dropped to 70% for that session. Another session with the probability of chimes following correct responses set at .60 was run immediately, and his performance improved to 97% accurate. Accuracy was maintained at 93% when feedback probability was dropped to .20 for one session prior to the insertion of probes. Subject B.B.'s accuracy on training trials was 100% for two sessions with chimes following every correct response and one session in which feedback probability was .60. It dropped only slightly (to 97%) when the feedback probability was reduced to .20.

Probes: AC/CA

Both subjects received one set of each type of AC/CA probe, i.e., colors and shapes with the printed concept words COLOR and SHAPE, following training. For both subjects, these performances were at chance levels (see Table 10, post-training). Baseline performances remained above the 90% accuracy level during all probe sessions.

Review I

Both subjects next received two training review sessions, one with .60 probability of chimes following correct responses and one with .20 feedback probability. Performances for both subjects in both review conditions were at least 90% correct.

Probes: AC/CA

Because of experimenter error, B.S. had two probe sessions with A1 or A2 and C1 probe trial configurations (colors) and none with A3 or A4 and C2 (shapes). He related the stimuli correctly on 12 of 16 probe trials, which was just above chance (the chance range was 5-11 correct). Subject B.B. had one session with each type of probe configuration; his performances were at chance accuracy levels (post-review I, Table 10).

Review II

Following a school vacation, both subjects received two training review sessions, one with chimes feedback for each correct response and one with feedback probability set at .20. All performances were better than 90% accurate.

Probes: AB/BA

To complete the testing for all relations that could have developed from the training these subjects received, probes identical to Experiment I probes were presented, i.e., tests for relations between A1 and B1, A2 and B2, A3 and B3, A4 and B4. Subject B.S. related the colors to their corresponding printed instance words on six of eight trials in the second probe session, so a third set of the same probes was administered. However, overall none of the probe performances for either subject were out of the range of chance (post-review II, Table 10).

Subject T.B.

Pretraining

This subject's performance on the pretraining identity matching tasks was 100% accurate with colors, shapes, and printed instance words for two sessions.

Probes: AC/CA and BC/CB

On probes for existing relations between stimuli from Sets A and C, and Sets B and C, T.B.'s performances were near chance (see Table 10).

Training

Subject T.B.'s first training session with chimes presented following each correct response was 100% accurate, but performance dropped to 87% in the next session so a third session was conducted. His performance returned to 100% accuracy. At .60 probability of feedback for correct responses, he maintained 97% accuracy, and at .20 it was still 93% so he proceeded to the probe conditions.

Probes: AC/CA

As indicated in Table 10 (post-training), T.B. correctly related the color symbols, A1 and A2, to the printed concept word COLOR (C1) and the shape symbols, A3 and A4, to the printed concept word SHAPE (C2) on most of these probe trials. His score on the second type of probes (A3, A4, and C2) was only slightly higher than his pre-training score on the same probes (14/16 vs 12/16), but met the criterion for demonstrating established AC/CA relations.

Probes: BC/CB

Next T.B. had three probe sessions testing for possible B1C1/C1B1 and B2C1/C1B2 relations, and three sessions testing for B3C2/C2B3 and B4C2/C2B4 relations. Such relations between the two sets of printed words (instance words and concept words) would have been both transitive and symmetric. However, T.B.'s performances on these probes were at chance levels (Table 10).

Probes: AB/BA

Existence of the BC/CB relations could have been made possible only by the prior existence of the AC/CA relations, which were demonstrated on the first set of post-training probes, and the AB/BA relations. The AB/BA relations thus were tested next. Time constraints allowed only one set of each type of AB/BA probe (colors and printed color instance words, shapes and printed shape instance words). In both sets, accuracy was within chance limits.

Discussion

One subject (T.B.) related printed concept words from Set C to the correct symbols from Set A following training where half of the trials began with stimulus C1 or C2 in the SS position and were completed correctly when an arbitrary match was made between two stimuli from the concept named by the SS. However, some of those relations (A3C2/C2A3, A4C2/C2A4) may have been present, though incompletely, prior to training (see Table 10). This subject did not relate Set B and Set A stimuli that had been presented in SS and ST positions for half of the training trials. Consequently he did not demonstrate the transitive BC/CB relations that should have emerged if both AB/BA and AC/CA relations had been learned. None of the other three subjects demonstrated that either AB/BA or AC/CA relations developed as a result of training.

The fact that T.B. demonstrated the AC/CA relations but not the AB/BA relations suggested that differences in the training trials could account for the differential stimulus control that developed. Trials that presented Set A and Set C stimuli together required the subject to make an arbitrary match between nonidentical Set A elements; the S- was always another Set A element but from a different dimension (color or shape) than the ST and S+. When Set A and Set B stimuli were presented in the same configuration, the task for the subject was to match identical Set A elements when the S- was another Set A element, but from the <u>same</u> dimension as the ST and S+. If these factors were important, they did not differentially affect the performances of B.S. and B.B., who performed equally poorly on tests for AB/BA and AC/CA relations, even after extensive training and review. Subject F.N. was not tested for AB/BA relations, but on tests for AC/CA relations he exhibited control by unintended features of the stimuli apparently based on preexperimental learning.

EXPERIMENT III

In the first two experiments, preschool children generally failed to match printed words to symbols following training sessions in which a word served to start each trial, and a response to the word was followed immediately by onset of one of the symbol stimuli, but the words and symbols were not otherwise explicitly related. Other stimulus equivalence studies (e.g., Sidman, 1971) have demonstrated that relations between printed words and symbols can be trained with match-to-sample procedures, and that two stimuli that have been related to a common third stimulus in training are then related transitively to one another. In most of the existing research, however, each stimulus used in training was related to only one element of any other set of stimuli (but see Dixon, 1978; Fucini, 1983). For example, relations between A1 and B1 and between A1 and C1 might have been trained, establishing the logical possibility for a transitive relation between B1 and C1. Stimulus A1, though related to two different stimuli, was not related to more than one other stimulus <u>in the same</u>

set (e.g., A1B2 was not trained). In the present experiment, one-to-one relations were trained between Set A elements (symbols) and Set B elements (printed instance words), but each of the two elements in Set C (printed concept words) were related to two Set A elements. Trained and potential transitive relations between color and shape stimuli are diagrammed in the upper and lower panels of Figure 3, respectively. The transitive relations between Set B and Set C stimuli made possible by such training were unique in two ways: two elements of Set B could be related transitively to each element of Set C; and the transitive relations, if they developed, would involve nonidentical printed words. No other stimulus equivalence research has examined such cases with purely visual stimuli (but see Dixon, 1978; Fucini, 1983). It was the purpose of Experiment III to do so.

Method

Subjects

Five participants from Experiment I and Experiment II were subjects for this experiment: M.D., B.S., A.A., B.B., and J.C. Due to high absenteeism and failure to pass the first training condition, M.D. and B.B. were dropped from the study. Their results to the point at which they were dropped are presented here. Each of the

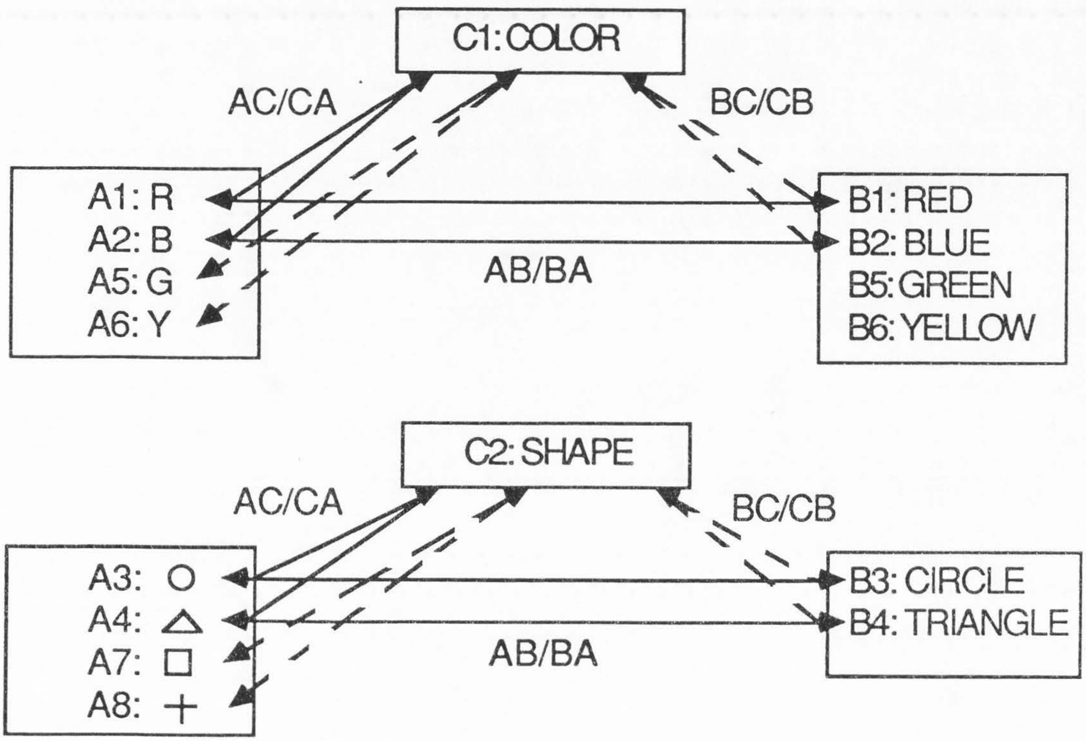

Figure 3. Trained relations (solid lines) and tested relations (broken lines) among stimuli in Experiment III. R = red, B = blue, G = green, Y = yellow (hues); ○ = circle, △ = triangle, □ = square, + = cross (line drawings). All other stimuli were printed words.

remaining three subjects underwent slightly different training and probe sequences, so results are presented for each of them individually.

Training and Probe Procedures

All of the subjects for this experiment completed pretraining previously, and upon starting this experiment each of them had received training with Set B (printed instance words) and Set C (printed concept words) elements in the SS position for trials on which either identity or arbitrary matches between elements from Set A (symbols) were reinforced. Repeated probes demonstrated that none of these subjects learned the AB/BA or AC/CA relations as a result of that training. Stimuli for Experiment III were the same as for Experiment II, i.e., Sets A, B, and C (refer to Table 3), with the difference that for most conditions in this experiment the printed words (Set B or Set C) served as STs and COs instead of appearing only in the SS position. Relations between Set A (symbols) and Set B (printed instance words), or between Set A and Set C (printed concept words), were trained directly. Probes assessed whether transitive and symmetric relations between Set B and Set C stimuli had developed as a result of training. Conditional relations trained or tested and corresponding stimulus configurations are presented in Table 11. The four-key arrangement that was used in the previous experiments was maintained for this experiment, so the SS and ST were identical.

The sequence of conditions for each subject in Experiment III is listed in Table 12. The plan was to train the AB/BA relations first followed by the AC/CA relations with M.D.,A.A., and J.C., while B.S. and B.B. received AC/CA training followed by AB/BA training. All subjects would then be presented with probes for the transitive and symmetric BC/CB relations (see Figure 3). Subject M.D. failed to complete AB/BA training and B.B. did not complete AC/CA training, leaving two subjects who received AB/BA training first and one who received AC/CA training first. The number and type of training and probe conditions these remaining three subjects were able to complete varied and will be described in detail in the following section.

Posttests

Following regular training and probe sessions, the three subjects who completed this experiment were given a brief series of tests with the experimental stimuli on 4" x 6" cards. On a word matching posttest they were given 12 match-to-sample trials with all possible combinations of printed words (Sets B and C). The second posttest

Table 11

Stimulus Configurations, Experiment III

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
TRAINING: AB/BA				
A1B1	R	R	RED	BLUE
B1A1	RED	RED	R	B
A2B2	B	B	BLUE	RED
B2A2	BLUE	BLUE	B	R
A3B3	○	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	CIRCLE	○	△
A4B4	△	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	TRIANGLE	△	○
Mixed A1B1 & A2B2	Random mixture of first four configurations			
Mixed A1-A4/B1-B4	Random mixture of all above configurations			
TRAINING: AC/CA				
A1C1	R	R	COLOR	SHAPE
C1A1	COLOR	COLOR	R	○ or △
A2C1	B	B	COLOR	SHAPE
C1A2	COLOR	COLOR	B	○ or △
A3C2	○	○	SHAPE	COLOR
C2A3	SHAPE	SHAPE	○	R or B
A4C2	△	△	SHAPE	COLOR
COLOR	SHAPE	SHAPE	△	R or B
Mixed A1-A4/C1-C2	Random mixture of above configurations			
REVIEW				
Mixed AA with B and AA with C (See Table 8)				

(table continues)

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
PROBES				
AB/BA				
A1B1	R	R	RED	BLUE
B1A1	RED	RED	R	B
A2B2	B	B	BLUE	RED
B2A2	BLUE	BLUE	B	R
A3B3	○	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	CIRCLE	○	△
A4B4	△	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	TRIANGLE	△	○
BC/CB				
B1C1	RED	RED	COLOR	SHAPE
C1B1	COLOR	COLOR	RED	CIRCLE or TRIANGLE
B2C1	BLUE	BLUE	COLOR	SHAPE
C1B2	COLOR	COLOR	BLUE	CIRCLE or TRIANGLE
B3C2	CIRCLE	CIRCLE	SHAPE	COLOR
C2B3	SHAPE	SHAPE	CIRCLE	RED or BLUE
B4C2	TRIANGLE	TRIANGLE	SHAPE	COLOR
C2B4	SHAPE	SHAPE	TRIANGLE	RED or BLUE

(table continues)

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
New AC/CA				
A5C1	G	G	COLOR	SHAPE
C1A5	COLOR	COLOR	G	□ or +
A6C1	Y	Y	COLOR	SHAPE
C1A6	COLOR	COLOR	Y	□ or +
A7C2	□	□	SHAPE	COLOR
C2A7	SHAPE	SHAPE	□	G or Y
A8C2	+	+	SHAPE	COLOR
C2A8	SHAPE	SHAPE	+	G or Y
BC/CB with A				
B1C1 with A1	R	RED	COLOR	SHAPE
C1B1 with A1	R	COLOR	RED	CIRCLE or TRIANGLE
B2C2 with A2	B	BLUE	COLOR	SHAPE
C2B2 with A2	B	COLOR	BLUE	CIRCLE or TRIANGLE
B3C2 with A3	○	CIRCLE	SHAPE	COLOR
C2B3 with A3	○	SHAPE	CIRCLE	RED or BLUE
B4C2 with A4	△	TRIANGLE	SHAPE	COLOR
C2B4 with A4	△	SHAPE	TRIANGLE	RED or BLUE
New AA				
A5A5	GREEN	G	G	Y
A6A6	YELLOW	Y	Y	G
New AB/BA				
A5B5	G	G	GREEN	YELLOW
B5A5	GREEN	GREEN	G	Y
A6B6	Y	Y	YELLOW	GREEN
B6A6	YELLOW	YELLOW	Y	G

Note. R=red, B=blue, G=green, Y=yellow (hues); ○=circle, △=triangle, □=square, +=cross (line drawings). All other stimuli were printed words. The letters A, B, and C denote stimulus sets (see Table 3) and numbers specify elements within sets.

