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Joint Control and the Selection of Stimuli from Their Description

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This research examined the role the two constituents of joint control, the tact and the echoic, play in producing accurate selections of novel stimuli in response to their spoken descriptions. Experiment 1 examined the role of tacts. In response to unfamiliar spoken descriptions, children learned to select from among six successively presented comparisons which varied in their color, shape, and border features. Repeated testing and training revealed that accurate selecting with new combinations of the same colors, shapes and borders, did not occur until after the children could themselves tact the individual color, shape and border features with the unfamiliar descriptions. Experiment 2 examined the role of self-echoics. Here, the stimulus features were given their familiar names, but the rehearsal of these names, while searching among the six successively presented comparisons, was impeded by a distracter task. Under these conditions selection of the correct comparison was found to depend on its position in the order of presentation. Correct comparisons presented earlier in the order, and presumably less effected by the distracter task, were more likely to be selected than correct comparisons presented later in the serial order. Taken together, these data suggest that generalized stimulus selection must be under joint tact/echoic control. The data also illustrate the distinction between mediated selection of a stimulus in response to its description (i.e., selection under joint control) and the traditional conception of an unmediated selection response evoked as a result of a heightened response probability in a conditional discrimination.

Key words: joint control, verbal behavior, conditional discrimination, generalization, delayed matching, stimulus control, children.

Although a critical issue, and thus the target of much investigation (Horne & Lowe, 1996; Sidman & Tailby, 1982), the selection of objects in response to their spoken names, or to other objects, has proven difficult to explain in a strictly operant fashion. Consider, for example, the ordinary account of selection within a simple conditional discrimination. The ordinary account treats the unmediated selection of a red comparison in response to a *red* sample object the same way it treats the selection of a *blue* comparison in response to a red sample (e.g., as arbitrary matching). In both cases selections of appropriate comparisons in the presence of the respective samples have been reinforced. But the *logical* relation of *identity* that exists between the members of the first pair of stimuli, but not the second, is simply not recognized by this account. (Lowenkron, 1998, 2004, p. 81).

Turning from logical to semantic relations, we find a similar problem in describing the connection between words and objects. Thus, if the only connection between a word and an object is based on the unmediated selection just described, then in word-object matching the listener can respond to no relation between the stimuli other than that which was explicitly trained. And so, after a subject is trained in a conditional discrimination to select the appropriate shapes in response to the phrases *square over circle* and *triangle over line,* unmediated selection cannot account for untrained generalization to novel combinations of these words so that listeners, with no additional training, now select appropriate stimuli in response to the phrases *square over line* and *triangle over circle*. Clearly, a rationale broader than the notion of unmediated selection is needed, and providing the empirical basis for such a rationale is the focus of the research reported here.

In a recent article Lowenkron (1998) demonstrated the utility of the notion of *joint control* in providing this broader rationale. Joint control involves nothing beyond the familiar

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notions of operant stimulus control, but it does so in cases where a single topography comes under the (joint) control of *two* verbal operants. Thus, with respect to the abstraction of *identity,* if a person was briefly shown an unfamiliar object (e.g., a small, red-and-green vase) and after it was removed was asked to select a duplicate object from among a variety of similar vases, the joint control account would say that the subject rehearsed the object's description first when the object was shown, and occasionally again while searching for it and, coincidentally, yet again when the described object was actually encountered. This last repetition would then have occurred under *joint control* because the topography at this moment was emitted both as a *self-echoic* (a verbal operant under the control of the previously spoken instances of rehearsal) and (jointly) as a *tact* (a verbal operant under control of the stimulus features of the now-encountered object.)

Selecting the object that enters into this joint-control relation thus necessarily produces an identity match. Selection is thus freed from the specifics of any particular stimulus. Instead, reinforcement is contingent upon selecting the comparison that enters into joint control. This thereby provides a consistent basis for *generalized selection* of the comparison identical to the sample. Joint control, it may be said, is a generic event, and it is this generic feature that allows for generalized responding.

To its credit, however, beyond the *logical* relation of identity the joint control account also describes the *semantic* relation (i.e., meaning) where, for example, the sample is a spoken description of an object rather than the object itself. But this makes no real difference: Regardless of its source, the subject still rehearses the description (initially self-generated or else mimicked from someone else) as a self-echoic, and can still select under joint control. Conceptually, then, the notion of joint control seems to be one of significant utility for the behavioral perspective. Indeed, a broad sampling of the role joint control plays in the conceptual analysis of many abstract performances is provided in Lowenkron (1998).

There is, though, empirical evidence for the functioning of joint control as well. Thus, in a series of systematic replications, across a variety of matching tasks, all based on abstract relations such as *identity, larger/smaller, before/after,* and *clockwise from,* Lowenkron (1984, 1988, 1989) and Lowenkron & Colvin (1992, 1995) showed that the generalization of these relational matching performances to novel stimuli uniformly depended on first bringing the comparison-selection response under joint control. In contrast, where responding was simply unmediated comparison selection, subjects showed no generalized responding with novel stimuli. These studies, however, showed something else beside the variety of relations joint control might mediate, because each of these systematic replications used a different mediating topography as well. These topographies included hand signs, mechanical representations of the orientations, and lengths of stimuli and of the distances between stimuli. The reason for studying this diversity of performances was as follows.

As Sidman (1978) has noted, stimulus-control relations cannot be observed directly, but may only be inferred from characteristics of the behavior they control; so it is with joint control. There is, in fact, no way of directly observing the effect of the two sources of stimulus control (tact and self-echoic) over a common topography. One can only observe a correlation between some characteristic of these responses and an observable stimulus event.

It is for this reason that the variety of overt, directly observable mediating response topographies was used in the series of systematic replications cited above. Not only did these overt replications most clearly illustrate the dependence of generalized responding on joint control, but they also provided for the most direct observation of the component responses that comprise joint control and thus the generalized matching performance it mediates.

Thus, in Lowenkron (1988) developmentally disabled children were trained in an identity-matching task to tact the shape of the sample stimuli by making directly observable handsigns to each of four shapes. The children were also trained to maintain unchanged (rehearse) each hand sign across a delay interval of a few seconds and then select the comparison stimulus that evoked the currently rehearsed and unchanged hand sign. Where any of these mediating responses did not occur, subjects invariably selected incorrectly in a generalization tests with *novel* stimuli. That is, where subjects did not select under jointly accurate tact/self-mimetic control, they generally failed to select the comparison appropriate to the current sample. The data were thus in accord with what one would expect if subjects were in fact selecting comparisons under joint control.

In another experiment—this with young normal children (Lowenkron, 1984)—rather than using handsigns as the overt mediators, subjects "tacted" the spatial orientation of each sample geometric figure by rotating a paper arrow so that it was oriented in accord with the orientation of the axes of symmetry of the sample figure. Next, the subjects were taught to change the orientation of the paper arrow by rotating it 90 degrees clockwise from its initial orientation, and then maintain this transformed orientation (rehearsal) until they encountered a comparison stimulus itself in the orientation for which this currently maintained arrow's orientation was appropriate. Subjects thus learned to match based on the spatial relation *clockwise from.* What is critical here is that accurate generalized responding once again depended on the emergence of those mediating responses specified by the notion of joint control.

Similarly, in Lowenkron (1989), again with young children, mediating behavior was made directly observable when subjects were trained to represent the lengths of lines, and the distances between points, using a mechanical compass. Once again, accurate generalized responding involving relations such as *longer/shorter* and *further/nearer* all depended on the emission of the mediating behavior specified by the notion of joint control.

In general, all of the studies indicated that directly training the target performance (unmediated selection) with one set of stimuli, was not adequate to produce generalized performances of that behavior with other, untrained members of the same stimulus set. Rather, these studies showed that for generalized responding to occur, subjects had to act in accord with the stimulus-control relations described by joint control.

As to the studies reported here, they are intended to further the applicability of the joint control account by applying it to what is certainly the most important sort of mediating behavior for human functioning—namely, vocal behavior. Technically, of course, the problem with such behavior is that it may occur at a covert level beyond the reach of current technology. Thus, to gain conceptual rigor, the studies reported here should be viewed as extensions of the overt systematic replications reported above, with close correspondences between the components of joint control (tact and self-echoic) made overt and explicit in the earlier studies, and those not directly observable with the vocal mediation used here.

Finally, as to the overall logic of this pair of experiments, the general idea here was to manipulate, in separate experiments, each of the components of joint control, the tact and the self-echoic, and thereby advance the joint-control account by showing the function of each component within the joint control relation. Further, whereas the earlier experiments were designed to make the components of joint control as directly observable as possible, the current experiments were intended to make the components as authentic as possible by using vocal, rather than mechanical, mediating responses.

Thus, Experiment 1, while holding self-echoic behavior constant, manipulates tact strength by first training a conditional discrimination that requires no accurate tact performance but also produces no generalized responding. Then, increasing amounts of tact training are provided until generalized matching occurs in the conditional discrimination, thereby showing the relevance of tacting to performances mediated by joint-control.

The second experiment controls for tacting behavior while it manipulates the availability of the self-echoic leg of joint control by varying the length of time the subject must engage in a distracting task until the correct comparison appears. This demonstrates that with an increasing length of time in which the self-echoic cannot be practiced, the accuracy of generalized matching falls, thus showing the relevance of the self-echoic leg to selection under joint control.

EXPERIMENT 1

If generalized matching does indeed require that comparison selection occur under joint control, and if, in turn, joint control does indeed depend on a subject's ability to accurately tact stimuli prior to selecting, then, all else being equal, generalized matching with novel stimuli should only emerge as tacts, for these stimuli are first acquired and then emitted by the subject to mediate the matching task. To study this relation this experiment examines the correlation between the acquisition of tacts and the emergence of generalized matching.

To do this, subjects were first trained to select six different stimuli in response to three-word spoken descriptions. Each word of a description was the name of a color, shape or border feature of the stimulus. This auditory-visual conditional discrimination training was then followed by a test for generalized selection with six new, untrained stimuli—all comprised of novel combinations of the same color, shape, and border features. After finding no evidence of either generalized selection, nor even any ability to reliably tact the individual color, shape, or border features of the stimuli, subjects were next trained, over a series of procedures, to tact these features. After each tact-training procedure was completed, its effect on generalized matching was assessed.

Thus, the first tact-training procedure trained subjects to tact the color, shape, and border features when each feature was presented alone. In the subsequent test it produced no generalized responding to the untrained stimuli. A second procedure then trained tacting when the features were presented in the same six combinations used in the auditory-visual conditional discrimination training. Though this level of tact training might seem adequate to produce generalized tacting of these color, shape, and border features no matter how else combined (and thus generalized matching to novel stimuli), a third generalization test revealed it did not. Therefore, following this test, additional tact training was given using six *novel combinations* of the color, shape, and border features (these were neither the original six combinations used in the conditional discrimination training, nor the six used in the generalization test). This tact training was followed by a another test for generalized matching. Cumulatively improving tacting performances over these three training procedures was expected at some point to produce generalized selection, thereby replicating with vocal stimuli a finding regularly demonstrated with overt mediating responses: namely, that generalized selection with novel stimuli requires the emission of appropriate tacts to those stimuli (Lowenkron, 1984, 1988, 1989).

Method

Subjects

Six girls (AG, JB, BS, RR, JA, and SS) and two boys (AL and MB) from the first grade of a local elementary school were run initially. Girls SB and EB were added later. Subjects' ages ranged from 5.2 to 7.2 years.

Apparatus and Setting

Apparatus. Stimuli were presented by a Commodore 128D® computer on a 45 cm Amdek II® color monitor. The monitor-screen locations touched by the children were measured by a touch-sensitive screen (Personal Touch Corp. IBM® analog model) through an interface specially modified for the computer.

Setting. Sessions were run in a small room at the school. The child sat at a small table facing the monitor. The experimenter sat to the side of the child and in front of the computer keyboard. An observer sat behind the child.

Stimuli and Consequences

Stimuli. All sample stimuli (Table 1) were three-word spoken descriptions of the comparison stimuli. The three words in these descriptions were arbitrarily assigned as the names of the color, shape, and border feature (e.g., king-bus-clip) of each comparison stimulus. In order to avoid any pronunciation problems, the names were all familiar English words.

All comparison stimuli appeared as pictures approximately 3 cm high x 3 cm wide on the monitor on a white background screen. The pictures all contained three features: a shape surrounded by a border; both of the same color (Figure 1). These picture stimuli were constructed by combining one of three color features, purple, aqua and orange (named king, pond, and leaf), with one of three shape features, a rhombus, a trapezoid, and an X (named bus, trap, and flag), and one of three borders (named point, sol, and clip). There were thus 27 possible stimulus combinations. Some of these stimuli are shown in Figure 1, Panel A, and all are described by the feature names listed in Table 1.

Six of these combinations were selected for the *training set* (Table 1). The six combinations chosen were selected so that the three features on each of the three dimensions (color, shape, and border) appeared in two different stimuli, but never twice with the same features on the other two dimensions. This provided a logical basis for comparing stimuli, and thereby

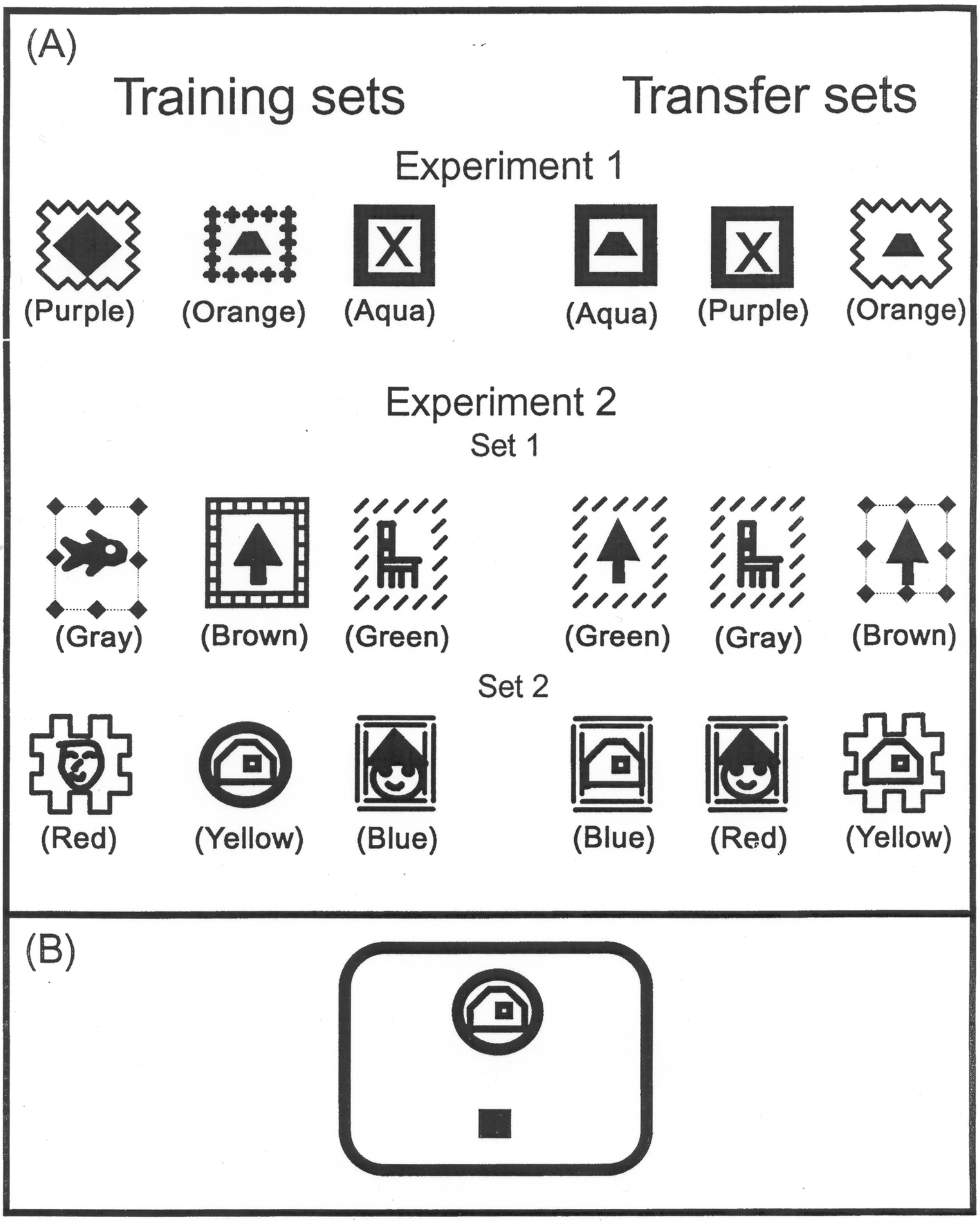

Fig. 1. (A) Some of the stimuli comprising the training and transfer sets in each experiment. The word below each stimulus indicates the color of the stimulus. The three training-set stimuli shown here for Experiment 1 were named *king-bus-clip, leaf-trap-check,* and *pond-flag-sol.* The three transfer-set stimuli shown here are *pond-trap-sol, king-flag-sol,* and *leaf-trap-clip*.

For Experiment 2 shown here from Set 1 are the training-set stimuli *gray-fish-dots, brown-tree-ladder,* and *green-chair-lines;* and the transfer set stimuli *green-tree-lines, gray-chair-lines,* and *brown-tree-dots*. The Training-Set 2 stimuli are *red-boy-fence, yellow-house-circle,* and *blue-clown-box.* The transfer-set stimuli are *blue-house-box, red-clown-box,* and *yellow-house-fence*.

(B) An example of the monitor screen as it appeared during the third stage of conditional-discrimination training and during all baselines and tests. The subject may either push on the comparison stimulus to select it, or else push the black square to see the next comparison.

Table 1
Descriptions of stimuli by feature names.

Experiment 1	
Training Set	Novel-tact Training Set
king bus clip	king flag clip
pond bus check	leaf bus sol
king trap sol	leaf flag check
leaf trap check	king bus check
leaf flag clip	king bus sol
pond flag sol	pond trap check
Transfer Set 1	Transfer Set 2
king flag check	king trap clip
pond trap sol	pond flag check
leaf bus clip	leaf flag sol
king flag sol	king trap check
pond bus clip	pond trap clip
leaf trap clip	leaf bus check

Experiment 2	
Training Set 1	Training Set 2
gray fish dots	red boy fence
green fish ladder	blue boy circle
gray tree line	red house box
brown tree ladder	yellow house circle
brown chair dot	yellow clown fence
green chair line	blue clown box
Transfer Set 1	Transfer Set 2
gray chair ladder	red clown circle
green tree line	blue house box
brown fish dot	yellow boy fence
gray chair line	red clown box
green fish dot	blue boy fence
brown tree dot	yellow house fence

Note: Training Set and Transfer Set 1 of Experiment 1 also appear in Experiment 2 as Set 3.

identifying the names of the nine stimulus features during conditional discrimination training. Although highly unlikely with children this young, this property of the stimulus set still served the important function of permitting the children, in principle, to isolate the name of each feature and thus emit generalized matching immediately after being trained to select these six stimuli in response to their descriptions, and before receiving any tact training.