Table 12

Sequence of Conditions for Subjects in Experiment III

M.D.	B.S.	A.A.	B.B.	J.C.
1. Training: AB/BA	1. Training: AC/CA	1. Training: AB/BA	1. Training: AC/CA	1. Training: AB/BA
	2. Review: AA with B, AA with C	2. Training: AC/CA		2. Training: AC/CA
	3. Probes: AB/BA	3. Training: AB/BA		3. Probes: BC/CB
	4. Training: AB/BA	4. Probes: BC/CB		4. Probes: New AC/CA
	5. Probes: BC/CB	5. Review I: AA with B, AA with C		5. Posttests
	6. Probes: New AC/CA	6. Probes: BC/CB		
	7. Review I: AC/CA	7. Probes: BC/CB with A		
	8. Probes: New AC/CA	8. Review II: AC/CA		
	9. Review II: AC/CA	9. Probes: New AC/CA		
	10. Probes: New AC/CA	10. Posttests		
	11. Probes: BC/CB with A			
	12. Review III: AC/CA			
	13. Probes: New AC/CA			
	14. Review IV: AB/BA			
	15. Probes: New AA			
	16. Probes: New AB/BA			
	17. Posttests			

presented modified match-to-sample trials on which an element of Set A was presented first, with C1 (COLOR) and C2 (SHAPE) as comparisons. If the subject selected the correct CO, the two corresponding elements from Set B were presented as comparisons, i.e., B1 (RED) and B2 (BLUE) were comparisons following the subject's selection of C1 (COLOR), and B3 (CIRCLE) and B4 (TRIANGLE) were comparisons for C2 (SHAPE). Finally, subjects were simply asked to name all the printed word stimuli that had been used in the experiment (Sets B and C). In preparation for these posttests, to insure that the subject could match the card stimuli to their counterparts on the apparatus, a training session was run on the apparatus that presented mixed AB/BA and AC/CA trials in random order. The experimenter sat next to the subject at a small table on which all the cards were arranged in random fashion. When a stimulus appeared on the apparatus, regardless of its position, the experimenter instructed the subject to look at it, then point to the card that was just like it. When the subject did so correctly, the experimenter responded with verbal praise and the subject was allowed to press the apparatus key to continue the trial. If the subject selected the incorrect card, the experimenter said, "No, that's wrong. Find the one that looks the same." If the subject selected the correct card at this point there was no verbal praise, and the subject was told to press the key to continue. It was never necessary to repeat this correction procedure more than once. The session continued until the subject had selected the correct card in response to each stimulus shown on the apparatus on three consecutive opportunities.

Results

Subjects M.D. and B.B.

Training on the AB/BA relations for M.D. began with sessions that included all possible relations between Set A and Set B stimuli, i.e., A1B1/B1A1, A2B2/B2A2, A3B3/B3A3, and A4B4/B4A4 (see Table 11). After three such sessions with 1.0 probability of chimes following correct responses, M.D.'s performance was only slightly above chance accuracy (60%). At this point a correction procedure was instituted, so that when the subject responded incorrectly on a trial, the trial was repeated until a correct response was made. Token delivery was also added to the chimes feedback following correct responses. Subject M.D. completed six sessions with chimes and a token presented after each correct response and the correction procedure, and his best performance was still only 70% accurate with a mean of 62%. The task was then reduced to only four relations, A1B1/B1A1 and A2B2/B2A2, with chimes and a token presented after each correct response and the correction procedure still in place. After three sessions with the reduced number of relations, M.D.'s accuracy rose as high as 77% for two sessions, but then dropped to 67% and 73% in the next two sessions. This subject was absent from preschool for extended periods during the experiment and eventually refused to participate in the experiment. He was dropped from the study.

For subject B.B., training involved the relations A1C1/C1A1, A2C1/C1A2, A3C2/C2A3, and A4C2/C2A4. His first four sessions provided chimes following all correct responses but no correction; his best performance under those conditions was 63% accuracy. The correction procedure and token delivery were instituted and B.B. completed 11 sessions with 100% feedback and correction. His performance was no better than 73% for those 11 sessions, with a mean of 60.6%. The AC/CA training sessions could not be modififed to present fewer relations without creating a possible imbalance in the valence of the stimuli that were used (Fields et al., 1984). For example, if only the relations involving the color stimuli (A1, A2, and C1) were included in a training session, the shape stimuli (A3, A4, and C2) would necessarily appear only in the S- position, possibly confounding stimulus control. Given that problem and the fact that B.B. also missed a large number of sessions, he was dropped from the research.

Subject B.S.

Training: AC/CA

This subject's training began with the AC/CA relations. After five sessions with chimes sounding after each correct response, his accuracy rose from an initial 47% to 87%. The correction procedure was added and his performance improved to 93% and 100% for two sessions with feedback after each correct response and was 97% for one session with probability of feedback for correct responses reduced to .20.

Review and Probes: AB/BA

The question arose as to whether, having been trained to match symbols to printed words in the AC/CA training, this subject might show a generalized tendency to relate other printed words to symbols without explicit reinforcement for so doing. To test this he was given one review session with configurations of the type used in Experiment II, where Set B and Set C printed word stimuli appeared only in the SS position to start each identity matching or arbitrary matching trial. His performance on the review was 93% accurate. He then completed several sets of probes for the AB/BA relations, results of which are reported in Table 13 (post-training). His performances on those probes were near chance.

Training: AB/BA

The AB/BA relations were then trained directly, beginning with only the A1B1/B1A1 and A2B2/B2A2 relations with chimes after each correct response and correction. Subject B.S.'s accuracy for two such sessions was 93% and 97%. When the remaining four relations were added -- A3B3/B3A3 and A4B4/B4A4 -- his accuracy dropped to 83% initially but improved to 90% and was maintained at that level when the probability of chimes following correct responses was dropped to .20.

Probes: BC/CB

Next the transitive and symmetric relations BC/CB were tested. The expected relations did not emerge (Table 13, post-training).

Probes: New AC/CA

Another series of probes was administered to determine whether B.S. would match novel elements of Set A to Set C stimuli without being trained to do so. That is, would he match two new colors (green and yellow) to the printed word COLOR and two new shapes (square and cross) to the printed word SHAPE? On the first set of

Table 13

Performances of Experiment III Subjects on Probes for Conditional Relations Between Set A, Set B, and Set C Stimuli

		Results by Subject		
Condition	Relations	B.S.	A.A.	J.C.
	AB/BA			
Post-training	A1B1/B1A1	13/24		
	A2B2/B2A2			
	A3B3/B3A3	8/16		
	A4B4/B4A4			
	BC/CB			
	B1C1/C1B1	11/24	4/8	6/16
	B2C1/C1B2			
	B3C2/C2B3	13/24	1/8	10/16
	B4C2/C2B4			
	New AC/CA			
	A5C1/C1A5	5/8		8/8
	A6C1/C1A6			
	A7C2/C2A7			8/8
	A8C2/C2A8			
	New AC/CA			
Post-review I	A7C2/C2A7	3/8		
	A8C2/C2A8			

(table continues)

Condition	Relations	B.S.	A.A.	J.C.
	BC/CB			
	B1C1/C1B1		9/15	
	B2C1/C1B2			
	B3C2/C2B3		3/16	
	B4C2/C2B4			
	BC/CB with A			
	B1C1/C1B1 with A1		10/24	
	B2C1/C1B2 with A2			
	B3C2/C2B3 with A3		11/24	
	B4C2/C2B4 with A4			
	New AC/CA			
Post-review II	A5C1/C1A5	9/16	12/16	
	A6C1/C1A6			
	A7C2/C2A7	14/16	9/16	
	A8C2/C2A8			
	BC/CB with A			
	B1C1/C1B1 with A1	5/16		
	B2C1/C1B2 with A2			
	B3C2/C2B3 with A3	7/16		
	B4C2/C2B4 with A4			

(table continues)

Condition	Relations	Results by Subject B.S.	A.A.	J.C.
	New AC/CA			
Post-review III	A5C1/C1A5	13/16		
	A6C1/C1A6			
	A7C2/C2A7	7/8		
	A8C2/C2A8			
	New AA			
Post-review IV	A5A5	24/24		
	A6A6			
	New AB/BA			
	A5B5/B5A5	7/16		
	A6B6/B6A6			

Note. Numbers in the body of the table represent number correct per number of opportunitites to demonstrate each set of relations.

probes involving only the color stimuli (A5, A6, and C1; see Table 13, post-training, column 3), he did not relate the stimuli correctly, and his baseline performance (consisting of previously trained AC/CA trials) deteriorated to 36% correct. He was given two review sessions on the previously trained AC/CA relations with chimes sounding after every correct response and the correction procedure, and 93% accuracy was regained. A set of probes with the two novel shapes (A7 and A8) and C2 (SHAPE) was completed next (post-review I; see Table 13). Accuracy on probes was near chance, and baseline accuracy again dropped, but only to 87%. After a second review session in which performance was above criterion, two probe sessions with the novel colors and two with the novel shapes were administered (post-review II, Table 13). Performances on the color probes did not improve, but accuracy on the shape probes improved to 14/16. Baseline performance remained above criterion for those probe sessions.

Probes: BC/CB with A

The next series of probes was designed to test whether the BC/CB relations that should have been enabled by this subject's previous training would be demonstrated if the stimulus to which both the B and C stimuli had been related in training was visible when the B and C stimuli were presented. For each probe trial, the sample (ST) and the correct comparison (S+) were a Set B and a Set C element, or vice versa. The stimulus from Set A that had been related to those particular Set B and Set C stimuli was presented in the superordinate (SS) position. For example, on a probe trial with B1 (RED) as the ST and C1 (COLOR) as the S+, A1 (red) appeared to start the trial and remained visible when the subject selected a comparison. Performances on these probes, as summarized in Table 13, column 3, suggested that expression of the transitive BC/CB relations was not facilitated by the presence of the common stimulus that should have linked B and C stimuli.

A possible source of interference with the development of BC/CB relations among these stimuli was the presence of common features, in the form of letters, in certain STs and COs. The most obvious features were common beginning or ending letters. If responses were controlled by a common beginning letter, for example, a subject might select the incorrect choice CIRCLE in response to COLOR rather than selecting RED or BLUE to demonstrate a transitive CB relation. None of the other words presented as STs and COs had common beginning letters. However, four words -- SHAPE, BLUE, CIRCLE, and TRIANGLE -- had a common ending letter. If the subject were matching words by their ending letter, certain error patterns should be evident. When the ST was SHAPE, the comparisons BLUE, CIRCLE, and TRIANGLE should be selected equally often. When BLUE or TRIANGLE was the ST, the comparison SHAPE should be selected more often than the comparison COLOR. On trials where the ST was CIRCLE and the comparisons were COLOR and SHAPE, a subject could select COLOR on the basis of the common beginning letter, or SHAPE on the basis of the common ending letter; the data should indicate whether one controlled more often than the other. Of course, a subject might also have matched common letters appearing in any position within the ST and COs.

To help identify systematic error patterns that might have been attributable to control by common features, the BC/CB probe performances of B.S., A.A., and J.C. were analyzed for sample-comparison relations, as depicted in Table 14. All possible STs (samples) are listed in rows, and COs (comparisons) are listed in columns in this table. Numbers in the body of the table represent the number of times each subject selected each CO in response to a particular ST. Responses to nominally incorrect COs are underlined. The upper portion of Table 14 shows B.S.'s responses on BC/CB probes. When RED was the ST, COLOR and SHAPE were selected equally often; neither of those COs has a

Table 14

Comparisons (Columns) Selected in Response to Samples (Rows) on BC/CB Probes by each Subject in Experiment III

SAMPLES

COMPARISONS

B.S.

	RED	BLUE	CIRCLE	TRIANGLE	COLOR	SHAPE
RED					2	2
BLUE					6	4
CIRCLE					8	4
TRIANGLE					4	6
COLOR	5	3	5	3		
SHAPE	5	7	3	5		

N=72 trials

A.A.

	RED	BLUE	CIRCLE	TRIANGLE	COLOR	SHAPE
RED					3	5
BLUE					3	4
CIRCLE					7	6
TRIANGLE					7	5
COLOR	8	5	9	8		
SHAPE	2	5	1	2		

N=80 trials

(table continues)

J.C.

	RED	BLUE	CIRCLE	TRIANGLE	COLOR	SHAPE
RED					0	1
BLUE					1	1
CIRCLE					4	3
TRIANGLE					3	3
COLOR	1	4	3	1		
SHAPE	3	0	1	3		

N=32 trials

Note. Underscored numbers indicate number of responses to nominally incorrect comparisons.

beginning or ending letter in common with RED. When BLUE was the ST, however, SHAPE was selected more often than COLOR; BLUE and SHAPE have a common ending letter. The case is less clear for the STs CIRCLE and TRIANGLE, although the subject selected COLOR in response to CIRCLE (common beginning letter) and SHAPE in response to TRIANGLE (common ending letter) more often than the other available CO. When the ST was COLOR and CIRCLE was available as a CO, B.S. tended to select CIRCLE. On trials where SHAPE was the ST, the COs BLUE, CIRCLE, and TRIANGLE were selected almost equally often. All of those COs have the same ending letter as SHAPE.

Review and Probes: New AC/CA

At this point AC/CA training was reviewed to enable further probes for AC/CA relations involving untrained stimuli, specifically the A5,A6, and C1 relations (green, yellow, and COLOR) that were not demonstrated in earlier tests. The subject's performances in two review sessions were 87% and 97% accurate. Two sets of A5C1/C1A5 and A6C1/C1A6 probes were administered, and B.S. demonstrated a substantial improvement over previous tests with the same configurations (see Table 13, post-review III). One set of A7C2/C2A7 and A8C2/C2A8 probes (square, cross, and SHAPE) confirmed that those relations were still strong.

Review: AB/BA

Reviews of AB/BA training were administered to provide B.S. with reinforcement for matching symbols to their corresponding printed names. Two review sessions reintroduced all eight relations between A1-A4 and B1-B4, but the subject's performance in both sessions was only 63% correct. A third review session was conducted with only four relations involving A1, B1, A2, and B2, and performance improved to 87%. Even though this was just below criterion, B.S. proceeded to the next condition because he was available for only a few more sessions, and because in the next probe condition the previously trained A1B1/B1A1 and A2B2/B2A2 relations would serve as baseline and correct responses would continue to be followed by feedback with .20 probability.

Probes: New AA

Three sets of eight probe trials were administered on which the ST and the nominally correct CO were either stimulus A5 (green) or A6 (yellow). Corresponding untrained elements of Set B, the printed names for each of those colors, appeared in the SS position to start each trial. The subject's performance on these 24 probes was 100% correct, demonstrating reflexivity or generalized identity matching with colors (post-review IV, Table 13).

Probes: New AB/BA

Two final sets of probes tested for untrained relations between the two colors presented in the identity matching probe tasks just preceding and the corresponding printed words that appeared as SSs on those probe trials. The subject's accuracy on these probes was no better than chance (post-review IV, Table 13).