From the remaining combinations six other stimuli were selected so as to be maximally different from the training set and from each other. This set, Transfer Set 1, was used to test for generalization. From the still remaining combinations, a third set of six was chosen as the novel-tacting set (Table 1). This set was used to train tacting behavior with previously untrained stimuli, but never used in a test. Finally, six of the remaining stimulus combinations comprised Transfer Set 2.

Training, baseline and test trial displays. During training trials, various numbers of stimuli appeared on the screen. During those steps in which one comparison appeared, it was in the center of the top third of the screen. When two or three comparisons appeared, they were equally spaced horizontally across the top third of the screen. On baseline and test trials there was always a single comparison in the center of the top third of the screen along with a 3 cm by 3 cm black square in the center of the bottom third of the screen (Figure 1, Panel B).

Baseline trials and generalization-test trials. These two types of trials differed from each other only in terms of the types of stimuli they contained. Baseline trials only contained training-set stimuli, while generalization-test trials also contained stimuli from a transfer set: either from Transfer Set 1 or else from Transfer Set 2 depending on what the current test was.

On both baseline trials and generalization-test trials subjects were required to select comparison stimuli in response to their 3-word spoken descriptions. Both baseline- and generalization-test trials began with a blank white screen. The experimenter then said the three-word sample description. The subjects then had to repeat this description aloud. If they did not, the description was repeated by the experimenter, prefaced by the prompt *Say*. If subjects mispronounced a word, they were similarly prompted. As soon as subjects repeated the description correctly, a single comparison appeared at the top center of the screen (Figure 1, Panel B). Below the comparison there appeared the black square. If subjects did not select the comparison, they could touch the black square in order to reject it and replace it with another stimulus from the same set. Each time they touched the black square, they were required to repeat the sample description (self-echoic rehearsal). Failure to do so brought a prompt to comply ("What are you looking for?"). If the subject could not say the description, the experimenter supplied it and the subject was prompted to repeat it. Six such touches on the black square cycled through all the stimuli in the current stimulus set and so brought back the first stimulus. Subjects could thus press the black square to cycle repeatedly through all the members of the set of stimuli (training set or a transfer set) being shown on that trial (Table 1) until they finally selected a comparison stimulus by touching it. This selection also required that subjects repeat the current sample description as they touched the selected comparison. (Thereby, it was presumed, causing that particular rehearsal of the description to occur under joint tact/self-echoic control). Failure to do so again brought the prompt "What are you looking for?"

Baseline blocks and generalization-test blocks. Baseline blocks consisted of 12 trials with the training-set stimuli. Within this block, each of the six stimuli in the training set was the correct choice on two trials. All six stimuli were balanced with respect to the serial position of the correct choice, and so for no two appearances of the same stimulus was the same serial position correct. These stimuli appeared in a single fixed order as the subject pressed the black square and cycled through the comparisons. This block, usually given before a generalization-test, was used to insure that a specified level of selection accuracy prevailed with the training stimuli before a generalization test was given.

Generalization-test blocks also contained 12 trials. On four of these trials (Trials 1, 3, 6, 9) stimuli from the training set appeared. On the eight trials remaining in the block, stimuli from either Transfer Set 1 or Transfer Set 2 appeared—depending on the phase of the experiment. Thus, with eight generalization trials but only six transfer-set stimuli, each of these stimuli could appear in the generalization-test blocks with only roughly equal frequencies. Generalization-test blocks were always presented two or more times so as to collect at least 24 trials of data: eight training-set trials and 16 test trials.

Reinforcement in baseline blocks and in generalization-test blocks. In both the baseline blocks and generalization- test blocks, correct selections with the training-set stimuli on Trials 1, 3, 6 and 9 were reinforced as described below, while selections (correct or incorrect) on the remaining eight trials (with the transfer-set stimuli) had no differential consequences—producing only the blank white screen that marked the start of the next trial. As a result, during the baseline blocks, subjects learned to respond without continuous reinforcement, and during test blocks, selections on the eight generalization-test trials were without consequence. Generalization was thus measured without reinforcement. In both kinds of blocks, baseline and generalization, incorrect selections on Trials 1, 3, 6 and 9 produced a vocal *no* and a 3-s screen blackout followed by the start of the next trial.

The contingencies of reinforcement. The baseline and test blocks were presented within a simple video game in which a correct selection on a reinforcement trial (Trials 1, 3, 6, 9 in either a baseline or a generalization-test block) was followed by a 2-s tone with the simultaneous appearance of the Sesame Street® character Big Bird® at the center of the screen. The screen then cleared, and a string of colored dots, or *cookies,* appeared from left to right across the upper portion of the screen. A little boy then appeared to the right of the rightmost cookie. Touching the screen at the location of the boy caused him to move to the left and pick up one cookie after which the screen cleared and the next trial began.

On the first reinforcement trial within a baseline or test block, 12 cookies appeared. On each subsequent reinforcement trial the same sequence of events reoccurred, but the number of cookies presented diminished across trials so as to reflect those cookies that had been picked up on prior reinforcement trials within the block. After the twelfth cookie was picked up, the program ended with a brief animated musical display, and the subject was allowed to select a sticker.

In both baseline and generalization-test blocks, on trials without differential consequences (Trials 2, 4, 5, 7, 8, 10, 11, 12) one cookie was *credited* for each correct selection. These credited cookies could be picked up on the next reinforcement trial (1, 3, 6 or 9) in which a correct selection was made. In this case, after the correct selection was made, all the cookies remaining since the last pickup were presented, and the boy, when pressed, picked up the next cookie. Now, however, the screen did not clear. Rather, the boy remained to be pressed again: once for each cookie previously credited until all the cookies credited since the last reinforcement trial had been picked up. For example, a subject making correct selections on (unreinforced) Trials 4 and 5 would be credited with two cookies. If the subject then made a correct selection on (reinforced) Trial 6, the string of all as-of-yet uncollected cookies was presented, and the subject could press the boy three times: once each to pick up the two cookies credited for Trials 4 and 5, and once for the correct selection on Trial 6.

If the selection on Trial 1, 3, 6 or 9 was incorrect, the trial ended and neither the tone, the bird, or the cookies appeared. Rather, the count of cookies owed were left to accumulate until a correct selection was made on Trial 1, 3, 6, or 9. Thus, reinforcement density was correlated with selection accuracy, but no response on a generalization trial was ever immediately reinforced.

Baseline phases and generalization-test phases. In baseline phases, only data on the first 12 trials was collected as the subject responded to the baseline block. However, because 12 correct selections were required to collect all the cookies, the actual number of trials required to collect the cookies and end the game could vary. And so, if by the twelfth trial the subject had not collected all 12 cookies, (e.g., due to incorrect selections on some trials), the baseline block was restarted from the beginning, now without data collection, and continued until all 12 cookies had been picked up. At this point the game ended and the child was awarded a sticker.

Generalization tests were very short in order to minimize learning during the repeated testing. During generalization-test phases the 12-trial test block was presented at least twice so that 24 trials of data were collected (16 trials with the current transfer-set stimuli, and 8 trials with the training-set stimuli). Thus, in the generalization test, if the subject selected without error, and thus took only 12 trials to pick up all the cookies and end the game, a reinforcing sticker was provided and the game was immediately restarted (with 12 more cookies available) to collect the 24 trials of data. On the other hand, if the subject made too many errors to collect the first 12 cookies, the test block was simply recycled until 24 trials of data were collected, at which point the screen went blank (black) and the game was terminated even though cookies remained to be collected. If, however, despite the errors, the subject managed to collect all 12 cookies and end the game in less than 24 trials, a reinforcing sticker was provided, and the game was immediately restarted (with 12 cookies) and played until a total of 24 trials of data had been collected. Data collection then ceased, but the game itself continued until all the cookies were collected. The game then ended normally.

Procedure

Overview of procedure. Subjects were seen in three 30-min sessions per week. Generally, all previously trained performances were reviewed before any new behavior was trained.

The procedure was designed to examine the correlation between the acquisition of tacts and the emergence of generalized matching. In the first step, the children were given *conditional discrimination training* in which they learned to select the six training-set stimuli in response to their spoken descriptions (i.e., the names arbitrarily assigned to the colors, shapes, and borders of the stimuli). Next, the ability of the children to themselves use these arbitrary names as responses to describe the stimuli (i.e., as tacts) was tested in a *naming test*. This was followed by a test for generalization of the conditional discrimination performance to the selection of transfer-set stimuli in response to their descriptions. Subjects were next trained (*feature tacting*) to tact the color, shape, and border features, as each was presented individually. This was followed by another test for generalized matching.

Next, subjects were taught to use the feature names to tact the colors, shape, and borders contained in each of the six training-set stimuli (*stimulus tacting*) and again tested for the emergence of generalized matching. Subjects were then trained with the *novel-tact training set* to tact the very same features, but here when they appeared in novel stimuli). They were then tested a third time for the emergence of generalized matching. The details of the procedure are as follows.