Posttests

Results of the posttests for all three subjects are reported in Table 15. On the word matching posttest, which repeated probes for the transitive and symmetric BC/CB relations, B.S.'s responses on some individual trials corroborated the apparent feature matching that occurred on earlier probe trials. When COLOR was the ST and CIRCLE was available as a CO, B.S. selected CIRCLE instead of RED or BLUE on both opportunities, and when CIRCLE was the ST on one trial he selected COLOR instead of SHAPE. These COLOR-CIRCLE matches could have been controlled by the common feature, the letter C, at the beginning of each word. On the remaining trials where ST and an incorrect comparison had an obvious common feature, B.S. matched SHAPE to BLUE and vice versa on two of three opportunities. In other words, five of the eight errors the subject made on this posttest could be accounted for by a tendency to match words by their

Table 15

Experiment III Posttest Results

Test	Results by subject B.S.	A.A.	J.C.
I. Word matching	4/12	7/12	6/12
II. Modified match-to-sample:			
Symbol (A) to concept word (C)	7/8	8/8	8/8
Concept word (C) to instance word (B)	4/8	4/8	6/8
III. Oral naming:			
RED	"Don't know"[a]	"white"	"Don't know"
BLUE	"	"bus"	"
CIRCLE	"	"C"	"
TRIANGLE	"	"two"	"
COLOR	"	"Don't Know"	"
SHAPE	"	"stop"	"

[a] Subject named all letters in each word, but when prompted to name the whole word replied "I don't know."

common beginning or ending letters. After each trial the subject was asked why the ST and his selection went together; he did not verbalize a reason on any of the 12 trials.

On the second posttest, trials began with a stimulus from Set A (red, blue, circle, or triangle) as ST and C1 (COLOR) and C2 (SHAPE) as comparisons. Two trials were presented with each Set A stimulus, for a total of eight tests of the AC relations. The subject responded correctly on seven of eight trials. The second part of each trial then presented the two stimuli from Set B (printed instance words) that should have been related transitively to the Set C stimulus the subject had just responded to in the first part of the trial. Only one of those stimuli had been related to the Set A stimulus that started the test trial and remained visible when the subject selected one of the Set B comparisons. Subject B.S. selected the correct Set B stimulus on half of these posttest trials.

On the naming posttest, B.S. replied "I don't know" when asked to name each of the six printed words that had been used in the experiments. He could name all the letters in the words, but apparently did not have oral names for any of the printed words.

Subject A.A.

Training: AB/BA

Training began with all eight relations involving stimuli A1-A4 and B1-B4. In three sessions without a correction procedure, A.A.'s accuracy was no better than 70% with a mean of 60%. Her performance did not improve over four sessions with the correction procedure in place, so the task was reduced to only four relations, A1B1, B1A1, A2B2, and B2A2. In only two sessions with the correction procedure, performance improved to 97% accuracy and remained at that level with probability of chimes following correct selections reduced to .20.

Training: AC/CA

Next A.A. received training on all the AC/CA relations (previously described for B.S.). Seven sessions with a correction procedure were required for her performance to reach criterion on this condition.

Training: AB/BA

At this point the two AB/BA relations that had not been learned successfully were added. Three sessions were conducted with all relations involving A1-A4 and B1-B4, including the correction procedure and feedback (chimes) following correct responses. The subject's performances were 67%, 73%, and 93% correct. At a .20 level of feedback her performance remained at criterion.

Probes: BC/CB

Two sets of probes for the transitive and symmetric BC/CB relations were administered, one set with B1 (RED), B2 (BLUE), and C1 (COLOR), and one set with B3 (CIRCLE), B4 (TRIANGLE), and C2 (SHAPE). Results of these and all other probes are summarized in Table 13. This subject's overall performances on the two probe sets were near chance (5/16), but that total included a below-chance performance (1/8) on the shape word set, possibly because she matched some words on the basis of common letters. That possibility is addressed later in this section. Baseline accuracy levels fell to 54% and 68% for the two probe sessions, so a review session was inserted.

Review I: AA with B

For review, A.A. completed three sessions of trials of the type used in Experiment II, i.e., where the Set B and Set C stimuli were used only in the SS position to start trials and did not appear as STs or COs. This was done to set the stage for later probes, and to determine whether this indirect presentation of the AB and AC relations would suffice as a review now that those relations had been taught directly. Her performances in these review sessions were 97%, 100%, and 97% correct.

Probes: BC/CB

Two sets of each of the previously described BC/CB probes were administered after the review (post-review I, column 4 in Table 13). Baseline performance remained above criterion for these probe sessions, but overall performance on the BC/CB probes was within or slightly below chance limits.

Probes: BC/CB with A

As with subject B.S., a series of probes was conducted to determine whether presentation of the Set A stimulus that should have linked Set B and Set C stimuli would facilitate expression of the BC/CB relations. Three probe sets each with the color and shape stimuli were administered (post-review I, Table 13). The accuracy with which A.A. matched B to C stimuli was still essentially chance performance and reflected no improvement over performance on similar probes without the putative linking Set A stimulus.

To examine possible feature control on these and previous BC/CB probes, A.A.'s data were analyzed for sample-comparison relations and error patterns as described for B.S. Results are presented in the middle portion of Table 14. She demonstrated a tendency to match the words COLOR and CIRCLE as did B.S.: when CIRCLE was the ST she selected COLOR instead of SHAPE almost exclusively, and when the ST was COLOR she selected CIRCLE much more often than RED or BLUE. She showed a similar strong tendency to match the words COLOR and TRIANGLE regardless of their position as ST or CO, a pattern that is not as clearly attributable to control by common features.

Review II: AC/CA

The previously trained AC/CA relations were reviewed in preparation for the next probe phase. In each of three sessions with continuous feedback and correction, A.A.'s performance was 73% correct. Because this subject's enrollment in the preschool was quickly nearing an end, and since these relations would continue to be reinforced with .20 probability as baseline for the probe sessions, she proceeded to the next probe condition.

Probes: New AC/CA

These probes presented the untrained stimuli A5 (green) and A6 (yellow) as STs or correct COs with the trained C1 (COLOR), and the untrained A7 (square) and A8 (cross) with C2 (SHAPE). Subject A.A. selected the correct comparison on color probe trials at a level just above chance, and accuracy on shape probe trials was at chance (Table 13, post-review II). Baseline accuracy levels ranged from 68%-82% for these four probe sessions, so the trained AC/CA performance never regained criterion level. Subject A.A.'s participation in the experiment terminated following the last of these probe sessions and the posttests.

Posttests

Posttest results are summarized in Table 15. On the word matching posttest, A.A.'s accuracy level was comparable to her performance on analogous probe trials administered during the experiment. Of the five errors she made, she matched the words COLOR and CIRCLE on all three opportunities to do so, and BLUE and SHAPE on another, although she did not select BLUE when the ST was SHAPE. These errors suggested a tendency to match words on the basis of common letters, and when asked why the two words went together on each trial, she verbalized a common letter. However, her selections were not consistent: in some cases she named the beginning letter, in others the ending letter, and in still others a letter that was in an interior position in both words. Her other error was selection of the word TRIANGLE (instead of BLUE) when the ST was COLOR. Her responses on these posttests were consistent with her performances on the BC/CB probes, discussed previously.

On the second posttest, A.A. selected the correct Set C stimulus in response to a Set A sample on the first segment of all eight trials. However, on the second segment of these trials she selected the Set B stimulus that had been trained to the Set A stimulus for that trial on only half of the trials.

This subject gave oral names for five of the six printed words, but none were correct. The name she gave for each stimulus is shown in Table 15.

Subject J.C.

Training: AB/BA

This subject's training began with the eight A1-A4 and B1-B4 relations (refer to Table 11). In two sessions with chimes following each correct response but no correction his performances were below 50% correct. The correction procedure was added, and over four sessions J.C.'s accuracy with all eight relations was no higher than 67%, with a mean of 57.5%. The number of relations in a training session was then reduced to four (A1B1,B1A1, A2B2, B2A2), with a correction procedure and chimes following all correct responses. By the sixth such session J.C.'s accuracy had risen to 93%. The remaining four AB/BA relations were added so that training sessions once again included all eight relations between stimuli A1-A4 and B1-B4. Continuous feedback and correction were maintained. For two sessions with all eight relations, J.C.'s accuracy levels were 90% and 100%.

Training: AC/CA

Training on all AC/CA relations began with chimes following all correct responses and a correction procedure. Performances for two sessions were 87% and 97% accurate. When the feedback probability was dropped to .20, J.C.'s matching accuracy remained at criterion.

Probes: BC/CB

Two probe sessions each for transitive and symmetric relations between printed color instance words (B1, B2) and C1 (COLOR), and printed shape instance words (B3, B4) and C2 (SHAPE) were administered (post-training; Table 13, Column 5). Responses congruent with formation of BC/CB relations were demonstrated on only half of these probe trials. Baseline performances (mixed AB/BA and AC/CA) remained above criterion.

As with the two preceding subjects, J.C.'s responses on these probe trials were examined for evidence of matching words by common letters. Although he had fewer probes of this type than B.S. and A.A., the lower portion of Table 14 suggests that he had a similar tendency to match the words COLOR and CIRCLE, the only words with common beginning letters.

Probes: New AC/CA

In the limited remaining time that this subject was available, two probe sessions were conducted that presented eight probe trials testing untrained conditional and symmetric relations between C1 (COLOR) and the novel stimuli A5 (green) and A6 (yellow), and between C2 (SHAPE) and the novel stimuli A7 (square) and A8 (cross). In each of those sessions, J.C.'s responses were correct on all eight probe trials (Table 13).

Posttests

As shown in Table 15, J.C. responded correctly on half of the word matching trials. Five of his errors were matches between COLOR and CIRCLE (3/3 opportunities) and between SHAPE and BLUE (2/3 opportunities). On each of those trials he replied with the name of the common beginning or ending letter when asked why the words went together. The sixth error was selection of RED instead of CIRCLE in response to the sample, SHAPE.

On the second posttest, when a Set A stimulus was presented J.C. selected the correct Set C comparison on all eight trials. In the second segment of each trial, when given Set B comparisons while the Set A and Set C stimuli remained visible, he selected the correct CO on six of eight opportunities (see Table 15). He missed the same type of trial twice, one on which A4 (triangle) was the first ST, in response to which he correctly selected C2 (SHAPE), but then when B3 (CIRCLE) and B4 (TRIANGLE) were presented as COs he selected B3.

Subject J.C. responded "I don't know" when asked the names of the six printed word stimuli that had been used in the experiment.

Discussion

Three subjects were taught AB/BA and AC/CA relations, and then tested for the transitive and symmetric BC/CB relations (see Figure 3). None of the three demonstrated that BC/CB relations had emerged as a result of training. The BC/CB probe trials displayed printed words in the SS, ST, and both CO positions which, on certain configurations, presented the opportunity for subjects to match stimuli on the basis of common features (i.e., letters) or on the basis of a transitive relation between them. Analyses of probe performances revealed high frequencies of errors on trials where the ST and the incorrect CO had an obvious feature in common in the form of the beginning or ending letter of the word (e.g., COLOR and CIRCLE). Posttests with the printed word stimuli on cards confirmed that all three subjects tended to match words by their common letters, although subjects did not always verbalize such a rule, nor did they all consistently match words by their beginning or ending letters. Performances on BC/CB probes did not improve when the Set A stimulus to which both the B and C stimulus had been related in training was included in the stimulus display, whether those stimuli were presented on the experimental apparatus or in modified form with cards. Although these subjects were taught the conditional relations that should have led to the development of BC/CB relations, a plausible explanation as to why BC/CB relations did not emerge is that preexisting identity matching relations among letters prevented the emergence or the expression of transitive relations among the printed words.

Performances of two of the three subjects in this experiment demonstrated conditional and symmetric relations between each of two untrained color symbols and the printed concept word COLOR, and between two untrained shape symbols and the printed concept word SHAPE. Although these subjects were not provided with any auditory labels for the concept words, and on posttests did not produce oral names for the words, they sorted untrained symbols into the correct concept groupings on visual match-to-sample tasks. For B.S. this behavior emerged completely only after he reviewed previously trained instances of each concept, but J.C. demonstrated it on the first opportunity to do so.

EXPERIMENT IV-A

In Experiment III, subjects were explicitly trained to relate printed word stimuli from Set B and Set C to stimuli from Set A. Prior to that training, they had received extensive training where Set B and Set C printed word stimuli served to start each trial but were not related directly to the symbols in Set A. None of the subjects in Experiment III demonstrated the BC/CB relations that should have emerged from their AB/BA and AC/CA training. Those results raised a question as to whether a subject who did not have a training history in which printed words were unnecessary to the match-to-sample tasks would demonstrate the predicted transitive and symmetric relations among printed words. Experiment IV-A was designed to answer that question. In addition to the BC/CB relations, the training provided in Experiment III established the logical possibility for other transitive relations to develop. Since two elements from Set A were related to each of the Set C elements (red and blue to COLOR; circle and triangle to

SHAPE), the pairs of Set A elements could be related transitively (see Figure 4). If the BC/CB relations in fact emerged, such that two Set B elements were related to each of the Set C elements (RED and BLUE to COLOR; CIRCLE and TRIANGLE to SHAPE), then those pairs of Set B elements could also be related transitively. In turn, transitive relations could then exist between each Set A element and the Set B element that was previously related directly to the other member of that Set A pair (e.g., red and BLUE; triangle and CIRCLE; see Figure 4). All of the possible transitive relations that could develop as a result of this type of training are indicated by the broken lines in Figure 4. A second purpose of Experiment IV-A was to test for the emergence of all of those possible untrained relations.

Method

Subject

Subject M.A. was the sole participant in this experiment. As all the subjects in this research, her pretest results indicated that she could identify and name most of the Set A stimuli but could not accurately identify or name the printed words in Sets B and C.

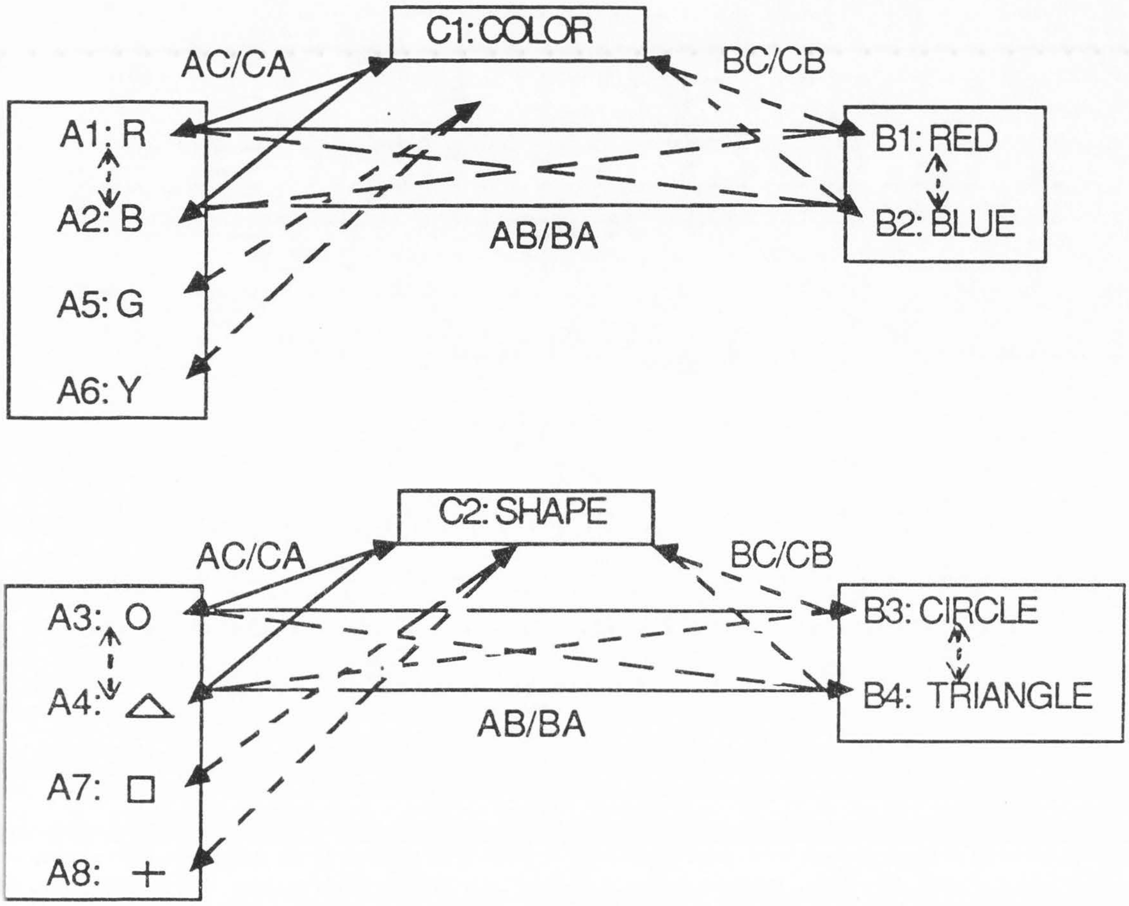

Figure 4. Trained relations (solid lines) and untrained relations (broken lines) among stimuli in Experiment IV-A. R = red, B = blue, G = green, Y = yellow (hues); O = circle, △ = triangle, □ = square, + = cross (line drawings). All other stimuli were printed words.

Training and Probe Procedures

Pretraining was conducted as described for Experiments I and II to insure that the subject could perform match-to-sample tasks and to establish generalized identity matching with colors and shapes. An important procedural difference was that for pretraining, training, and all probe conditions in this experiment, no stimulus ever appeared in the superordinate (SS) position. All trials were three-key match-to-sample tasks, initiated by onset of the ST and presenting two COs. Stimuli were the same as for Experiment III, i.e., Sets A, B, and C (see Table 3). The correction procedure previously described was in effect at all times during training. Conditional relations between Set A (symbols) and Set B (printed instance words) were trained directly, followed by conditional relations between Set A and Set C (printed concept words). As in the preceding experiments, all training was bidirectional; that is, each stimulus appeared an equal number of times as ST and CO. All conditional relations that were trained or tested and corresponding stimulus configurations are presented in Table 16.

The sequence of conditions for this subject is listed in Figure 5. Following training, the BC/CB relations were tested. A review of AC/CA training was

Table 16

Stimulus Configurations, Experiment IV-A

TASK	SAMPLE	COMPARISONS	
TRAINING: AB/BA			
A1B1	R	RED	BLUE
B1A1	RED	R	B
A2B2	B	BLUE	RED
B2A2	BLUE	B	R
A3B3	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	○	△
A4B4	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	△	○
Mixed A1B1 & A2B2	Random mixture of first four configurations		
Mixed A1-A4/B1-B4	Random mixture of all above configurations		
TRAINING: AC/CA			
A1C1	R	COLOR	SHAPE
C1A1	COLOR	R	○ or △
A2C1	B	COLOR	SHAPE
C1A2	COLOR	B	○ or △
A3C2	○	SHAPE	COLOR
C2A3	SHAPE	○	R or B
A4C2	△	SHAPE	COLOR
C2A4	SHAPE	△	R or B
Mixed A1-A4/C1-C2	Random mixture of all AC/CA configurations		
TRAINING: AB/BA & AC/CA	Random mixture of all above configurations		

(table continues)

TASK	SAMPLE	COMPARISONS	
PROBES:			
BC/CB			
B1C1	RED	COLOR	SHAPE
C1B1	COLOR	RED	CIRCLE or TRIANGLE
B2C1	BLUE	COLOR	SHAPE
C1B2	COLOR	BLUE	CIRCLE or TRIANGLE
B3C2	CIRCLE	SHAPE	COLOR
C2B3	SHAPE	CIRCLE	RED or BLUE
B4C2	TRIANGLE	SHAPE	COLOR
C2B4	SHAPE	TRIANGLE	RED or BLUE
New AC/CA			
A5C1	G	COLOR	SHAPE
C1A5	COLOR	G	□ or +
A6C1	Y	COLOR	SHAPE
C1A6	COLOR	Y	□ or +
A7C2	□	SHAPE	COLOR
C2A7	SHAPE	□	G or Y
A8C2	+	SHAPE	COLOR
C2A8	SHAPE	+	G or Y

(*table continues*)

TASK	SAMPLE	COMPARISONS	
AA TRANSITIVES			
A1A2	R	B	○ or △
A2A1	B	R	○ or △
A3A4	○	△	R or B
A4A3	△	○	R or B
BB TRANSITIVES			
B1B2	RED	BLUE	CIRCLE or TRIANGLE
B2B1	BLUE	RED	CIRCLE or TRIANGLE
B3B4	CIRCLE	TRIANGLE	RED or BLUE
B4B3	TRIANGLE	CIRCLE	RED or BLUE
AB TRANSITIVES			
A1B2	R	BLUE	CIRCLE or TRIANGLE
B2A1	BLUE	R	○ or △
A2B1	B	RED	CIRCLE or TRIANGLE
B1A2	RED	B	○ or △
A3B4	○	TRIANGLE	RED or BLUE
B4A3	TRIANGLE	○	R or B
A4B3	△	CIRCLE	RED or BLUE
B3A4	CIRCLE	△	R or B

Note. R = red, B = blue, G = green, Y = yellow (hues); ○ = circle, △ = triangle, □ = square, + = cross (line drawings). All other stimuli were printed words. The letters A,B, and C demote stimulus sets (See Table 3) and numbers specify elements within sets.

1. Pretraining: AA, BB
2. Probes: BC/CB
3. Training: AB/BA
4. Training: AC/CA
5. Training: AB/BA and AC/CA
6. Probes: BC/CB
7. Review: AC/CA
8. Probes: New AC/CA
9. Probes: AA Transitives
10. Probes: BB Transitives
11. Probes: AB Transitives

Experiment IV-B

Posttests

Figure 5. Sequence of conditions for subject M.A., Experiment IV-A.

then conducted, followed by all the remaining probes and, after Experiment IV-B, an oral naming posttest.

Results

Pretraining

In two pretraining sessions, M.A.'s performances on identity matching tasks with colors, shapes, and words mixed were 95% and 100% accurate.

Probes: BC/CB

Results of these and all other probes are summarized in Table 17. Before training commenced, M.A. matched Set B and Set C stimuli correctly on a total of six of 16 probe trials, but all of the six correct trials involved shape words (B3, B4, and C2). The fact that she did not select the correct CO on any of the eight probes with color words (B1, B2, and C1) suggested the possibility that some systematic control existed. Results of those eight probe trials were examined, and errors were distributed evenly among all the incorrect COs. No particular patterns of responding were evident, so it seemed unlikely that there were preexisting relations among these stimuli for this subject.

Table 17

Performances of Subject M.A. on Experiment IV-A Probes for Conditional Relations Between Set A, Set B, and Set C Stimuli

Condition	Relations	Results
	BC/CB	
Pre-training	B1C1/C1B1	0/8
	B2C1/C1B2	
	B3C2/C2B3	6/8
	B4C2/C2B4	
	BC/CB	
Post-training	B1C1/C1B1	16/16
	B2C1/C1B2	
	B3C2/C2B3	16/16
	B4C2/C2B4	
	New AC/CA	
Post-AC/CA Review	A5C1/C1A5	16/16
	A6C1/C1A6	
	A7C2/C2A7	14/16
	A8C2/C2A8	
	AA Transitives	
	A1A2/A2A1	16/16
	A3A4/A4A3	

(table continues)

Condition	Relations	Results
	BB Transitives	
	B1B2/B2B1	15/16
	B3B4/B4B3	
	AB Transitives	
	A1B2/B2A1	14/16
	A2B1/B1A2	
	A3B4/B4A3	12/15
	A4B3/B3A4	

Training: AB/BA

Training on the AB/BA relations began with the reduced set of relations A1B1/B1A1 and A2B2/B2A2. In four sessions M.A.'s accuracy rose from 53% to 90%. The remaining four relations (A3B3/B3A3 and A4B4/B4A4) were added and her performances for three sessions were 93%, 90%, and 100% accurate.

Training: AC/CA

Six sessions were required before M.A.'s performance on AC/CA relations met criterion.

Training: Mixed AB/BA and AC/CA

When AB/BA and AC/CA relations were mixed, color stimuli (A1,A2,B1,B2,C1) and shape stimuli (A3, A4, B3, B4, C2) were presented in separate sessions. In two sessions of the first type with chimes following all correct responses, M.A. performed with 100% and 93% accuracy. For two sessions of the second type with continuous feedback, performances were 93% and 97% accurate. When the feedback probability was reduced to .20, performances were 93% and 90% with colors and shapes, respectively.

Probes: BC/CB

Subject M.A.'s performance on probes for the transitive and symmetric BC/CB relations was perfect (Table 17, post-training).

Review: AC/CA

In preparation for the next set of planned probes, one session was conducted to review the previously trained AC/CA relations. The subject's accuracy for that session was 93%.

Probes: New AC/CA

Subject M.A. next received probes for untrained conditional and symmetric relations between two untrained elements of Set A and C1 (COLOR) and two other untrained Set A elements and C2 (SHAPE). Results are shown in Table 17, column 3 (post-AC/CA review).

Probes: AA Transitives

These probes assessed transitive and symmetric relations between each element of Set A that had been related to a common Set C stimulus in training (A1 and A2, A3 and A4). Such relations were demonstrated on all probe trials.

Probes: BB Transitives

Next, probes were administered to test for transitive and symmetric relations between each element of Set B that was related transitively to a common Set C stimulus (B1 and B2, B3 and B4). Those relations were demonstrated on all but one probe (Table 17).

Probes: AB Transitives

Relations demonstrated on preceding probes made possible transitive and symmetric relations between each element of each Set A pair that had a Set C stimulus in common, and the other Set B element to which the Set A element had never been related in training; i.e., A1B2/B2A1, A2B1/B1A2, A3B4/B4A3, and A4B3/B3A4 (see Figure 4). These relations were probed in two sets, one involving the color stimuli (A1B2/B2A1, A2B1/B1A2) and one with the shape stimuli (A3B4/B4A3, A4B3/B3A4). On the first two sets of probes M.A.'s performance suggested that the relations were not firmly established: she responded correctly on six of eight probes with color stimuli and four of seven with shape stimuli (a program error resulted in omission of one probe trial). The subject's baseline performances in those sessions were 76% and 79% accurate, the only condition in which this subject's trained performance appeared to be disrupted by the insertion of probes. However, on the second set of these probes she selected COs that were related transitively to STs on all eight trials with color stimuli and all eight trials with shape stimuli, yielding the overall totals shown in the bottom two rows in Table 17. Baseline performances returned to 93% and 100% accuracy.

Naming Posttest

Of the six printed words used in the experiments, M.A. produced the correct name for only RED and TRIANGLE. The remaining words and the names she provided for them are as follows: BLUE - "square"; CIRCLE - "triangle"; COLOR - "blue"; SHAPE - "circle".

Discussion

After explicit training on the AB/BA and AC/CA relations, this subject demonstrated transitive and symmetric relations between Set B printed instance words and Set C printed concept words (Figure 4). Those relations were not trained and were demonstrated perfectly the first time the subject had the opportunity to do so. There was no interference from the occurrence of common letters in some of the words presented as STs and COs on the BC/CB probes. She also demonstrated that transitive and symmetric relations among elements within sets and previously unrelated elements across sets developed as a result of the visual match-to-sample training she was provided (refer to Figure 4). Eight relations were trained directly, and 12 more emerged without explicit training. Of the emergent relations, eight were of particular interest because they demonstrated stimulus equivalence that depended upon context. For instance, on training trials the subject had to respond as if A1 (red), A2 (blue), B1 (RED), and B2 (BLUE) were not equivalent to one another in order to obtain reinforcement on trials where A1 or A2 was the ST and B2 and B3 were the comparisons. If the subject had treated all those stimuli as equivalent, she would have selected the correct comparison on only 50% of the trials like those just described. Yet on probe trials where, for instance, A1 (red) was the ST with B1 (blue) and A3 (circle) or A4 (triangle) as comparisons, the subject correctly matched A1 and B1 while maintaining their nonequivalence on sparsely reinforced baseline trials. In other words, the stimulus A1 (red) was treated as a specific instance (related to its corresponding printed instance word) on training configurations, and as a member of a larger class of equivalent stimuli ("colors") on probe trials. The same analysis applies to all other elements of Set A and Set B. The context that dictated differential treatment of the same stimulus appeared to consist of the ST and the incorrect CO on a given trial (cf. Fucini, 1983).

This subject also included untrained elements of Set A (two new colors and two new shapes) in conditional and symmetric relations with Set C printed concept words (COLOR and SHAPE) following AC/CA training with four Set A elements and the same Set C elements. These findings replicated results from two of three subjects in Experiment III. Apparently the dimensional similarities between the trained and untrained elements were sufficient to enable M.A. to sort the untrained elements into their respective concept groupings by relating them visually to the printed words COLOR and SHAPE.

Selective stimulus equivalence by context and assignment of previously untrained Set A elements to the correct Set C elements occurred without the benefit of auditory or orally produced labels for any of the stimuli involved. The subject was never provided with spoken names for stimuli, and although she could name most of the Set A stimuli before the experiments began, she could not name most of Set B and Set C stimuli before or after her participation. These results provide further evidence that oral naming is not necessary for the development of equivalence relations (Lazar & Kotlarchyk, in press; Mackay & Sidman, 1984; Sidman et al., in press).

EXPERIMENT IV-B

In Experiment III, the failure to obtain evidence for the transitive and symmetric BC/CB relations and subsequent error analyses suggested that preexisting trained relations among stimuli might have interfered with the development or expression of transitive relations among printed words. No such interference was evident in Experiment IV-A with a subject who, unlike Experiment III subjects, had no prior experimental training where printed words were irrelevant to conditional discrimination tasks. However, Experiment IV-A documented the existence of both directly trained and transitive relations for subject M.A. In a situation where the expression of either type of relation is possible, which type is most likely to control responding? Experiment IV-B explored relational control in a series of probe trials with two STs where the subject could select either a CO that was related directly to one ST, or a CO that was related transitively to the other ST.

Method

Subject

Subject M.A. was the only participant in this experiment.

Training and Probe Procedures

All of M.A.'s training to this point had involved one ST and two COs, so it was necessary to introduce a four-key procedure presenting two stimuli in the ostensive ST positions, with the first ST appearing in the topmost key on the apparatus (formerly the SS position in Experiments I-III) and the second appearing in the usual ST position, directly below the first. The CO positions were unchanged. To initiate this training, the experimenter sat next to the subject before the apparatus and said, "Today you're going to play a new game. First you'll see a picture up here (pointing to top key). After you touch it, you'll see a picture here (pointing to second key). When you touch that one, two pictures will come on down here (indicating the two lower keys). Touch the one down here that goes with either this one (pointing to top key) or this one (pointing to second key)". A training session started, and the experimenter remained with the subject and repeated brief versions of the instructions until it was clear that the subject understood the task. At the start of the next session, the instructions were repeated but the subject completed the session without experimenter assistance.

Two four-key training sessions were conducted (see Table 18). In the first of these, on each trial a printed word was presented behind the top key, called ST1 for this experiment, and a symbol (color or shape) was presented behind the second key (called ST2). In the second session, ST1 and ST2 were identical printed words or symbols. Every correct response was consequated with the sound of chimes. Over the two training sessions, the subject had an approximately equal number of trials on which ST1 and ST2 were redundant and nonredundant, and comparable numbers of trials on which colors, shapes, and printed words appeared in each position in the stimulus configuration. Only relations the subject had learned previously were reinforced in these sessions.