Conditional-discrimination training. Over three stages of training, this procedure taught subjects to select each training-set stimulus

(Table 1) in response to its spoken description when said at a normal conversational pace. Here, every correct selection was followed immediately by a 3-sec musical phrase and then, immediately, by the beginning of the next trial. Incorrect selections were followed by a 3-sec screen blackout and the beginning of the next trial.

The first stage of training used only the first two stimuli of the training set. On each trial, the two stimuli appeared *simultaneously* on the monitor on a white screen. The experimenter gave the description (said the names of the three features) of the first stimulus to be selected and pointed to it. The child was vocally prompted to repeat the description aloud and select the stimulus named by pressing it. Whenever the subject did not pronounce the description correctly, the experimenter said the names again and instructed the subject to say them correctly. On the next trial, the same procedure was followed with the second stimulus. On all subsequent trials, the experimenter gave the description, but did not point, leaving the subject to repeat the description and then select the correct comparison.

To complete this step subjects had to make three consecutive correct selections of each of the two stimuli in response to its description. In the subsequent steps of this stage, the remaining training-set stimuli were added, one by one, until the subject selected correctly from all possible pairs of six stimuli drawn from the training set. In the second stage, this same procedure was continued, except the number of stimuli appearing simultaneously on the screen on each trial, increased from two to three.

In the third stage, each trial began with a blank white screen, and subjects had to select from among three comparisons presented *successively*. Now, when the experimenter gave the description, the subject was prompted to repeat it in order to see a screen containing the first comparison and the black square (Figure 1, Panel B). By means of prompts, subjects learned they could view each of the remaining two comparisons, one at a time, by repeatedly pressing the black square; thereby cycling through the three comparisons until they located the one described. On these trials subjects, were prompted to repeat the description aloud: first as a repetition of the words spoken by the experimenter (an echoic), once again each time they pressed the black square (a self-echoic), and once more when they selected a comparison (a self-echoic). Failures to repeat the description aloud (virtually nonexistent) were followed by a request to say the name aloud, along with a prompt saying the current name. These failures had no consequences for the scoring of a selection as correct or incorrect. Training continued to a criterion of 18 consecutive correct trials: three correct selections of each of the six training-set stimuli when presented in a random order.

Naming pretest. As mentioned previously, the training set was constituted of stimuli selected so that it was logically possible to isolate the names of all the features during conditional-discrimination training. To determine if subjects had in fact, by some means, acquired feature names during conditional-discrimination training, or indeed could even remember the names of the six stimuli they had just learned to select, a naming pretest was given in the session in which the 18-trial training criterion was first met. In this test, the stimuli of the training set were shown one at a time, and subjects were prompted to supply the names ("What's this one called?") that had just been used in the conditional discrimination training. These names were recorded in writing by the experimenter but produced no consequences for the subject. To evaluate the possibility that the prompt in this test affected subsequent behavior, this naming pretest was not given to subjects BS or MB.

Baseline 1. In the next session, the baseline block was presented and practiced repeatedly until the full 12-trial baseline block was completed without error. The task differed from the third stage of conditional discrimination training only in that subjects were now selecting from among six successively presented comparisons on each trial instead of three, and reinforcement was now intermittent—as described above regarding the contingencies of reinforcement in baseline blocks.

Test 1. In the next session, the three stages of conditional-discrimination training were briefly reviewed, and then the 12-trial baseline block was presented for the baseline phase. If the baseline block was completed with no more than one error, the generalization-test phase was run using the Transfer Set 1 stimuli (Table 1). Otherwise, the baseline block was presented three more times for practice, and the session ended. During these trials, if they did not do so by themselves, the subjects were prompted to repeat the descriptions as described above.

Feature-tact training. In the first session after completing Test 1, the children were taught to name the individual stimulus features of each dimension. To train the names of each color, the entire screen changed to one of the colors as the experimenter said the name and pointed to the color (e.g., with a purple screen the experimenter said, "This is *king*.") Subjects were then asked to repeat the name ("What color is this?") a few times, and then the second and then the third color was presented; this training was repeated with each. On the subsequent trial, children were asked to tact each color as it appeared. If they could not, the experimenter said the name and asked the subject to repeat it. Training continued until subjects could tact all three colors without prompting when they appeared twice in random order.

In the next phases, the same procedure was then used to train tacts for the three shapes and then for the three borders. On these trials, each shape or border appeared alone, colored black, on a white screen. In the final phase, trials with the three colors, the three shapes, and the three borders were all interspersed, and subjects were required to name all nine features accurately.

Test 2. The next session began with a very brief review of the three stages of conditional-discrimination training (two trials per stage). Then, feature tacting was reviewed by asking the subject to name each of the nine features as each was shown alone. If there were more than two errors in any task, appropriate training was provided and the session was concluded. Otherwise, subjects continued in the feature-tacting task until they correctly named each of the nine features twice. Next, a baseline phase was given. If this was completed with no more than one error, the generalization—test (Test 2) was presented—still with Transfer Set 1. If there was more than one error in the baseline phase of the test, the baseline block was presented for practice as time permitted, and this entire Test 2 procedure was repeated in the next session.

Stimulus tact training. In the session, after subjects completed Test 2, they were trained in stimulus tacting. Here they were taught, over three stages, to describe complete stimuli by naming the color, shape, and border features of each stimulus as each stimulus was presented alone on the screen. In the first stage of this training, the full screen changed to one of the stimulus colors. The subject was then prompted to name it ("What's that?"). When the subject named the color (e.g., *king*), a shape in that color appeared against the usual white background. The subject was then asked to name both the shape and its color (e.g., *king-bus*). When the subject did so, a border appeared around the colored shape, and the subject had to provide the names of all three features of the stimulus (e.g., *king-bus-clip*). Practice continued until subjects could do this errorlessly with all six stimuli of the training set.

In the second stage, the color-only screen was omitted, and trials started with a color-shape combination. In response, the child had to name the color and shape before seeing and naming the color-shape-border combination. In the third stage, complete stimuli (a colored shape and border) was presented, and subjects had to provide the names all three features. At each stage, subjects were prompted by the phrases "What is this?" and "What else is this?" If they could not give the correct answer, it was provided. Practice continued in the third stage until subjects could accurately name all the features contained in each of the six stimuli.

Test 3. In the next session, to examine the effects of the stimulus-tact training on generalized responding, the procedures described for Test 2 were repeated with subjects RR, SS, JA, MB, and EB as Test 3, except that the preliminary review of feature tacting that preceded Test 2 was replaced now by a preliminary review of stimulus-tacting. In this review subjects had to provide the correct names of the three stimulus features contained in each of the six stimuli of the training set.

Novel-tact training. Using *both* the training-set stimuli and the *novel*-tact training set (Table 1), the procedures for stimulustact training were then repeated for all subjects.

Test 3N. To examine the effect of the preceding stimulus tact training with *novel* stimuli, the procedures described for Test 3 were repeated for all subjects as Test 3N. (The suffix 3N indicates that, in contrast to Test 3, which was given after tact training just with the familiar stimuli of Transfer Set 1, here the administration of Test 3 was given after novel stimulus-tact training with the novel stimuli listed in Table 1 as the novel-tact training set; hence, 3N.

Test 4. The procedures described for Test 3

Table 2
Experiment 1. Trials to criterion at each stage of conditional discrimination training and the number of features correctly named in the naming pretest for each stimulus.

	Conditional discrimination training Trials to criterion			Naming pretest Number of features correctly named.			
	Stage 1	Stage 2	Stage 3	3	2	1	0
AG	293	30	25	2[a]	1	2	1
JB	328	49	36	5	0	1	0
BS	474	83	41				
AL	326	29	14	5	0	1	0
SB	370	56	45	1	2	2	1
RR	286	37	46	0	2	2	2
SS	453	67	39	3	0	1	2
JA	265	25	48	2	1	2	1
MB	479	80	48				
EB	633	70	19	3	0	3	0

Note: To evaluate the possibility that the naming pretest affected subsequent behavior, it was not given to BS or MB.
[a] Number of stimuli evoking correct names of this number of features.

were repeated for subjects EB and SB, but with Transfer Set 2 replacing the stimuli of Transfer Set 1 on generalization test trials.

Naming posttest. All stimuli of Transfer Set 1 and Transfer Set 2 stimuli were shown in mixed order as the subject was asked to name each.

Results

Acquisition during the three stages of conditional discrimination training was very slow and difficult (Table 2) requiring an average of 485 trials to learn to select all six stimuli of the training set in response to their description. No subject completed conditional discrimination training in less than four sessions.

Despite this greatly extended practice, and despite the fact that subjects needed virtually no prompts to correct their pronunciations of the features' names, no subject correctly named the color, shape, and border features of all the training-set stimuli (Table 2). This was true even though the training set was constituted so that the names of all the features could be logically deduced by the end of Stage 1 of the conditional-discrimination training. Instead, the data suggest that during the average 485 exposures to these stimuli, along with the required repetitions of their description while selecting, subjects just memorized part or all of the descriptions as intraverbal strings (memorized sequences), but did not connect these words to the individual features of the stimuli.