Probe trial configurations are described in Table 19. These trials presented one CO that was related directly to one ST, and one CO that was related transitively to the other ST. Numerous combinations of stimuli were logically possible, but since it was not possible to test all of them, this subset was selected to provide equal numbers of trials on which symbols and printed words appeared in each of the ST positions and

Table 18

Four-Key Training Configurations, Experiment IV-B

	ST-1	ST-2	COMPARISONS	
Session 1				
	RED	R	R	B
	BLUE	B	B	R
	COLOR	R or B	B or R	○ or △
	CIRCLE	○	○	△
	TRIANGLE	△	△	○
	SHAPE	○ or △	△ or ○	R or B
Session 2				
	COLOR	COLOR	R	○ or △
	R	R	COLOR	SHAPE
	COLOR	COLOR	B	○ or △
	B	B	COLOR	SHAPE
	SHAPE	SHAPE	○	R or B
	○	○	SHAPE	COLOR
	SHAPE	SHAPE	△	○
	△	△	SHAPE	COLOR

Table 19

Probe Configurations, Experiment IV-B

		COMPARISONS			
ST-1	ST 2	Direct-ST1	Transitive-ST1	Direct-ST2	Transitive-ST2
R	SHAPE	RED			CIRCLE
B	SHAPE	BLUE			TRIANGLE
○	COLOR	CIRCLE			RED
△	COLOR	TRIANGLE			BLUE
RED	○		COLOR	SHAPE	
BLUE	△		COLOR	SHAPE	
COLOR	○		RED	CIRCLE	
COLOR	△		BLUE	TRIANGLE	

both COs were from the same dimension (i.e., both printed words as opposed to one printed word and one symbol). Probe trials were also balanced with respect to the combinations of types of relations (direct and transitive) between COs and both STs. The eight configurations described in Table 19 constituted a set of probes, which were embedded in a baseline consisting of a combination of all the four-key training configurations described previously (see Table 18) with the probability of feedback for correct responses set at .20. Responses on probe trials were never followed by feedback. Five probe sets were administered.

Results

Training

The subject's performance in both four-key training sessions was 100% accurate.

Probes

Table 20 summarizes the results of all 40 probe trials. Each of the eight trial configurations described in Table 19 was presented five times. As the row totals indicate, M.A. responded to a CO that was related directly to either ST1 or ST2 on 28 trials, while she selected a transitively related CO on only 12 trials (70%

vs. 30% of all probe trials). The column totals show that she tended to select the CO that was related to ST1, whether directly or transitively, more often than the CO that was related to ST2 (60% vs. 40% of all probe trials). The subject's baseline performance remained above the 90% accuracy criterion for all five probe sessions.

Table 20

Experiment IV-B Probe Results

	ST1	ST2	Totals
Direct	16	12	28
Transitive	8	4	12
Totals	24	16	

If the subject's responses were random, i.e., if there were no systematic stimulus control, then the expected frequency of selection of each ST position/relation type combination (each cell in Table 20) would be 10. The observed frequencies were considerably different from those predicted by a hypothesis of no systematic control, suggesting that directly trained relations tended to control this subject's CO selection on these test trials.

Discussion

A post-hoc inference that preexisting, directly trained conditional relations interfered with the development or expression of transitive or emergent relations was drawn from subjects' error patterns on Experiment III BC/CB probes. That experiment did not, however, provide any direct tests of relative control in contexts where directly trained and emergent relations might compete. In the present experiment, where the results of such competition were assessed more directly, the subject's responses were controlled more by trained relations than by emergent relations. That control was exerted regardless of the order in which the two STs appeared in the particular probe configurations used here.

Several studies (e.g., Lazar et al., 1984; McDonagh et al., 1984; Sidman et al., 1985) have demonstrated that stimulus classes can be expanded to include stimuli that are related transitively as well as directly to existing members of the class. No other research to date has explored the relative strength of the two types of relations. Here, when the two types of relations were set against each other in a forced-choice situation, directly trained relations appeared stronger for this subject.

EXPERIMENT V

Experiment III findings suggested that transitive and symmetric relations between Set B and Set C stimuli failed to develop at least in part because of subjects' propensity to match printed words from the two sets by their common letters regardless of their trained relations to other stimuli. Experiment V was conducted to determine if a preschool subject could be taught the BC/CB relations directly; if so, training on another leg of the ABC triangle, such as AB/BA (see Figure 6), should establish the possibility for transitive and symmetric relations between stimuli that did not have obvious common features.

Method

Subject

One subject, P.E., was the subject for this experiment. His pretest results demonstrated that he could identify all Set A stimuli, and he could name all Set A stimuli except A8 (cross), but he did not identify

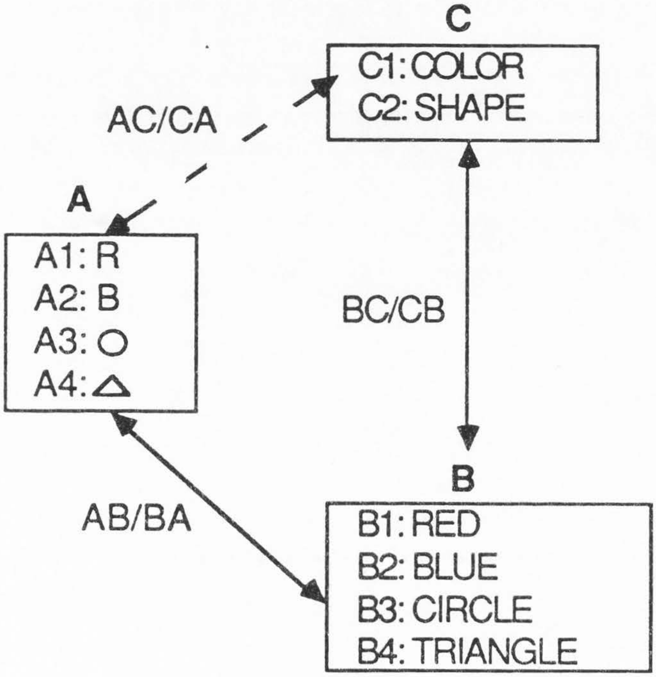

Figure 6. Trained relations (solid lines) and tested relations (broken lines) among stimulus sets in Experiment V. R = red, b = blue (hues); O = circle, △ = triangle (line drawings). All other stimuli were printed words.

or name Set B and Set C printed word stimuli with better than chance accuracy.

Training and Probe Procedures

Stimuli from Sets A, B, and C were used (refer to Table 3). The conditional relations involved in each task and corresponding stimulus arrays are described in Table 21. Pretraining (identity matching with colors, shapes, and words) was identical to pretraining completed by all preceding subjects. All training and probe trials were three-key match-to-sample tasks (one ST and two COs), and all general training and probe procedures were as described for Experiment IV.

Figure 7 lists the sequence of conditions for this experiment. Subject P.E. was trained first on the BC/CB relations, then the AB/BA relations (Figure 6). Because of difficulties encountered in training, only those BC/CB and AB/BA relations involving color stimuli were mixed to provide a baseline in which to insert probes.

Table 21

Stimulus Configurations, Experiment V

TASK	SAMPLE	COMPARISONS	
TRAINING: BC/CB			
B1C1	RED	COLOR	SHAPE
C1B1	COLOR	RED	CIRCLE or TRIANGLE
B2C1	BLUE	COLOR	SHAPE
C1B2	COLOR	BLUE	CIRCLE or TRIANGLE
B3C2	CIRCLE	SHAPE	COLOR
C2B3	SHAPE	CIRCLE	RED or BLUE
B4C2	TRIANGLE	SHAPE	CIRCLE
C2B4	SHAPE	TRIANGLE	RED or BLUE
Mixed B1C1 & B2C1	Random mixture of first four configurations.		
Mixed B3C2 & B4C2	Random mixture of second four configurations.		
Mixed B1-B4/C1-C2	Random mixture of all above configurations.		
TRAINING: AB/BA			
A1B1	R	RED	BLUE
B1A1	RED	R	B
A2B2	B	BLUE	RED
B2A2	BLUE	B	R
A3B3	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	○	△
A4B4	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	△	○
Mixed A1B1 & A2B2	Random mixture of first four configurations.		
Mixed A1-A4/B1-B4	Random mixture of all above configurations.		

(table continues)

TASK	SAMPLE	COMPARISONS	
TRAINING: BC/CB & AB/BA			
Mixed B1C1, B2C1, A1B1, A2B2	Random mixture of first four BC/CB configurations and first four AB/BA configurations.		
Mixed B3C2, B4C2, A3B3, A4B4	Random mixture of second four BC/CB configurations and second four AB/BA configurations.		
PROBES: AC/CA			
A1C1	R	COLOR	SHAPE
C1A1	COLOR	R	○ or △
A2C1	B	COLOR	SHAPE
C1A2	COLOR	B	○ or △

Note. R=red, B=blue (hues); ○=circle, △=triangle (line drawings). All other stimuli were printed words. The letters A, B, and C denote stimulus sets (see Table 3) and numbers specify elements within sets.

1. Pretraining: AA,BB
2. Probes: AC/CA
3. Training: BC/CB
4. Training: AB/BA
5. Training: BC/CB and AB/BA
6. Probes: AC/CA

Naming Posttest

Figure 7. Sequence of conditions for subject P.E., Experiment V.

Probes tested for transitive and symmetric relations between A1 (red), A2 (blue), and C1 (COLOR) (see Figure 6). Analogous relations between A3 (circle), A4 (triangle), and C2 (SHAPE) were not tested because the underlying relations could not be trained and maintained in the time available.

Posttest

Subject P.E. also completed a naming posttest with all Set B and Set C printed word stimuli at the experiment's conclusion.

Results

Pretraining

The subject's accuracy in two sessions of identity matching pretraining with colors, shapes, and words mixed was 97% and 100%.

Probes: AC/CA

Two sets of probes were administered before training commenced, one set with color stimuli (A1, A2, and C1) and one with shape stimuli (A3, A4, and C2). The subject's selections on these probes were within chance limits (Table 22).

Training: BC/CB

Training began with the four relations involving color stimuli: B1C1/C1B1 and B2C1/C1B2. In four sessions, P.E.'s matching accuracy rose from 47% to 97%. At that point the four relations involving shape stimuli (B3C2/C2B3, B4C2/C2B4) were added to the four previously trained relations. After six sessions with all eight relations, the subject's accuracy remained at about chance levels (43%-67%). He was then returned to the first training condition involving only four relations, and by the fourth session was responding 100% accurately.

Table 22

Performances of Subject P.E. on Experiment V Probes for Conditional Relations Between Set A and Set C Stimuli

Condition	Relations	Results
	AC/CA	
Pre-training	A1C1/C1A1	5/8
	A2C1/C1A2	
	A3C2/C2A3	2/8
	A4C2/C2A4	
	AC/CA	
Post-training	A1C1/C1A1	18/24
	A2C1/C1A2	

A second attempt was made to train all eight relations in the same session, with token delivery added to the chimes following correct responses. The subject's accuracy rose as high as 83% for two sessions, but ranged from 70%-77% in five other sessions. Next, the four relations involving shape stimuli (B3C2/C2B3, B4C2/C2B4) were presented in separate training sessions, and for three such sessions P.E.'s performances were 80%, 97%, and 93%. Three more sessions involving only the four color stimuli were conducted next, and his performances were 67%, 83%, and 90% accurate.

Training: AB/BA

Initially only four relations among color stimuli (A1B1/B1A1, A2B2/B2A2) were trained. Six sessions were required before P.E. attained the 90% criterion. The four relations involving shape stimuli (A3B3/B3A3, A4B4/B4A4) were added to the trained baseline, and in four sessions with all eight relations the subject scored 77%, 87%, 83%, and 90%.

Training: BC/CB and AB/BA

The BC/CB and AB/BA relations among color stimuli were mixed for three sessions, and performances were 70%, 87%, and 93% accurate. In one session with the analogous relations involving shape stimuli, however, P.E.

responded correctly on only 67% of the trials. In the interest of time and considering the difficulty he had demonstrated with more than eight relations in the same baseline, P.E. was given another session of BC/CB and AB/BA relations mixed, but including only color stimuli (A1, A2, B1, B2, and C1). Accuracy remained at 90% for those trials with chimes and a token after each correct response, but when the feedback probability was reduced to .20, accuracy fell to 67%. Criterion responding was regained when feedback for every correct response was reinstated. At this point P.E. was moved to the probe condition because only two more days of his school year were available for experimental sessions, and because baseline responding would continue to be reinforced with .20 probability during probe sessions.

Probes: AC/CA

Probe results are summarized in Table 22. Because of the difficulties this subject experienced in maintaining accurate performance when all BC/CB conditional relations were presented in a baseline with AB/BA conditional relations, the baseline and probe trials for these sessions presented only the color stimuli (A1, A2, B1, B2, and C1). On 75% (18/24) of the probes for transitive and symmetric relations between A1 and C1, and A2 and C2, P.E. responded correctly. This performance was above chance levels for 24 trials (chance range: 9-15 correct).

Naming Posttest

This subject produced correct names for only two printed words post-experimentally, TRIANGLE and BLUE. The remaining printed words and his responses to them were : RED - "cross"; CIRCLE - "square"; COLOR - "circle"; SHAPE - "circle."

Discussion

Conditional relations between printed words from Set B and Set C (see Figure 6) proved difficult for this subject to learn, particularly when all four elements from Set B and both Set C elements were used in the same training session. In fact, after a total of 27 training sessions the subject could maintain criterion accuracy levels only when the total number of relations in a single session was reduced to four, and since all training was bidirectional, half of the trials merely reversed the ST and CO without otherwise changing the configuration. The AB/BA relations (symbols and printed instance words) were less difficult but still required 10 training sessions. When BC/CB and AB/BA relations were mixed, it was necessary to drop the shape stimuli altogether, and thus to probe only for transitive and symmetric relations among A1 (red), A2 (blue), and C1 (COLOR).

Transitive and symmetric relations between the Set A and Set C stimuli tested were demonstrated on 75% of the probe trials. This performance suggested that such relations were incompletely formed, possibly because the underlying relations were still not firmly established, or because there was an insufficient number of probe trials to permit the relations to develop. Other research has demonstrated that transitive relations can actually develop in the process of testing for them (e.g., Lazar et al., 1984; Sidman et al., 1985). Further testing may have produced stronger evidence for the existence of AC/CA relations, but some improvement over pre-training chance performances was demonstrated on the post-training probes that were completed (cf. Mackay & Sidman, 1984).

As with subject M.A. in Experiment IV, there was evidence that equivalence relations were developing in the absence of oral names for the stimuli involved in those relations.

EXPERIMENT VI

In Experiment III, some preschool subjects tended to track features of printed word stimuli -- i.e., common letters -- on trials where the task was to match nonidentical printed words. Transitive and symmetric relations between printed words were not expressed despite the presence of the necessary underlying relations. Experiment VI asked whether providing dictated names for some of the printed words would prevent control by single elements or features, and result in the development of the expected transitive and symmetric relations. Other studies that have investigated the role of naming in mediating stimulus equivalence have provided dictated samples in the context of experimental match-to-sample tasks (e.g., Sidman et al., 1974; Sidman et al., in press). This experiment examined the effects of auditory-visual matching and oral naming training conducted outside the experimental training and testing context, with visual stimuli presented on cards rather than on the match-to-sample apparatus.

Method

Subject

Subject A.M., a five-year-old female, was the subject for Experiment VI. On pretests she correctly identified all the colors in Set A but responded inconsistently to the shapes (75% correct). She did not identify printed words with better than chance accuracy (30% correct). On naming pretests she named all four colors correctly on two consecutive trials, but again responded inconsistently to shapes, naming two of them correctly on one trial and all of them on the second trial. None of the printed words to be used in the experiment were named correctly.

Training and Probe Procedures

Pretraining for this subject was identical to that conducted with Experiment I and II subjects, i.e., identity matching with colors, shapes, and printed words using the four-key configuration with the SS and ST identical to one another. All training and testing on the apparatus used four-key procedures.

In addition to stimulus Sets A, B, and C described previously, four new stimulus sets were employed in this experiment: Set D consisted of dictated instance words;

Set E was a set of the corresponding instance words named orally by the subject; Set F was dictated concept words; and Set G was the concept words named orally by the subject. These stimulus sets and their elements are described in Table 4 and Figures 8a and 8b. Sets D, E, F, and G were used only in training procedures, described below; none were involved in probes. Only one element of Sets F and G was used in training, F1 ("COLOR") and G1 ("color"). As with the preceding experiments, stimuli in Sets A, B, and C were visual and were used in both training and probe procedures.

Subject A.M. received auditory-visual matching and oral naming training that did not involve stimulus presentations on the experimental apparatus. Instead, stimuli from Sets A, B, and C were presented on 4" x 6" cards; elements of Sets D and F were STs dictated by the experimenter; and elements of Sets E and G were oral names produced by the subject in response to printed word STs. Relations trained and trial configurations are described in the top portion of Table 23. Procedures for each such training condition are described briefly below. In all of these conditions, correct responses were followed by praise from the experimenter ("Right", "OK", "Good"). Incorrect responses were followed by "No" from the experimenter and the next scheduled trial. The

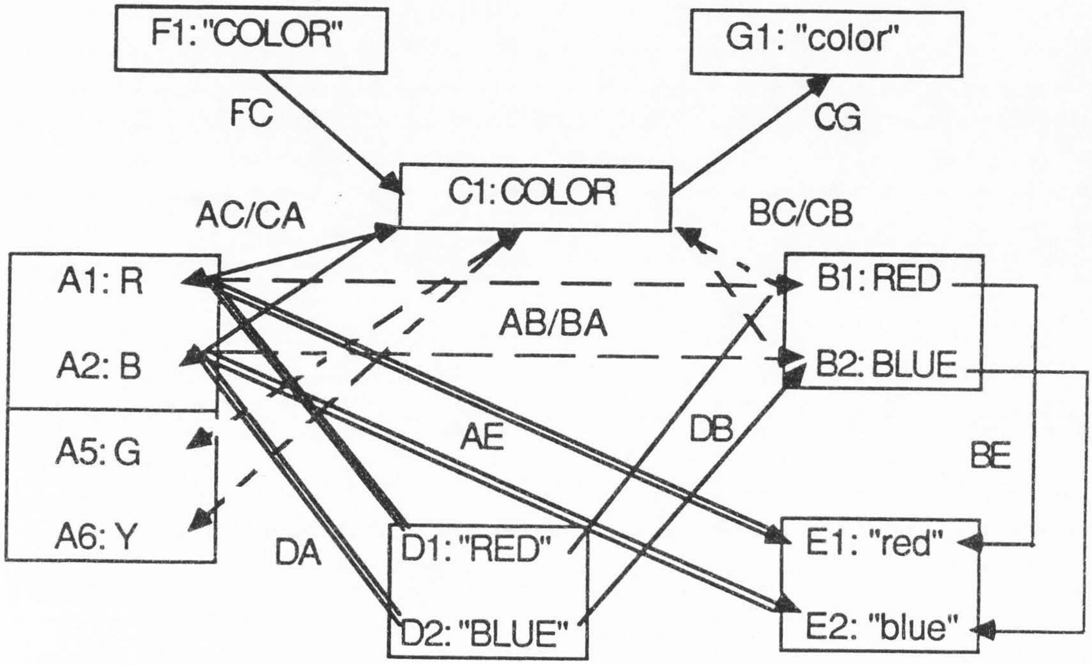

Figure 8a. Pretested relations (double lines), trained relations (solid lines), and untrained relations (broken lines) among color stimuli in Experiment VI. R = red, B = blue, G = green, Y = yellow (hues). Other stimuli were printed words (Sets B and C), words dictated by the experimenter (Sets D and F), and words named orally by the subject (Sets E and G).

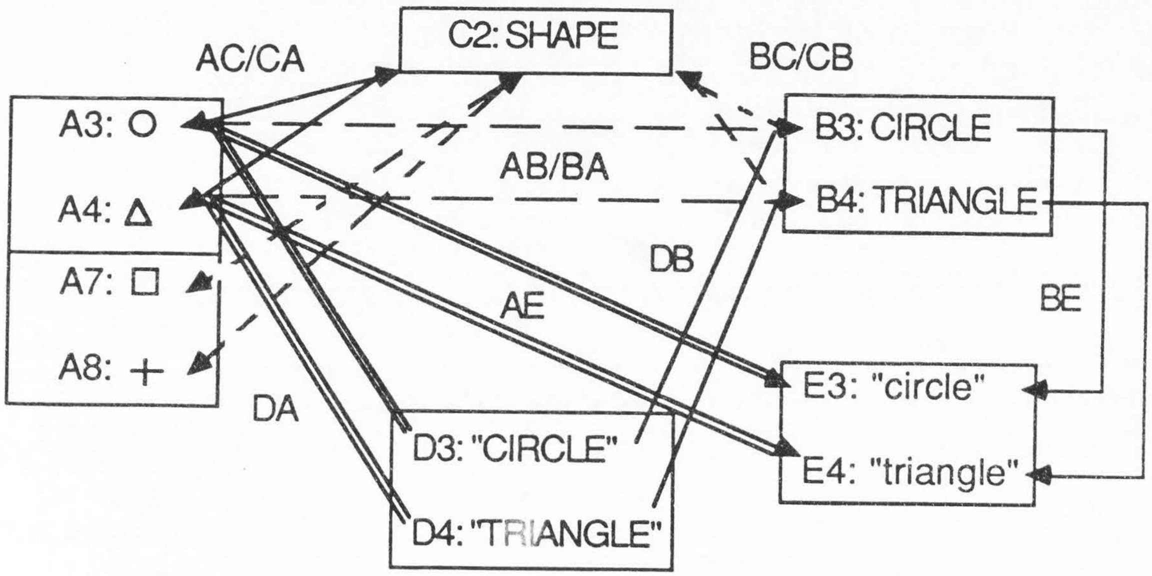

Figure 8b. Pretested relations (double lines), trained relations (solid lines), and untrained relations (broken lines) among shape stimuli in Experiment VI. ○ = circle, △ = triangle, □ = square, + = cross (line drawings). Other stimuli were printed words (Sets B and C), words dictated by the experimenter (Set D), and words named orally by the subject (Set E).

Table 23

Stimulus Configurations, Experiment VI

TASK	SAMPLE	COMPARISONS	
TRAINING: DB			
D1B1	"RED"	RED	BLUE
D2B2	"BLUE"	BLUE	RED
D3B3	"CIRCLE"	CIRCLE	TRIANGLE
D4B4	"TRIANGLE"	TRIANGLE	CIRCLE
TRAINING: FC			
F1C1	"COLOR"	COLOR	SHAPE
TRAINING: BE			
B1E1	RED	"red"	-
B2E2	BLUE	"blue"	-
B3E3	CIRCLE	"circle"	-
B4E4	TRIANGLE	"triangle"	-
TRAINING: CG			
C1G1	COLOR	"color"	-

	SUPERORDINATE	SAMPLE	COMPARISONS	
TRAINING: AA with B				
A1A1 with B1	RED	R	R	B
A2A2 with B2	BLUE	B	B	R
A3A3 with B3	CIRCLE	○	○	△
A4A4 with B4	TRIANGLE	△	△	○
Mixed AA with B	Random mixture of above configurations			
TRAINING: AB/BA				
A1B1	R	R	RED	BLUE
B1A1	RED	RED	R	B
A2B2	B	B	BLUE	RED
B2A2	BLUE	BLUE	B	R
A3B3	○	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	CIRCLE	○	△
A4B4	△	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	TRIANGLE	△	○
Mixed A1-A4/B1-B4	Random mixture of above configurations			

(table continues)

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
TRAINING: AC/CA				
A1C1	R	R	COLOR	SHAPE
C1A1	COLOR	COLOR	R	○ or △
A2C1	B	B	COLOR	SHAPE
C1A2	COLOR	COLOR	B	○ or △
A3C2	○	○	SHAPE	COLOR
C2A3	SHAPE	SHAPE	○	R or B
A4C2	△	△	SHAPE	COLOR
C2A4	SHAPE	SHAPE	△	○
Mixed A1-A4/C1-C2	Random mixture of above configurations			
PROBES:				
AB/BA				
A1B1	R	R	RED	BLUE
B1A1	RED	RED	R	B
A2B2	B	B	BLUE	RED
B2A2	BLUE	BLUE	B	R
A3B3	○	○	CIRCLE	TRIANGLE
B3A3	CIRCLE	CIRCLE	○	△
A4B4	△	△	TRIANGLE	CIRCLE
B4A4	TRIANGLE	TRIANGLE	△	○
BC/CB				
B1C1	RED	RED	COLOR	SHAPE
C1B1	COLOR	COLOR	RED	CIRCLE or TRIANGLE
B2C1	BLUE	BLUE	COLOR	SHAPE
C1B2	COLOR	COLOR	BLUE	CIRCLE or TRIANGLE
B3C2	CIRCLE	CIRCLE	SHAPE	COLOR
C2B3	SHAPE	SHAPE	CIRCLE	RED or BLUE
B4C2	TRIANGLE	TRIANGLE	SHAPE	COLOR
C2B4	SHAPE	SHAPE	TRIANGLE	RED or BLUE

(table continues)

TASK	SUPERORDINATE	SAMPLE	COMPARISONS	
New AC/CA				
A5C1	G	G	COLOR	SHAPE
C1A5	COLOR	COLOR	G	□ or +
A6C1	Y	Y	COLOR	SHAPE
C1A6	COLOR	COLOR	Y	□ or +
A7C2	□	□	SHAPE	COLOR
C2A7	SHAPE	SHAPE	□	G or Y
A8C2	+	+	SHAPE	COLOR
C2A8	SHAPE	SHAPE	+	G or Y

Note. Upper case words inside quotes were dictated samples. Lower case words inside quotes were oral names produced by the subject. R=red, B=blue, G=green, Y=yellow (hues); O=circle, Δ=triangle, □=square, +=cross (line drawings). All other stimuli were printed words. The letters A-G denote stimulus sets (see Table 4) and numbers specify elements within sets.

experimenter recorded the subject's responses on a data sheet.

1. DB. An element of Set D (instance words) was dictated by the experimenter, and the subject pointed to one of two cards displaying Set B elements (printed instance words).

2. FC. An element of Set F (concept words) was dictated by the experimenter, and the subject pointed to one of the two Set C elements (printed concept words). Trials of this type were mixed with DB trials.

3. BE. An element from Set B (printed instance words) was presented to the subject and the experimenter asked "What is this?".

4. CG. One of the Set C elements (printed concept words) was presented, and the experimenter asked "What is this?". These trials were mixed with BE trials.

Subject A.M. also received visual match-to-sample training on the experimental apparatus with procedures identical to those used in the preceding experiments. Relations trained in this fashion and their corresponding trial configurations are described in the middle portion of Table 23, and probe configurations are shown in the lower portion of the same table. All relations trained and tested in this experiment are also diagrammed in Figures 8a and 8b. Note that the DA and AE relations existed (although incompletely for some elements) before the experiment began, as documented by the subject's pretest performance in identifying colors and shapes in response to dictated words, and naming colors and shapes.

The conditions A.M. experienced are listed in Figure 9. Following pretraining and an initial set of probes on the apparatus, she received the auditory-visual matching and oral naming training described above with a subset of all the stimuli, a set of probes, visual matching training on the apparatus, and another set of probes. Reviews of trained auditory-visual relations and training on the remaining auditory-visual relations followed, with probes after each set of review and training sessions. Next, additional relations were trained with visual match-to-sample procedures on the apparatus, followed by the final probe sets. Each of these conditions is described in conjunction with the results, following.

Results

Pretraining

Twelve pretraining sessions were required for A.M. to attain the criterion of 90% correct on each type of visual identity matching trial (colors, shapes, and printed words).

1. Pretraining: AA,BB
2. Probes: AB/BA
3. Training: DB and FC
4. Training: BE and CG
5. Probes: AB/BA
6. Training: AA with B
7. Probes: AB/BA
8. Review: DB
9. Review: BE
10. Probes: AB/BA
11. Training: DB
12. Training: BE
13. Probes: AB/BA
14. Probes: BC/CB
15. Training: AB/BA
16. Training: AC/CA
17. Probes: BC/CB
18. Probes: New AC/CA

Figure 9. Sequence of conditions for subject A.M., Experiment VI.

Probes: AB/BA

All probe results are presented in Table 24. Two sets of probes tested for any preexisting relations between stimuli from Sets A (symbols) and B (printed instance words). One set of probes presented the color stimuli (A1, A2, B1, B2) and the other presented the shape stimuli (B1, B2, B3, B4). The subject selected the nominally correct comparisons at chance levels (Table 24, pre-training).

Training: DB and FC

Initially auditory-visual training was conducted on only two DB relations, D1B1 and D2B2 (Figure 8a); that is, on each trial the experimenter dictated D1 ("RED") or D2 ("BLUE") and the subject selected either B1 (RED) or B2 (BLUE). Other trials had F1 ("COLOR") as the dictated sample and C1 (COLOR) and C2 (SHAPE) as printed word COs (Figure 8a). Each dictated sample was presented ten times in a 30-trial session, with the sequence of trials and the position of the correct CO (on the subject's left or right) randomized from trial to trial. She responded correctly on nine of ten D1B1 trials, all ten D2B2 trials, and all ten F1C1 trials.

Table 24

Performances of Subject A.M. on Experiment VI Probes for Conditional Relations Between Set A, Set B, and Set C Stimuli

Condition	Relations	Results
	AB/BA	
Pre-training	A1B1/B1A1	4/8
	A2B2/B2A2	
	A3B3/B3A3	2/8
	A4B4/B4A4	
	AB/BA	
Post-training	A1B1/B1A1	6/8
(DB, FC, BE, CG)	A2B2/B2A2	
	AB/BA	
Post-training	A1B1/B1A1	9/24
(AA with B)	A2B2/B2A2	
	AB/BA	
Post-review	A1B1/B1A1	14/16
(DB, BE)	A2B2/B2A2	
	AB/BA	
Post-training	A3B3/B3A3	16/16
(DB, BE)	A4B4/B4A4	
	BC/CB	
Post-training	B1C1/C1B1	5/8
(DB, BE)	B2C1/C1B2	
	B3C2/C2B3	0/8
	B4C2/C2B4	

(table continues)

Condition	Relations	Results
	BC/CB	
Post-training	B1C1/C1B1	22/24
(AB/BA & AC/CA)	B2C1/C1B2	
	B3C2/C2B3	18/24
	B4C2/C2B4	
	New AC/CA	
Post-training	A5C1/C1A5	16/16
(AB/BA & AC/CA)	A6C1/C1A6	
	A7C2/C2A7	16/16
	A8C2/C2A8	

Training: BE and CG

The visual sample was either B1 (RED), B2 (BLUE), or C1 (COLOR), and A.M. was to produce the oral name. In the first session she responded correctly on seven of ten trials with B1, four of ten with B2, and all ten with C1. By the second session her performance improved to 10/10 and 8/10 on B1 and B2 trials respectively, while responses to C1 remained perfect. In the third session she responded correctly on all 20 trials with B1 and B2 and nine of ten trials with C1.