Thus, only with two of the stimuli could subject AG emit the names of the three features they contained. With one other stimulus she could name two features, with two other stimuli she could name but one feature, and in one stimulus, none of the features. This, even though she had named these features correctly when they appeared in other stimuli moments before or after. The data of subjects JB and AL show this even more clearly. Thus, both subjects correctly named all three features of five of the six training-set stimuli, but in both cases there was one stimulus, containing two features they had already correctly named in the other stimuli, that they now could not name. There was no time pressure here, no reason for these subjects, or any of the others, not to formulate correct descriptions from the feature names if these were indeed available as tacts. But the evidence conforms precisely to what one would expect from the procedure and subjects of this age: without explicitly focused, reinforced practice, tacts for the individual stimulus features did not develop. Rather, during this test subjects appeared to respond to the three-feature names as intact units.

In contrast to the trouble subjects had *naming* the training-set stimuli, no subject made

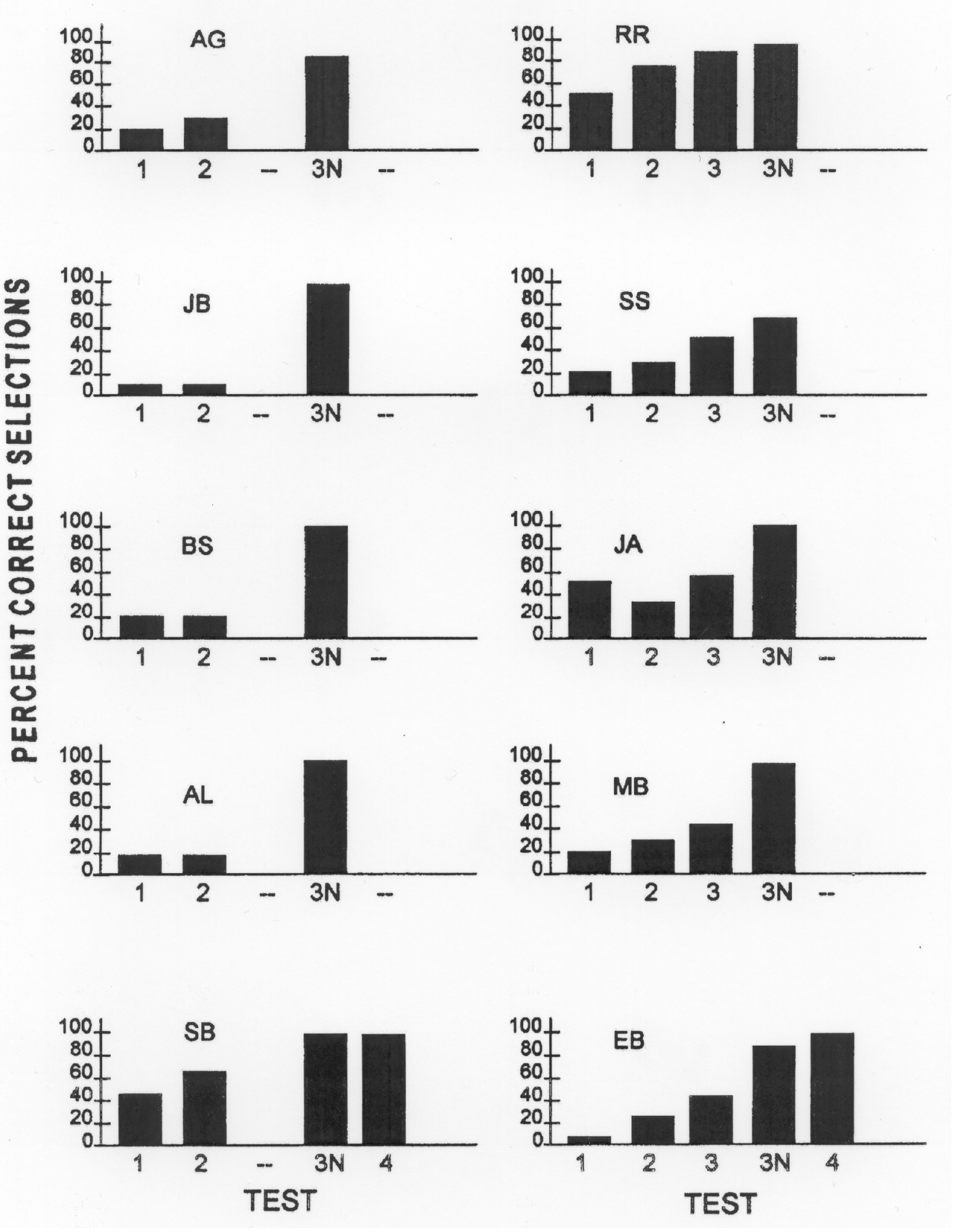

Fig. 2. Data for Experiment 1. Bars indicate the percentages of correct selections on the 16 test trials in Tests 1 to 4.

more than one error *selecting* these same stimuli in response to their names during the baseline phase immediately preceding Test 1 (nor did they make errors on any of the trials with the training-set stimuli interspersed in the test blocks in Test 1). Thus, *bi-directional symmetry* did not appear: even as subjects accurately selected in response to these names, they could not accurately emit these names as tacts.

Despite the accurate selection of training-set stimuli however, Figure 2 reveals no evidence of generalized selection with the Transfer Set 1 stimuli in Test 1. And indeed, subsequently training subjects to name each feature in feature-tact training (for an average of approximately 200 trials, including reviews) produced

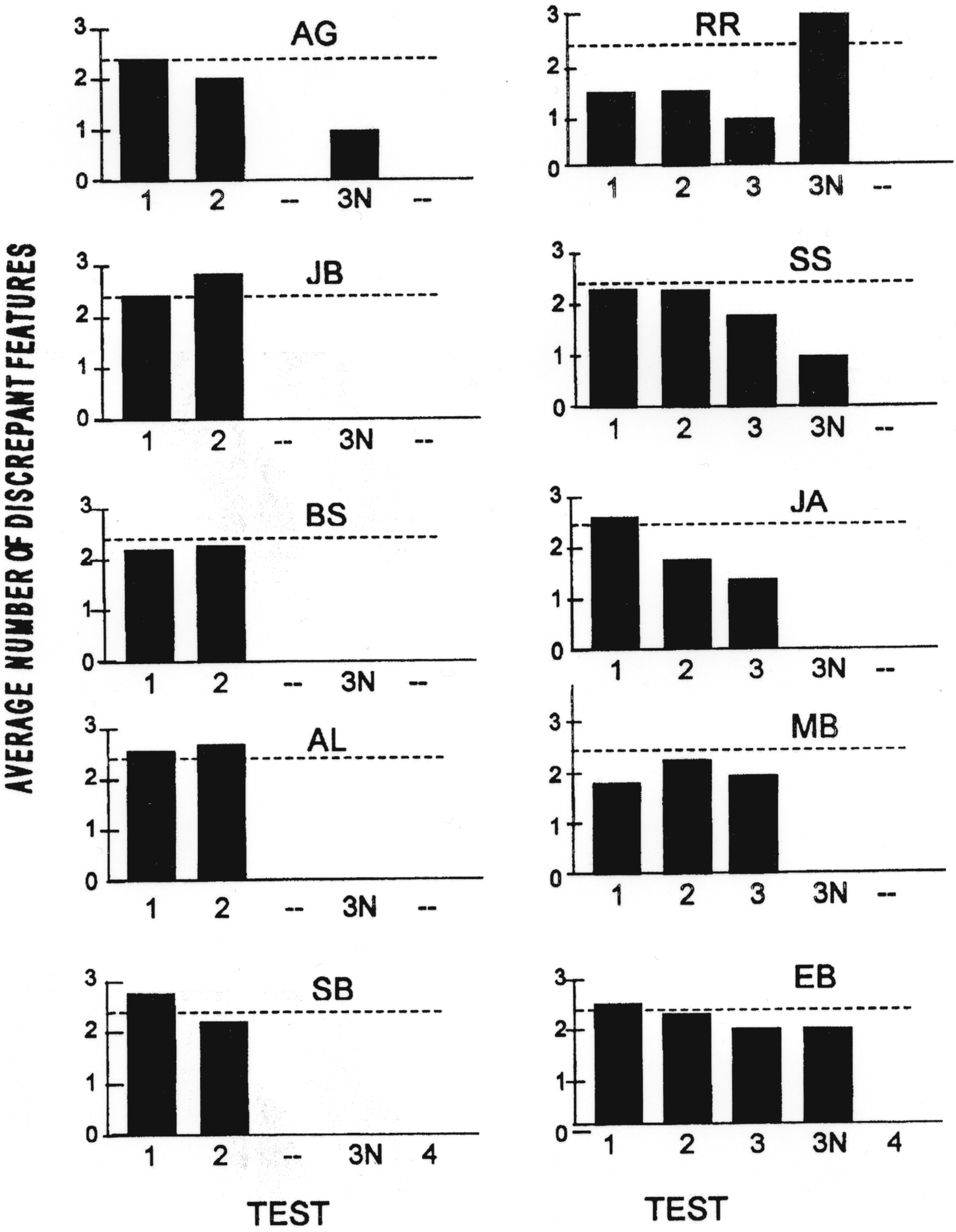

Fig. 3. The average number of features, across all selections in each test, by which erroneous selections were discrepant from their descriptions. The largest possible error was to select a stimulus discrepant from the description on all three dimensions. The dashed line at 2.36 indicates the expected discrepancy rate given random selection.

no consistent improvements in generalization during Test 2. Similarly, as shown in Test 3, the prior stimulus-tact training with the training-set stimuli (for an average of approximately 100 trials, including reviews) also had inconclusive effects in improving selection accuracy. In contrast, adding the novel stimuli to stimulus-tact training (average 40 trials) had a dramatic and profound effect: producing high levels of generalized selection in all subjects in Test 3N.