Probes: AB/BA

Since D1A1 and D2A2 relations were present in pretesting, and D1B1 and D2B2 relations had been trained, the prerequisites existed for transitive and symmetric relations between A1 and B1, and A2 and B2 (see Figure 8a). On one set of probes, A.M.'s accuracy was within the range of chance (Table 24, post-training DB, FC, BE, CG).

Training: AA with B

The AB/BA relations tested in the preceding probes appeared to be incompletely formed. This training condition was inserted to determine if repeated pairings of Set A and Set B stimuli would be sufficient to reinforce AB/BA relations, even though matches between

Set A and Set B stimuli were not directly reinforced. Trial configurations are described in Table 23. On each trial an element of Set B (printed instance words) was presented in the topmost (SS) position on the stimulus display. The corresponding element from Set A (symbols) appeared in the ST and correct CO positions, and another Set A stimulus was the incorrect CO. Chimes sounded after each correct response. In two sessions with color stimuli only (A1, A2, B1, B2) the subject's responses were 93% and 97% correct. Two sessions followed with shape stimuli only (A3, A4, B3, B4) and her performances were 87% and 93% correct. In two sessions with all stimuli used in mixed trials, she responded correctly on 93% and 100% of the trials, and when the probability of feedback (chimes) for correct responses was reduced to .20 her accuracy was 93%.

Probes:AB/BA

Three sets of probes were administered to test for transitive and symmetric relations between color stimuli from Set A and Set B (i.e., A1B1/B1A1, A2B2/B2A2; Figure 8a). The subject's overall accuracy was still within chance limits (Table 24, post-training AA with B).

Review: DB and BE

Brief reviews of the auditory-visual and oral naming relations described previously were conducted next. One session consisted of five D1B1 trials and five D2B2 trials in a random mixture. A.M. responded correctly on all five D1B1 ("RED" - RED) trials, and three of five D2B2 ("BLUE" - BLUE) trials. She was then given 20 oral naming trials consisting of ten trials with the visual sample B1 (RED) and ten trials with the visual sample B2 (BLUE). She named B1 correctly on all ten opportunities, and was correct on eight of ten chances with B2.

Probes: AB/BA

The A1B1/B1A1 and A2B2/B2A2 relations (refer to Figure 8a) were tested once again in two sets of eight probes per set. Subject A.M. selected the correct comparison seven times in each set, for a total score of 14/16 (Table 24, post-review DB, BE).

Training: DB

The two DB relations that were not trained previously were now trained with the auditory-visual matching procedures already described (see Figure 8b). Dictated samples were D3 ("CIRCLE") and D4 ("TRIANGLE"); printed word comparisons presented on cards were B3

(CIRCLE) and B4 (TRIANGLE). Ten trials with each sample were presented. After missing the first trial with each sample, A.M. responded correctly on the remaining 18 trials.

Training: BE

The remaining BE oral naming relations were trained by presenting the printed words B3 (CIRCLE) and B4 (TRIANGLE) on cards ten times each in random order, and requesting the oral name for each (Figure 8b). The subject produced the correct name on five of ten B3 trials, and seven of ten B4 trials.

Probes: AB/BA

Relations A3B3/B3A3 and A4B4/B4A4 (Figure 8b), which had not been tested since pre-training, were examined in two probe sessions. Responses indicated the presence of transitive and symmetric relations between shapes and their corresponding printed instance words on all 16 probe trials (Table 24, post-training DB, BE).

Probes: BC/CB

Probes just completed documented the existence of AB/BA relations. The subject had also been taught the oral names for Set B stimuli (DB and BE) and for stimulus

C1 (F1C1 and C1G1). (Refer to Figures 8a and 8b for trained and untrained relations). At this point probes were inserted to assess possible relations among stimuli in Sets B (printed instance words) and C (printed concept words). On one set of probes with color stimuli (B1, B2, and C1), A.M.'s responses were in the chance range. However, on an analogous set of probes with shape stimuli (B3, B4, C2), she did not make a correct selection on any of eight probes (Table 24, post-training DB, BE). This non-chance performance was examined for the possible existence of systematic stimulus control. No ST-CO combination was selected more than twice, and the same incorrect CO was selected in response to different STs (e.g., COLOR was selected twice in response to CIRCLE and twice in response to TRIANGLE). There were no clearly systematic patterns of responding on these probes.

Training: AB/BA

Although probe performances on the last AB/BA probes were well above chance, A.M. made some errors that suggested that relations A1B1/B1A1 and A2B2/B2A2 (Figure 8a) may not have been solidly established, so one training session was conducted to reinforce AB/BA relations directly. All eight relations were presented in this session: A1B1/B1A1, A2B2/B2A2, A3B3/B3A3, A4B4/B4A4. The subject's performance was 100% correct.

Training: AC/CA

The second leg of the ABC triangle diagrammed in Figures 8a and 8b was trained by reinforcing responses that matched A1 (red) and A2 (blue) to C1 (COLOR) and vice versa, and A3 (circle) and A4 (triangle) to C2 (SHAPE) and vice versa. On the first such training session, A.M.'s performance was 100% accurate. When the probability of chimes following correct responses was reduced from 1.0 to .20, her accuracy fell to 83% for one session but regained criterion (97%) in the next session.

Probes: BC/CB

The prerequisite relations for emergent BC/CB relations now existed, so three sets of probes each were administered with color stimuli (B1, B2, C1) and shape stimuli (B3, B4, C2). Performances on both types of probes were well above chance, but suggested that the transitive and symmetric relations between the shape instance words and the concept word SHAPE were not as completely developed as the relations between the color instance words and the concept word COLOR (Table 24, post-training AB/BA and AC/CA).

Probes: New AC/CA

These probes were conducted in an attempt to replicate findings reported earlier, where two untrained colors (A5 - green and A6 - yellow) and two untrained shapes (A7 - square and A8 - cross) were presented as STs or COs with the two printed concept words (C1 - COLOR and C2 - SHAPE). Two sets of color probes and two sets of shape probes were presented. Subject A.M. related the untrained colors and shapes to the appropriate concept word on all probe trials (Table 24, post-training AB/BA and AC/CA).

Naming Posttests

At the end of the experiment, all printed words used in the experiment were presented on cards and A.M. was asked to provide the oral name of each. She correctly named COLOR, RED, and BLUE on both posttest trials; TRIANGLE was named correctly on one of two trials; and CIRCLE and SHAPE were named "color" and "triangle" respectively on both naming trials.

Discussion

This subject was initially taught the oral names for the printed words RED and BLUE (relations D1B1, D2B2, B1E1, and B2E2 in Figure 8a). Pretesting showed that she already knew the oral names for the symbols red and blue (D1A1, D2A2, A1E1, and A2E2 in Figure 8a). The DA and DB relations made the transitive and symmetric relations A1B1/B1A1 and A2B2/B2A2 logically possible, but on the first set of probes for those relations A.M.'s performance (6/8 correct) indicated that those relations were not developed perfectly. The next training phase, where Set B stimuli appeared in the SS position on trials where identity matches with Set A stimuli were reinforced, seemed to disrupt rather than strengthen the AB/BA relations: her performance on three probe sets following that training was at chance. Following a review of the oral names for RED and BLUE (D1A1, D2A2, B1E1, and B2E2), performance on probes for the A1B1/B1A1 and A2B2/B2A2 relations improved. Next A.M. was taught the oral names for CIRCLE and TRIANGLE (relations D3A3, D4A4, B3E3, and B4E4 in Figure 8b), and demonstrated perfect transitive and symmetric relations A3B3/B3A3 and A4B4/B4A4 on subsequent probes. Thus four classes of equivalent stimuli each consisting of a symbol (A1-A4), a printed name (B1-B4), and an oral name (D1-D4, E1-E4) were established following relatively limited auditory-visual matching and oral naming training. This subject had only ten training trials and five review trials on the first two DB or auditory-visual matching relations

(RED and BLUE), and thirty training trials plus ten review trials on producing the oral names for the same two printed stimuli. Training with the second pair of printed words went more quickly, requiring only ten auditory-visual matching trials each with CIRCLE and TRIANGLE (D3B3 and D4B4 relations), and ten oral naming trials each with the same two printed stimuli (B3E3 and B4E4 relations).

Possible transitive and symmetric relations between RED and COLOR, and BLUE and COLOR (B1C1/C1B1 and B2C1/C1B2) were first tested after the AB/BA leg of the ABC triangle (see Figure 8a) was established. The other relations that should have been prerequisite to emergence of B1C1/C1B1 and B2C1/C1B2 -- A1C1 and A2C1 -- had not been demonstrated at that point. The subject had, however, been taught the oral names for the printed words COLOR, RED, and BLUE. If prior learning had established that red and blue were called "colors," then the AC/CA relations would also exist and the BC/CB relations between the color words could have developed. This did not appear to be the case, as A.M.'s accuracy on BC/CB probes was at chance. She did not correctly match SHAPE (C2) to CIRCLE (B3) or TRIANGLE (B4) on any of eight probes at this stage, which was not surprising since she had not been taught any of the underlying relations, nor had she learned the oral name for the printed word SHAPE.

After visual match-to-sample training on all the AC/CA relations (colors and shapes with corresponding printed concept words), the transitive and symmetric relations between the printed instance words RED and BLUE and the printed concept word COLOR were well developed (22/24 correct on probes). Similar probes for transitive and symmetric relations between the printed instance words CIRCLE and TRIANGLE and the printed concept word SHAPE indicated that those relations were less well established, though above chance (18/24 correct). The visual match-to-sample training on the AC/CA relations, together with the AB/BA relations that had emerged from earlier auditory-visual and oral naming training, was sufficient to enable an additional set of relations to emerge between printed words RED and BLUE and printed word COLOR. Although the same underlying relations existed to permit the development of transitive and symmetric relations between the printed words CIRCLE and TRIANGLE and the printed word SHAPE, these relations appeared not to have developed completely. The only difference in the training involving color words and shape words was that the subject was never taught the oral name for the printed word SHAPE. She also had fewer auditory-visual matching and oral naming trials with the printed words CIRCLE and TRIANGLE than with color words, but those performances were above criterion, and appeared sufficient to enable her to match those words to their corresponding symbols on AB/BA probes. While it seems clear that oral naming is neither necessary nor sufficient for the development of stimulus equivalence (Mackay & Sidman, 1984), in this case an equivalence class did not form as readily when a critical oral name was not trained.

As did several subjects in the earlier experiments, A.M. demonstrated conditional and symmetric relations among two untrained colors and the printed word COLOR, and two untrained shapes and the printed word SHAPE. The absence of an auditory label or name for SHAPE did not detract from her ability to sort two colors and shapes she had not seen in the context of this experiment ccording to their printed concept labels.

CONCLUSIONS AND GENERAL DISCUSSION

Contiguity *vs* Conditionality

In the first two experiments, mere contiguity of printed words and symbols over many trials proved insufficient for the development of associations between the stimuli for eight preschool children. Conditional relations between symbols (Set A) and printed concept words (Set C) developed for one subject in Experiment II, but that subject failed to demonstrate relations between symbols and printed instance words (Set B) following training in which printed words from both Set B and Set C were presented as nominal contextual stimuli. During training, different conditional relations were reinforced in the presence of particular contextual stimuli: identity matching relations between colors and shapes in the presence of corresponding printed instance words from Set B, and arbitrary matching relations between nonidentical colors and shapes in the presence of corresponding printed concept words from Set C. The children in the first two experiments apparently did not attend to the contextual stimuli when performing these simple discrimination tasks. Fucini (1983, Experiment I) reported analogous findings when subjects failed to discriminate the different contexts (in her case, consisting of different incorrect comparisons) in which conditional relations were reinforced. In the present research, the printed words appearing only as contextual stimuli were unnecessary to successful completion of the match-to-sample tasks; the problem on any trial could be solved simply by learning sample-comparison relations, so the printed words were uninformative (Egger & Miller, 1962, 1963). In fact, the children in this research may have learned not to respond to stimuli that were redundant or uninformative. Fucini (1983) provided her subjects with second-order conditional discrimination training to force them to attend to the S- that determined the context of each problem. In order for a contextual stimulus to exert control over responding, it may be necessary that the contextual stimulus be related conditionally to the conditional relations reinforced in its presence.

Interference with Emergent Relations

Three preschool children who had participated in one of the first two experiments were trained explicitly to relate each of four colors and shapes to their corresponding printed instance words (relations AB and BA; see Figure 3), and to relate two colors to the printed word COLOR and two shapes to the printed word SHAPE (relations AC and CA, Figure 3). Expected transitive and symmetric relations between printed instance words and printed concept words (relations BC and CB, Figure 3) were not demonstrated by any of these subjects. Several factors could account for this failure. First, these subjects all had considerable experience in Experiment I or II where printed words were insignificant to the task at hand. Even the extensive direct training on relations between symbols and printed words they received in Experiment III may have been insufficient to overcome their recent training history. Second, preexisting directly trained relations, i.e., identity matching relations between common letters in words, may have blocked or superceded the development or expression of transitive relations between printed words. Finally, conditional relations between printed words in general proved difficult for these preschool children. Most of the twelve children who served as subjects for this research performed identity matching with colors and shapes readily, but required some additional training to match identical printed words accurately.

Experiment V provided additional evidence that learning conditional relations between printed words is difficult for children who have little or no prior experience with such stimuli. Nonetheless, once the BC/CB relations between printed instance words and printed concept words were trained, and AB/BA relations were established between the colors red and blue and their printed names, transitive and symmetric AC/CA relations were demonstrated on 75% of the probe trials. That is, the two colors were matched to the printed word COLOR without training. There was evidence that an equivalence class consisting of the colors red and blue, the printed words RED and BLUE, and the printed word COLOR was developing following simple conditional discrimination training with visual stimuli. Unfortunately it was not possible to continue testing to see if the AC/CA relations would have strengthened with additional opportunities to express them, nor to test for equivalence among all the elements in the "color" class. However, some basic reading comprehension (Sidman, 1971) resulted from the visual conditional discrimination training received by the subject in Experiment V.

The single subject in Experiment IV-A was trained explicitly on the AB/BA and AC/CA relations (Figure 4) with standard match-to-sample procedures, i.e., there was no superordinate stimulus on any trial, and the only potential contextual stimuli were the incorrect comparisons present in each three-key stimulus array. Unlike the Experiment III subjects, this subject demonstrated the transitive and symmetric BC/CB relations between printed instance and concept words without any apparent interference due to the common features of some of the words. Although this child was about a year older than the children in the preceding experiments, she had had no preschool experience except the half-day kindergarten in which she was enrolled during the time the experiment was conducted, and she did not name printed words any more accurately than the younger subjects on either the pre- or posttests. The contrast between her performances on the BC/CB tests and those of the subjects in Exeriment III could be attributable to training history differences. This subject did not experience any conditions where printed words were uninvolved in the experimental tasks; from the outset of this experiment, printed words were always correlated with reinforcement. Although the subject in Experiment IV was slightly older than the children in the first three experiments, she also did not receive the possibly confounding training the younger subjects received, so the differences in their results could be correlated with age.

Selective Equivalence

In addition to the emergent BC/CB relations, M.A.'s other probe performances in Experiment IV-A demonstrated that several other relations had emerged as a result of her training. Transitive and symmetric relations were demonstrated between pairs of elements within stimulus sets (red and blue, circle and triangle, RED and BLUE, CIRCLE and TRIANGLE), and between elements in two different sets that were each related, directly or transitively, to a third common stimulus (red and BLUE, blue and RED, circle and TRIANGLE, triangle and CIRCLE). Other investigators (Dixon, 1978; Fucini, 1983) have reported equivalence between elements of the same stimulus set that had been trained to the same auditory sample, but in this experiment some of the transitively related stimuli had been directly trained to the same visual sample, while others were built upon underlying visual transitive relations.

This subject entered the experiment with oral names for the colors and shapes in stimulus Set A. The AB/BA training she received established bidirectional conditional relations between each color or shape and its printed name. Following AC/CA training, her performance on probe trials indicated that two visual equivalence classes had formed: one consisting of the colors red and blue, the printed words RED and BLUE, and the printed word COLOR; and the other made up of the shapes circle and triangle, the printed words CIRCLE and TRIANGLE, and the printed word SHAPE. However, within each of the sessions where her response on each probe trial indicated that a particular stimulus was a member of one of these stimulus classes, she also maintained previously trained conditional relations that had established that some of the stimuli were <u>subsets</u> of the larger class. For example, one probe session presented some trials where the ST was the color red, and comparisons were the printed words BLUE and TRIANGLE. Selection of BLUE was evidence that the colors and color words were members of the same class. In the same session, some trials in the sparsely reinforced baseline had the color red as ST, and comparisons were the printed words BLUE and RED. The red-RED relation had been trained, and on these trials selection of BLUE would have been incorrect. The only difference between the two types of trials was the incorrect comparison. On the probe trials, when the incorrect comparison was from the other class, the color red and printed word BLUE were appropriately treated as members of the same class. On baseline trials, where the incorrect comparison was from the same class as the ST, the color red and printed word BLUE were not equivalent.

During the first session with probes like these, the subject's performance on probes was near chance, and baseline performance deteriorated (i.e., on some baseline trials where the ST was the color red, she selected BLUE instead of RED). By the second session, without any intervening training or testing, her probe and baseline performances were both nearly perfect, suggesting that she began to discriminate that the S- was different on the two types of trials.

Fucini (1983) established four stimulus classes each consisting of an auditory stimulus and two visual stimuli. Two of the four classes had a common visual element. In her first experiment, following simple auditory-visual conditional discrimination training, subjects did not discriminate that the common stimulus had appeared with one S- when it was trained with the first stimulus class, and a different S- when it was trained with the second stimulus class; the two classes with the element in common became one larger equivalence class. Subjects in her second experiment were trained explicitly to attend to the S- on each trial, and their behavior on probes indicated that they treated the common stimulus as a member of the first class only when the S- trained with that class was present, and as a member of the second class with the S- from that class. Fucini referred to this behavior as "selective equivalence." In the present experiment, the relations that established certain stimuli as subsets of the equivalence classes (e.g., between the color red, its printed name, and its oral name) did not emerge without training but rather were trained directly, so the stimuli in those subsets cannot be described as equivalence classes (Sidman & Tailby, 1982; Sidman et al., 1982); therefore, this subject's performance on the types of trials discussed above is not perfectly analogous to that of Fucini's subjects. However, it was necessary for this subject to discriminate the context, the S-, on different trials in probe sessions to determine the equivalence or nonequivalence of stimuli such as the color red and the printed word BLUE. In contrast to Fucini's findings, contextual control developed following simple conditional discrimination training. There are several differences between the two studies that could account for the different results, and both direct and systematic replications are needed to clarify the development of contextual stimulus control. One obvious difference is that Fucini used auditory-visual conditional discrimination training procedures, while this experiment employed only visual stimuli. Whether that is a critical difference remains to be explored.

This experiment added to the evidence (e.g., Mackay

& Sidman, 1984) that simple reading comprehension can be trained with purely visual match-to-sample procedures. It represents a step toward an analysis of the type of stimulus control that occurs in some complex language behavior, where words exert contextual control over membership in stimulus classes.

Competing Stimulus Relations

In the second phase of Experiment IV, on probes where either directly trained or transitive relations could be expressed, directly trained relations tended to control responding more than transitive relations. These results raise interesting questions regarding the relative strength of different types of stimulus relations, particularly those that have been reinforced directly vs relations that generalize from other training and have never been reinforced. Transitive relations may be less robust than directly trained relations. The fact that transitive relations often emerge slowly during repeated testing for them may be further evidence of their tentative nature.

Investigators have capitalized on the efficiency of stimulus equivalence procedures for developing large stimulus classes, and applications to concept learning have been discussed in this paper and elsewhere. But a great deal remains to be learned about the role of emergent relations in concept formation. Suppose a child learns that a set of stimuli constitute an equivalence class. Some relations among members of the class may have been trained directly, while others developed transitively. Are directly trained relations recalled more easily or retained longer than transitive relations? In learning some concepts, individuals may be faced with situations where one stimulus is a member of two classes (cf. Fucini, 1983), or a stimulus is at once a member of a large class as well as a smaller class of stimuli that constitute a subset of the larger class (cf. Experiment IV-A). The decision as to class membership at a given moment may be influenced by explicit contextual cues (Fucini, 1983; Lazar & Kotlarchyk, in press); it may also be determined by the nature of the relations -- direct or transitive -- between the stimulus in question and the other elements in each stimulus class or subset. Exploring issues such as these will be necessary to advancing empirical analyses of complex behaviors (Sidman, in press).

Oral Naming and Equivalence

In Experiment VI, a preschool child was taught oral names for some of the printed word stimuli outside the experiment proper. The AB/BA relations (Figures 8a, 8b) between symbols and their corresponding printed names then emerged with repeated testing, and the AC/CA relations were trained with visual match-to-sample procedures. The transitive and symmetric BC/CB relations (printed instance words to printed concept words) were demonstrated without explicit training. In contrast to the subjects in Experiment III, subject A.M. in this experiment showed no tendency to match printed words by their common letters. The oral naming training she received may have made it less likely that she would track features of the printed word stimuli that were correlated with reinforcement. The auditory labels she was provided for the printed words may have established those stimuli as single units rather than composites of elements (letters).

While it seems clear that oral naming is neither necessary nor sufficient for the development of stimulus classes (Lazar et al., 1984; Mackay & Sidman, 1984), in this case oral naming may have facilitated the formation of equivalence classes. This subject was not taught an oral name for the printed concept word to which other "shape" stimuli were eventually linked by visual training. She was taught the oral name for the printed word COLOR. Probes provided some evidence for equivalence among the "shape" stimuli (75% correct on BC/CB probes), but it was not as strong as for the "color" stimuli (92% correct on BC/CB probes).

Few studies that have attempted to establish visual stimulus equivalence have tested oral naming after visual match-to-sample training and testing. The results of this research are consistent with those of studies that did report oral naming posttesting (Lazar et al., 1984; Sidman et al., in press): subjects in Experiments IV, V, and VI failed to apply common names to stimuli that were demonstrated to be members of the same visual classes, even though the fact that most of these subjects had oral names for the colors and shapes prior to the experiment might lead to the prediction that they would apply those names to other stimuli related to the colors and shapes in training. In addition, four subjects added untrained elements to categories identified by visual cues (printed concept words) without the benefit of oral names for the categories.

For the three subjects in Experiments IV, V, and VI, English was a second language. While their English language skills were sufficient for them to follow instructions given in English and to converse with the experimenter, their failure to identify and name printed words in pretesting did not examine the possibility that they entered the experiments with names for the printed word stimuli in their own language. The availability of names for the printed words may have facilitated or interacted with the stimulus relations they demonstrated in these experiments.

Other Untrained Stimulus Relations

Five subjects, three in Experiment III and one each in Experiments IV and VI, were tested for conditional and symmetric relations between the printed concept words COLOR and SHAPE and two untrained colors and shapes. Three subjects demonstrated such relations when first tested for them, one after some review of previously trained relations between the words and colors or shapes and retesting, and one subject failed to demonstrate them even after review and retesting. In other words, control by the printed concept words transferred readily to untrained stimuli regardless of sample/comparison positions for three subjects and eventually for a fourth. The untrained stimuli had not appeared in the experimental context until these tests, but they were from the same dimensions as previously trained stimuli. Hull (1939) and Spradlin and VanBiervliet (1980) defined equivalent responses to stimuli that shared some sort of physical identity or similarity as primary stimulus generalization, which may be the most parsimonious explanation for these results. The fact that these subjects categorized new instances according to a visual label, the printed concept word, demonstrates extension of a simple reading comprehension task to untrained stimuli.

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VITA

NAME: M. Regina Green

DATE OF BIRTH: February 15, 1951

PLACE OF BIRTH: Montgomery, Alabama, U.S.A.

MARITAL STATUS: Single

EDUCATION

Ph.D., Utah State University, Logan, UT, 1986.
Major: Psychology (Analysis of Behavior)
Minor: Computer-Assisted Instruction
Dissertation Topic: Contextual control of stimulus equivalence with preschool children
Major Professor: J. Grayson Osborne

M.A., Michigan State University, East Lansing, MI, 1975.
Major: Educational Psychology

B.A., Michigan State University, East Lansing, MI, 1973.
Major: Psychology

PROFESSIONAL EXPERIENCE

Research Associate	Microcomputer-Based Extended Day and Extended Year Project, Developmental Center for Handicapped Persons, Utah State University, Logan, UT.	1984-present
Research Assistant	Division of Services, Developmental Center for Handicapped Persons, Utah State University, Logan, UT.	1983-1984
Instructor	Department of Psychology and Lifespan Learning, Utah State University, Logan, UT.	1983, 1984, 1986
Behavior Specialist	Education Unit, Developmental Center for Handicapped Persons, Utah State University, Logan, UT.	1981-1983
Instructor	Field Service Unit in Physical Education and Recreation for the Handicapped, Michigan State University, East Lansing, MI.	1975-1980

OTHER TRAINING AND EXPERIENCE

Laboratory control with microcomputers; microcomputer programming (BASIC, limited PASCAL); biofeedback; psychoeducational assessment; project management.

ORGANIZATIONS

Member, Association for Behavior Analysis
Affiliate, American Psychological Association

COURSES TAUGHT

Psychology 366 - Educational Psychology
Psychology 372 - Behavior Modification
Psychology 711 - Learning, Cognition, Motivation and Emotion (teaching assistant to J. Grayson Osborne)
Psychology 681 - Seminar in Biofeedback (teaching assistant to Sebastian Striefel)

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Contributing author:

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PRESENTATIONS

Osborne, J.G., Striefel, S., & Green, G. (August 1985). Behavior management inservice workshop. Utah Schools for the Deaf and Blind, Salt Lake City, UT.

Green, G., Serna, R.W., & Osborne, J.G. (May 1985). Error analysis in complex matching-to-sample. Paper presented at the meeting of the Association for Behavior Analysis, Columbus, OH.

Green, G., Serna, R.W., & Thorkildsen, R. (October 1984). A computerized version of the Commons Game. Paper presented at the meeting of the North American Simulation and Gaming Association, Iowa City, IA.

Serna, R.W., Green, G., & Osborne, J.G. (May 1984). A microcomputer controlled match-to-sample system. Poster presented at the meeting of the Association for Behavior Analysis, Nashville, TN.

Osborne,J.G., McPherson,A., Bonem, M., Green, G., Nittrauer, S., McConaughy, E.K., Petrelli, J., Serna, R.W., & Trapp, N. (May 1984). Verbal Behavior: A preliminary study of its impact on research. Paper presented at the meeting of the Association for Behavior Analysis, Nashville, TN.

Green, G., & Striefel, S. (May 1984). Response restriction, substitution, and reinforcement with autistic children. Poster presented at the meeting of the Association for Behavior Analysis, Nashville, TN.

Green, G. (July 1983). Response probability and reinforcement with autistic children. Paper presented at the meeting of the National Society for Children and Adults with Autism. Salt Lake City, UT.

Drown, D., Green, G., & Walton, P. (July 1983). A comprehensive functional program for autistic children. Discussion presented at the meeting of the National Society for Children and Adults with Autism. Salt Lake City, UT.

Green, G., & Striefel, S. (April 1983). Response probability and reinforcement with autistic children. Poster presented at the meeting of the Rocky Mountain Psychological Association, Snowbird, UT.

Osborne, J.G., & Green, G. (May 1982). Vicarious instigation and vicarious classical conditioning: Fact or fiction? Invited address to the meeting of the Association for Behavior Analysis, Milwaukee.

Crossman, E.K., Bonem, E.J., Bonem, M.K., Green, G., & Trapp, N. (May 1982). Development of temporal patterns in small FRs: A microanalysis. Paper presented at the meeting of the Association for Behavior Analysis, Milwaukee.

Green, G., & Ascione, F. (April 1981). From the ideal to the real: Behavioral assessment in a large-scale field study. Paper presented at the meeting of the Rocky Mountain Psychological Association, Denver.

Green, G. (October 1979). The I CAN physical education system. Paper presented at the meeting of the Arizona Council for Exceptional Children Fall Conference on Exceptional Indian Children, Flagstaff, AZ.

Green, G., Carta, J., & Czajkowski, L. (April 1979). Implementing I CAN physical education services to the severely handicapped. Paper presented at the meeting of the Council for Exceptional Children, Dallas.

CONSULTATIONS

Southern Utah Navajo Development Council Head Start Program (subcontract to Developmental Center for Handicapped Persons, Utah State University). Psychoeducational evaluations and program recommendations for handicapped Head Start children. April 1985.

Utah State Office of Education Inservice Program for Principals (subcontract to Developmental Center for Handicapped Persons,Utah State University). Evaluation of inservice training project. March 1984.

Preston (Idaho) School District. Psychoeducational evaluations, behavioral assessments, program recommendations regarding behavior management in elementary school classrooms. September 1983.

Ft. Defiance Assessment Project, Developmental Center for Handicapped Persons, Utah State University. Psychoeducational evaluations and program recommendations for the Ft. Defiance Agency, Bureau of Indian Affairs. May 1981, May 1982, September 1982.

State of Michigan Department of Education Task Force on Field-Based Delivery Systems, Committee on Core Competencies for Regular Education Teachers with Handicapped Children. Formulation of state plan for teacher training. October 1979 - August 1980.

State of Michigan Ad Hoc Committee on Physical Education for the Handicapped. Liaison with State Committee on Core Competencies for Regular Education Teachers with Handicapped Children. October 1979 - August 1980.

Neonatal Intensive Care Unit, Sparrow Hospital, Lansing, MI. Behavioral management of a developmentally delayed infant. July 1979.

Clarkston SCAMP, Clarkston, MI. Evaluation of a day camp program for developmentally disabled children and youth. July 1979.

Michigan Easter Seals Society's Camp Hickory Ridge, Howell, MI. Development of plans for a residential camp program for autistic children. October - December 1978.

REVIEWS

Film script, "We Are One," depicting interactions between handicapped and nonhandicapped persons. Project MORE, George Peabody College, Nashville, TN. October 1978.

State of Michigan proposed special education rules. State of Michigan Department of Mental Health, Planning Council for Developmental Disabilities, Lansing, MI. November 1978.

HONORS AND AWARDS

Utah State University President's Summer Fellowship, 1985

Pamela G. Cheney Memorial Scholarship, Utah State University Department of Psychology, 1983 and 1984

Who's Who Among Students in American Colleges and Universities, 1983

Utah State University Research Fellowship, 1980-81