The effect of acquiring these accurate tacts may also be seen in the nature of the errors the subjects made during the generalization-test phase. Figure 3 depicts the average number of dimensions, across the 16 trials with transfer-set stimuli, by which incorrect selections were discrepant from the sample descriptions. The number reaches a maximum of three on those trials in which the comparison selected differed from the sample description on all three dimensions (color, shape, and border). The dashed line indicates the average discrepancy on error trials (2.36 dimensions) that would result from random selection, given the particular set of stimuli and descriptions used in the eight test trials contained in a test block.

In Tests 1 and 2, the numbers of discrepancies did not much differ from what would be expected under random selection. In contrast, in Tests 3N and 4, errors did differ from random selection. In Test 3N in most cases the discrepancies were on single dimensions. Thus, the four errors Subject AG made in Test 3N (Figure 2) all involved the selection of comparisons differing from the sample description by a single feature (Figure 3). On two trials she selected *trap* where *bus* was correct, and on two others she similarly confused *check* and *sol.* On the single error made by Subject RR, she selected a comparison differing from the description on all three features. This was almost certainly an accident given her uniformly accurate selections on all other trials.

In Test 4 there were no selection errors and thus no discrepancies. Indeed in response to completely novel descriptions subjects EB and SB were able to select novel comparisons without a single error and in the naming post-test both were able to provide fully accurate descriptions to all eight stimuli of Transfer Set 2 without a single error. Clearly, the training with the novel-tact training set had a powerful effect on all subsequent behavior!

Discussion

In general, various data, as well as the procedure itself, suggest that during conditional discrimination training subjects not only acquire the conditional discriminations, but the required rehearsing of the spoken stimulus descriptions before selecting also allowed subjects to acquire *some* of the descriptions as three-word echoics and as intraverbals.

But the subjects did not appear to acquire the descriptions as tacts of the individual stimulus features. Thus, as indicated in Table 2, an average of 485 trials was needed to train conditional discriminations with all six training-set stimuli. This slow pace is consistent with the possibility that the three-word descriptions served as nothing more than complex conditional stimuli in a conditional discrimination.

The naming pretest data suggest the same thing. Thus, as illustrated by the data in Table 2, by the end of conditional discrimination training, after hearing each of the six descriptions an average of approximately 80 times (485 training trials), and after repeating the feature names innumerable times as echoics while cycling through the six stimuli of the training and test blocks looking for the correct comparison, subjects still could not emit these names when shown the intact stimuli. This, despite the fact that the names were all common English words. Rather, as the naming test data indicate, when shown the stimuli subjects could name a few in their entirety, but only fragments or nothing at all for all the others. Further, even where a feature was accurately named when it appeared in one stimulus, this was no guarantee it would be correctly named when it appeared in some other stimulus. Subjects thus seemed not have tacts available for all stimulus features by the end of conditional discrimination training.

Assuming this to be so, the feature-tact training procedure, focused as it was on training individual tacts for each feature, should have taken care of the problem. Apparently, subjects simply did not use the individual tacts, even when trained, to control stimulus selection in Test 2.

The data of Test 3 also are consistent with this notion. Stimulus-tact training with the training set merely produced yet another exposure to stimuli and descriptions the subject had already seen and heard numerous times.

There was no aspect of the contingencies here that differentially reinforced tacting the features as opposed to emitting the feature names as previously heard intraverbals while the features of a stimulus cumulatively appeared.

This of course was not the case with the novel-tact training set and its effect on behavior in Test 3N. The old three-word intraverbals would not work with these novel stimuli, and the new names were so similar to the old that subjects could only differentiate their names by responding to the individual stimulus features. Thus the training set contained the stimulus *king bus clip,* while the novel-tact training set contained *king bus check* and similarly with *pond bus check* and *king bus check*. In contrast to the previous training, responding differentially to individual features within complex stimuli was differentially reinforced here.

Performances with the novel stimuli of Transfer Set 2 in Test 4 and in the naming post-test provided a striking contrast with performances with the then-novel stimuli of the naming pretest and Test 1. Thus, whereas no subject in the pretest accurately described all the stimuli—even after spending 400+ trials learning to select stimuli in response to their names—in the naming post-test SB and EB tacted all the novel post-test stimuli at first sight, and with no prior training at all. And it would certainly seem to be this tacting that allowed for the errorless generalized selection performances observed with both subjects in Test 4 as the notion of joint control would require.

Findings by Goldstein et al. (1987) support this interpretation. Instead of looking at generalized matching, they looked at the generalization of naming. Thus, they trained subjects to emit multipart names to each of a set of multielement stimuli, but also found this did not produce generalized naming: Subjects could not emit novel names when shown novel recombinations of the same elements. After the subjects were required to learn to name some novel recombinations, however, generalized naming appeared with other, novel recombinations. These data thus support directly the interpretation of the present study: that training subjects to name novel stimulus combinations resulted in the emergence of generalized, recombinative naming which then contributed to the appearances of generalized matching under joint control.

EXPERIMENT 2

Although many studies have looked at the general effect of acquiring sample-tacting responses (variously called naming or coding responses) on selection accuracy in delayed-matching tasks, none seem to have looked at the role played by the active rehearsal of these responses just before and during the comparison-selection phase of the performance (e.g., Cohen, Brady, & Lowry 1981; Eckerman, 1970; Parsons, Taylor, & Joyce, 1981; Urcioli, 1985). But if accurate comparison selection is to occur, some aspect of the topography related to the sample must be precisely maintained until comparison selection has occurred.

In the current experiment these maintained topographies, controlled as they are by prior rehearsals, are in fact self-echoics and the experiment analyzes the effect of these self-echoics on comparison-selection accuracy by studying the effect of preventing their rehearsal while subjects cycle through a sequence of successively presented comparisons, seeking a match to the sample. It is assumed here that the accurate selection of comparisons appearing earlier in the sequence, and thus nearer the experimenter's pronunciation, will be less disrupted than those occurring later in the sequence. Thus, a declining gradient of accuracy across sequence position was expected when subjects were prevented from self-echoic rehearsal. Conversely, if the mediating responses are not vocal, or if indeed they play no role in selection accuracy, as for example in an unmediated conditional discrimination, then flat gradients across sequence positions would be expected.

METHOD

Subjects

Three boys (RJ, KH and BS) and one girl (JL) participated. Their ages ranged from 6.8 to 7.1 years old.

Stimuli

Three sets of stimuli were used in this experiment (Table 1). Training and Transfer Sets 3 here were Training Set and Transfer Set 1 in Experiment 1. Training and Transfer Sets 1 and 2 here were composed of new features with appropriate names. (Figure 1). Thus the Training Set 1 stimulus described as *gray fish dots* was exactly that: a gray fish with the dot border. As illustrated in Table 1, all the stimuli in Training and Transfer Sets 1 and 2, were generated by systematically replacing the names and features of Training and Transfer Set 1 of Experiment 1 with new names and features so as to produce new training and transfer sets with compositions exactly comparable to those used in Experiment 1. Thus, although the names and features themselves were novel, their pattern of combination was the same across corresponding sets of stimuli.

Baselines and Tests

All baselines and tests for generalization were constructed and administered in the manner described in Experiment 1. They differed from those in Experiment 1 only in terms of the particular features they contained on the color, shape and border dimensions. And, in a corresponding fashion, so did the spoken names of these stimuli.

To measure the effects of rehearsal prevention, matching performance with the training set was measured using *rehearsal-prevention baseline blocks,* and performance with the transfer set was measured with *rehearsal-prevention test blocks*. Both types of rehearsal-prevention blocks were the same as regular baseline and test blocks, but with one addition: A series of single, black digits (0–9) appeared, one replacing the other every .8 s, 3 cm below the location of the bottom of the comparisons. The digits appeared on the blank white screen that started a trial, continued as the subjects pressed the black square to cycle through the comparisons, and vanished when the subject selected a comparison. Baselines still contained one 12-trial block, and tests still contained 24 trials (two 12-trial test blocks).

Procedure

Stimulus Set 1. All aspects of the training and testing procedures described in Experiment 1 up to, and including Test 1, were repeated but using Training Set 1 and Transfer Set 1 for Experiment 2 (Table 1 and Figure 1). Subjects thus first received conditional discrimination training, then the naming test, followed by a Set 1 baseline block, and then Generalization Test 1 with the stimuli of Transfer Set 1.

Response-prevention training. Following Generalization Test 1, performance on the rehearsal-prevention task was trained using the Set 1 baseline block. On the first trial, as the numbers began appearing on the otherwise blank white screen, subjects were prompted to read each number as it appeared with the prompt *What number is this?* After subjects began reading the numbers without further prompts, the experimenter said the name of the first comparison to be selected and caused the first comparison and the black square to appear on the screen.

Through further prompting and instruction, subjects were taught to continue to read the numbers as they appeared, while pressing the black square to cycle through the comparisons. Whenever subjects stopped reading the digits, they were immediately prompted (read the numbers) to continue to do so. Over further trials, training continued until subjects could maintain the number reading while pressing the black square and selecting comparisons. There was no criterion for matching accuracy as the intent here was simply to train subjects to read the numbers while selecting these already-trained comparisons.

Rehearsal-prevention Test 1. In the next session, after completing a regular baseline block in which all comparisons were selected correctly, two 12-trial rehearsal-prevention baseline blocks were administered to test the effect of rehearsal prevention on selection accuracy.

Stimulus Set 2. In the next session, subjects were given conditional-discrimination training with Training Set 2. At criterion this was followed by the naming test, a baseline block, and a test for generalized matching (Generalization Test 2 in Figure 4). In the following session, to measure the effect of rehearsal prevention, subjects were given a single rehearsal-prevention baseline block (Rehearsal-prevention Test 2) followed by two rehearsal-prevention test blocks all with the stimuli of Transfer Set 2 (Rehearsal-prevention Test 3).

Stimulus Set 3. In the next session, conditional discrimination training began with the training stimuli of Set 3 (Set 1 in Experiment 1). In a subsequent session, at criterion, this was followed by the naming test, a baseline block, and a test for generalized matching

Table 3

Experiment 2. Trials to criterion at each stage of conditional discrimination training and the number of dimensions named for each stimulus in the naming test.

	Set 1 (Familiar names)						
	Conditional discrimination training Trials to criterion			Naming test Number of features correctly named			
	Stage 1	Stage 2	Stage 3	3	2	1	0
RJ	94	18	27	4[a]	2	0	0
KH	84	23	29	6	0	0	0
JL	86	20	34	6	0	0	0
BS	92	28	33	6	0	0	0
	Set 2 (Familiar names)						
	Conditional discrimination training Trials to criterion			Naming test Number of features correctly named			
	Stage 1	Stage 2	Stage 3	3	2	1	0
RJ	44	24	17	6	0	0	0
KH	36	25	17	6	0	0	0
JL	41	27	17	6	0	0	0
BS	42	25	18	4	2	0	0
	Set 3 (Unfamiliar names)						
	Conditional discrimination training Trials to criterion			Naming test Number of features correctly named			
	Stage 1	Stage 2	Stage 3	3	2	1	0
RJ	219	17	41	4	0	1	1
KH	264	45	45	3	0	0	3
JL	234	18	38	3	1	0	2
BS	220	18	34	1	2	2	1

[a] Number of stimuli evoking correct names for this number of features.

(Generalization Test 3). In the following session, subjects were given two rehearsal-prevention baseline blocks with the training stimuli of Set 3 (Rehearsal-prevention Test 4). Subjects were then given feature-tact training for the names of the nine dimension features of Set 3, followed by a baseline test and then a test for generalization (Generalization Test 4).

Results

As illustrated in Table 3, on the average, subjects acquired the conditional discrimination with the familiar names for the stimuli of Training Set 1 in 142 trials. This is about a third as many trials as it took with the novel names for the stimuli used in Experiment 1. Furthermore, and again in contrast to Experiment 1, in the naming test, 3 of the 4 subjects gave correct names for all of the stimuli. RJ forgot the name *lines,* calling this border *ladder* when Stimulus 3 was shown, and *dot* when Stimulus 6 was shown.

Generalization in Test 1 was equally errorless (Figure 4), with three of the subjects making no errors. One of the two errors made by RJ was correlated with his performance in the naming test: He confused the lines with the ladder in Transfer Set Stimuli 1 and 4.

In Figure 5, the gradients of declining accu-

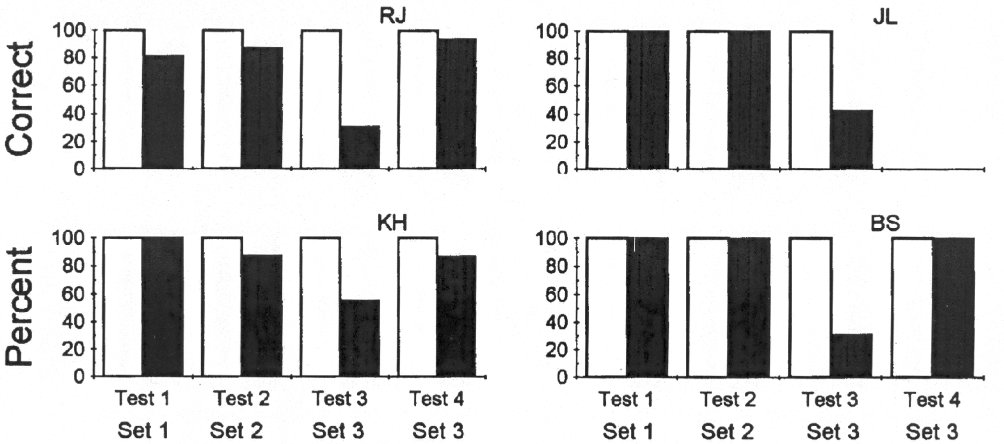

Fig. 4. Generalization data for Experiment 2, Tests 1 to 4. The open bars indicate the percentages of correct selections on training set trials. The filled bars describe performance with Transfer Sets 1, 2, and 3. Generalization Test 1 was conducted with Stimulus Set 1; Generalization Test 2 was conducted with Stimulus Set 2 and Generalization Test 3 with Set 3. Test 4 retests with Set 3.

racy illustrate the effect of preventing subjects from repeating the sample descriptions. In Response-prevention Test 1, the Page *L* statistic (Siegel & Castellan, 1988, p. 184) verified a significant decline in selection accuracy with Training Set 1 ($L = 346$, $p < .001$) as a function of the number of comparisons the subjects had to view before encountering the one that had been named by the experimenter; this, in contrast to the errorless selection performance with these same stimuli in the immediately preceding regular baseline block.

Performance with Set 2, also with familiar names, was comparable to Set 1. Once again (Table 3), the conditional discrimination was rapidly acquired (mean = 83 trials), and subjects named the stimuli accurately in the naming test. Subject BS called the border appearing in Stimuli 3 and 6 *square* instead of *box.*

Generalized conditional-discrimination performance in Set 2 (Figure 4) was again essentially errorless. No subject made an error on the training-set trials, nor more than two errors on the generalization test trials. Again, as illustrated in Figure 5, rehearsal prevention was found to influence selection accuracy: Significant gradients of declining selection accuracy were found with both in Rehearsal-prevention Test 2 with Training Set 2 (L=335, $P < .01$), and in Rehearsal-prevention Test 3 with Transfer Set 2 (L=345, $p < .001$).

In contrast to Sets 1 and 2, here, introducing the stimuli of Set 3 had a dramatic effect on the rate of acquisition of the conditional discrimination. These were the same stimuli and names used in Experiment 1 as the training set; and as in Experiment 1, here too, acquisition of the initial conditional discrimination (Rehearsal-prevention Test 2), though it took roughly half as many trials as in Experiment 1, was still very slow (mean = 298 trials, Table 3). Once again, the subjects did not learn names for the individual features. Thus, in the naming test, no subject named all of the features of more than four stimuli and all subjects failed to name any feature of one or more stimuli. As in Experiment 1, it appears that subjects simply repeated the complete sample names they remembered from the roughly 300 training trials it took to reach criterion. And as in Experiment 1, generalization with the transfer set was poor in Test 3 as well (Figure 4).

However, unlike the performances in Rehearsal-prevention Tests 1, 2, and 3, in Rehearsal-prevention Test 4, rehearsal prevention did not affect selection accuracy with the training-set stimuli here ($L = 304$, $p > .1$). Instead, the gradients (Figure 5) are flat: subjects made as many accurate selections with five interpolated comparison stimuli as with none.

As to generalized matching, after just feature-tact training with Set 3 (Figure 4), all subjects showed high levels of generalization in Test 4 (Subject JL left the experiment at this point). Thus, generalized matching with Set 3 was achieved here with far less training than

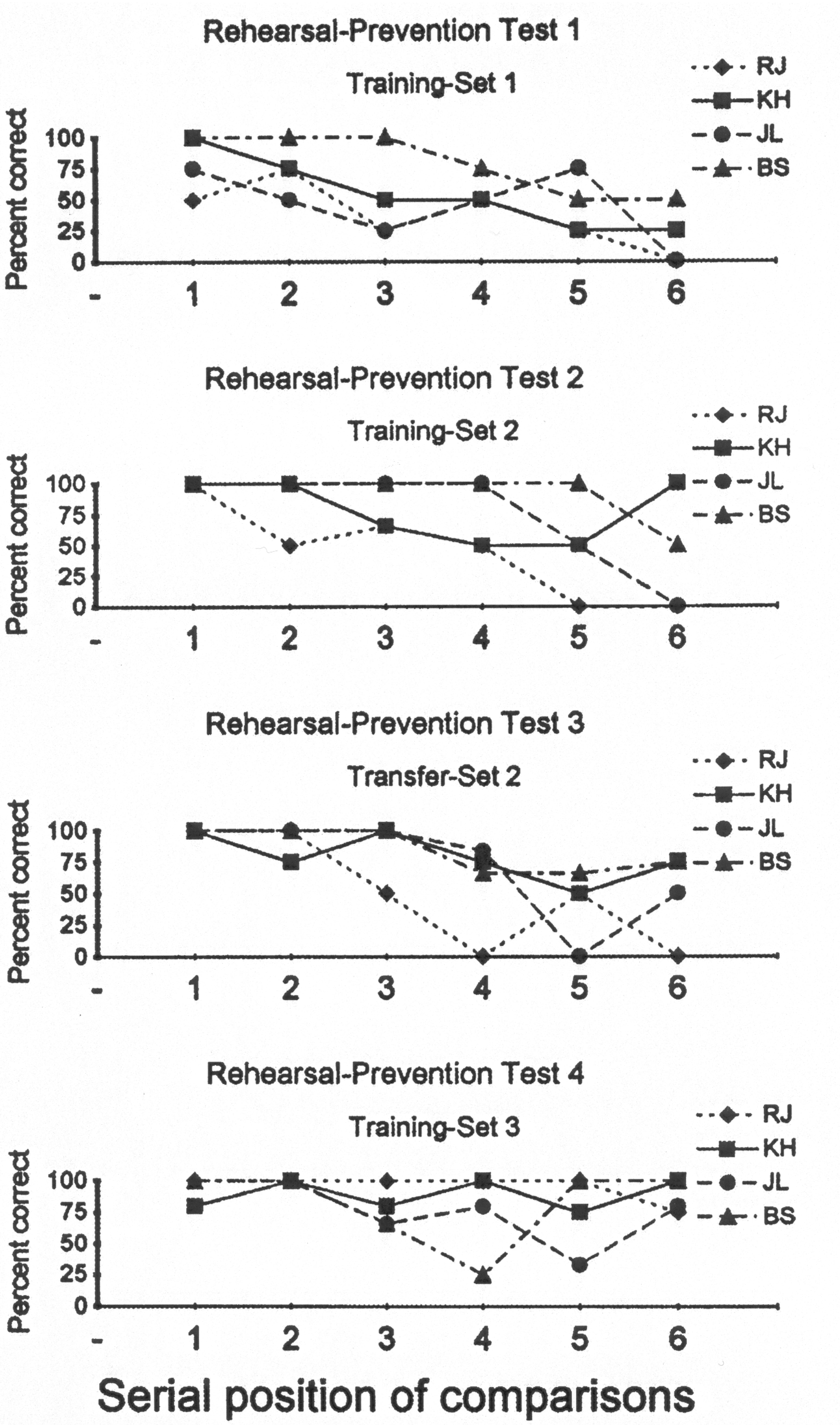

Fig. 5. Percentages of correct selections on rehearsal-prevention tests. All gradients, except for Training Set 3, show significant declines in selection accuracy ($p < .01$) as a function of the number of incorrect comparisons presented between the spoken sample and the appearance of the correct comparison.

in Experiment 1 where comparable generalization with this set was only achieved after stimulus-name training with novel stimuli.

Discussion

Once again, the role of tact availability in generalized selection was demonstrated. In Figure 4, in Sets 1 and 2, where the stimuli had familiar names, virtually errorless performance on the naming test was accompanied by high levels of generalization, while in Set 3 poor naming was accompanied by low levels of generalized matching in Test 3.

The data also show that self-echoic behavior had an important role in maintaining selection accuracy. In Figure 5, in Sets 1 and 2, the consistently declining gradients of selection accuracy when rehearsal was prevented indicate that selection accuracy depended on the availability of some cue derived from the sample and retained by rehearsal over the interval until the specified comparison appeared. That this cue was vocal is suggested by the fact that the sloping gradients were produced by requiring a competing vocal response (number naming).

In Set 3, however, rehearsal prevention produced no detectable gradient. Subjects performed just as well if the correct comparison was presented immediately, as if it was the last of the six comparisons. This suggests that whatever it was that may have mediated the delay interval here, it was not verbal behavior. Instead, given the fact that subjects had seen and selected these six training-set stimuli well over 200 times during conditional-discrimination training, it is possible that subjects used a visual mediator, perhaps using the sample description to picture the comparison to be selected. Conceivably, such seeing in the absence of the visual stimulus (Skinner, 1969) would be immune to competition from vocal responses. Thus, though it is admittedly speculative, it is also parsimonious to suggest that here (and in Tests 1 and 2 in Experiment 1 as well) subjects pictured the described object (Skinner, 1974, p. 82) and sought the comparison that entered into joint control with that image (i.e., that allowed the subject to continue to see the rehearsed image in the presence of the actual image).

If the declining gradients do indeed indicate a role for actively rehearsed vocal mediation in comparison selection, then they also indicate a role for vocal mediation in generalization; for in Sets 1 and 2 high levels of generalization were accompanied by declining gradients, while in Set 3 a flat gradient was accompanied by the absence of generalization. There thus seems to be a clear link between self-echoic rehearsal and generalized responding.

GENERAL DISCUSSION

Taken together, the data in Experiments 1 and 2 indicate that the generalized selection of comparisons in response to sample names depended on the availability of both of the elements that comprise joint control: accurate tacts and accurate self-echoic rehearsal. Precisely how these responses interact must, of necessity, remain subject to speculation, but the fact that the only selections that were reinforced were the selections of comparisons for which the rehearsed self-echoic also served (jointly) as an accurate tact certainly suggests that it was this event, this joint self-echoic and tact control by a single comparison, that provided the basis of generalization with the novel stimuli. In essence, the selection response was an autoclitic report of this generic stimulus control event (Lowenkron, 1991, 1998.)

But joint control was not the only means by which stimuli were selected. The data in Experiments 1 and 2 indicate that comparison selection was, at times, under some other form of stimulus control: namely, a non-verbal, and possibly visually mediated, conditional-discrimination control. And so, taken together, the data suggest two forms of stimulus control occurred here.

Thus, in Experiment 1, and with Set 3 of Experiment 2, when the stimuli had unfamiliar names acquisition of the initial conditional discrimination was very slow, subjects could *not* name the stimuli in the naming pretest, and generalization was poor. In Experiment 2, rehearsal prevention produced a flat gradient. This is just what would be expected if the discrimination was acquired under unmediated conditional stimulus control.

On the other hand, in Experiment 2, with Sets 1 and 2, the stimuli had familiar names, acquisition of the initial conditional discrimination was rapid, subjects could tact the stimuli when asked, generalization was immediate, and under rehearsal-prevention, selection accuracy deteriorated across the delay gradient. All this would be expected in a mediated performance—as, for example, one under joint control.

A dual basis for discrimination learning in children has been suggested before. These findings are strongly reminiscent of the extensive body of research comparing reversal and extra-dimensional shift performances (Kendler & Kendler, 1970; Lowenkron, 1969; Wolff, 1967). Those data, acquired from a developmental viewpoint, showed that children about the age of the present subjects generally tend to learn simple discriminations, involving multidimensional stimuli, in an unmediated single-unit fashion. With age, however, they could learn to select stimuli based on the products of their own mediating responses. Lowenkron (1969) and Lowenkron & Dreiessen (1971) extended these studies to adults, showing that even with this population various task variables could serve to determine which mode of responding (mediated or unmediated) subjects would select in. The current finding extends this, showing the dual basis (mediated and unmediated) for acquiring a *conditional* discrimination.

Additional evidence for the operation of two different forms of stimulus control is provided by the interaction observed between the type of names used in conditional discrimination training and the emergence of the arbitrary names for the stimulus features. Thus, in Experiment 1, training the initial conditional discrimination with unfamiliar stimulus names seemed to block the application of these tacts to stimulus selection. As a result, much additional training, in the form of both feature-tact training and stimulus-tact training with novel stimuli, was needed before generalized matching finally appeared. If, as the naming pretest data indicate, subjects responded to the three-part names as intact, undifferentiated units during conditional discrimination training, this may have interfered with any subsequent training to teach subjects to select comparisons based on matches between parts of the names and the corresponding parts of the comparisons. The effects seen here are reminiscent of the blocking effects of trial and error training in the transfer of stimulus control observed by Touchette, (1969) and Fields (1978) and in the blocking effect of pictures on the acquisition of names for printed words (Singh & Solman, 1990).

In contrast, in Experiment 2, when subjects were first trained with two sets of stimuli, both comprised of familiar names, and then given stimuli with unfamiliar names (Set 3), generalized matching appeared at full strength after only feature-tact training. Pretraining with the familiar names of Sets 1 and 2 thus seemed to *potentiate* the subsequent learning with the unfamiliar names of Set 3 and thereby hastened generalized responding.

This improvement emulates another developmental process. For had *adults* been exposed to the novel names of Set 1 in Experiment 1, almost certainly they would have attempted to isolate the names for each feature during the very first stages of conditional discrimination training—something possible given the logical structure of that set of stimuli. And success here almost necessarily would have contributed to success on both the naming pretest and in the tests for generalized matching.

Taken together, these data rationalize a distinction between the traditional notion of stimulus selection in a conditional discrimination and the notion of stimulus specification under joint control. In the traditional account (Michael, 1985), response strength is continuously variable, and in a conditional discrimination, a comparison stimulus is selected as a result of a heightened response probability to that stimulus in the presence of a given sample or some rehearsed representation of the sample. The availability of tacts or other differential responses to the comparison stimuli is immaterial.

In contrast, under joint control, the strength of the selection response is discrete, though not quantal in the sense described by Bickel & Etzel (1985). Rather, it is discrete in the sense that joint control either does or does not exist between the elements of the sample description and the elements of the comparison tact, and it is this discrete event that is reported by the autoclitic selection response. Thus in the present case, the experimenter's description specified one particular comparison: namely, the comparison that evoked a tact whose topography allowed a repetition of the self-echoic of the sample, but no other.

It would appear that such a distinction provides a clear, behavioral basis for viewing the commonplace notions of reference, description, and specification as something distinct from the notion of stimulus selection as the result of a heightened selection-response probability (Lowenkron, 1998). That is to say, while an S^D *evokes* a selection response, a description fits the object described in the sense that the description consists of, and the object evokes, two verbal operants (self-echoic and tact) with a common topography. And at this point the object could be said to have been recognized from its description.

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