

The Feature-Positive Effect in Adult Human Subjects

Joseph Newman, William T. Wolff, and Eliot Hearst
Indiana University

Previous experiments with animals and young children have shown that discriminations based on the presence versus absence of a single feature are learned more easily when the feature appears on reinforced rather than nonreinforced displays. Six experiments demonstrated an analogous effect in college students, across a range of stimulus materials, general procedures, kinds of feedback, pacing of trials, and instructions to the subject. The results were analyzed in terms of the exceptionally strong control of behavior by events that are present on positive trials. These findings have implications for theoretical interpretations of human concept learning and decision making, and offer additional examples of the difficulty organisms experience in using "nonoccurrence" as a cue.

Jenkins and Sainsbury (1969, 1970) used the term *feature-positive effect* (FPE) to describe a surprising asymmetry they observed in the pigeon's learning of discriminations based on the presence versus absence of a single distinguishing feature. When the feature was located on the positive, food-reinforced display (S+), subjects showed far superior discriminative performance than did subjects for which the feature appeared on the negative, nonreinforced display (S-). As a concrete example, consider a discrimination in which all of the trials involve the illumination of a response key, but on half of the trials a small black dot is present somewhere on the key and on half of the trials it is not. If trials with the dot constitute the S+ condition, and trials without the dot constitute the S- condition (i.e., the *feature* appears on *positive* trials [FP]), pigeons acquire a discrimination be-

tween S+ and S- much more rapidly than if no-dot trials constitute the S+ condition and dot trials constitute the S- condition (i.e., the *feature* appears on *negative* trials [FN]). The asymmetry in discrimination learning was enormous in the studies of Jenkins and Sainsbury; only 1 out of approximately 50 pigeons ever mastered the FN discrimination, whereas a large majority of the FP subjects were successful.

Although the extent of the FP superiority is usually less dramatic than in Jenkins and Sainsbury's experiments, the phenomenon appears to have rather broad generality across animal species (pigeons, rats, cats, and monkeys), appetitive and aversive reinforcement procedures (food or shock), types of features (auditory or visual), sequential and simultaneous presentations of the stimulus displays, and experimental settings (see Hearst, 1978, and Hearst & Jenkins, 1974, for reviews). Furthermore, a clear FPE has been reported in young children by Sainsbury (1971, 1973), who exposed his subjects to a simultaneous discrimination based on the presence versus absence of a particular symbol (e.g., a triangle) on one of two 2×2 matrix displays, the other seven elements of which were identical (e.g., squares). Although Sainsbury obtained a substantial FPE in 5-yr-old children, the phenomenon was not very pronounced in 7-yr-olds and was absent in 9-yr-

The pigeon work described here was supported by Grant MH 19300 from the National Institute of Mental Health to Eliot Hearst. Experiment 1 was part of the research performed by Joseph Newman for his senior thesis under the direction of Sidney Perloe at Haverford College.

We thank Sarah Bottjer, Ruth Capshaw, Alida Evans, Russell Fazio, Dexter Gormley, Peter Kaplan, Ione Kotis, Eileen Riffe, Lynn Sternberg, and Edward Walker for valuable advice and assistance.

Requests for reprints should be sent to Eliot Hearst, Department of Psychology, Indiana University, Bloomington, Indiana 47405.

olds. In experiments with nursery school children and university students, Norton, Muldrew, and Strub (1971) found that in both age groups the subjects learning FN discriminations made significantly more incorrect responses than the subjects learning FP discriminations; in their procedure, however, no clear-cut differences apparently occurred in terms of the number of subjects mastering each type of discrimination. Therefore, except for Sainsbury's results with 5-yr-olds (see also Bitgood, Segrave, & Jenkins's, 1976, replication and extension of Sainsbury's work), the FPE has not been very large in experiments with human beings.

Rather than concluding that the phenomenon is either absent or weak in human subjects older than 5 yr, we felt that the reported lack of a powerful FPE might be due to ceiling effects resulting from the simplicity of the tasks used in prior human work. Therefore, we set out to devise and investigate some arrangements that fulfilled the specifications of the FP versus FN paradigm and yet involved discriminations that were reasonably difficult for adults to learn. In this article we report a series of experiments yielding a robust FPE with college students in several tasks differing with respect to (a) the type of stimulus material (geometric symbols; letters in a trigram; line drawings of everyday objects), (b) the mode of presentation of the positive and negative displays (simultaneous; successive), (c) the kind of feedback delivered for correct and incorrect responses (verbal reinforcement by the experimenter; automatically controlled increases or decreases in points displayed on a counter; delivery of poker chips), (d) the length of the postfeedback (intertrial) interval, (e) the type of response required from the subject (vocal; manipulatory), (f) the details of the instructions to the subject, and (g) the size and nature of the set of "common" irrelevant elements (either held constant or varied nonsystematically from trial to trial so that they could not provide any reliable basis for discriminative performance). As will be argued, comparisons of the effects of these different treatments enable us to assess and exclude various alternative explanations of

the FPE obtained in any single type of arrangement. Finally, we describe an experiment with pigeons that utilized virtually the same apparatus and a procedure analogous to some of the specific work we performed with human beings, to determine whether the relatively complex tasks that we used in the human studies would also yield a FPE in the nonhuman organism that has served as the standard subject for experiments on this topic.

The focus of this article is primarily empirical; many of our experimental manipulations were designed to parallel investigations of the FPE with nonhuman subjects. However, the similarities in procedures employed and results obtained with both animal and human subjects prompted us to begin to integrate theoretical interpretations of the FPE in animals with the analysis of human concept learning and hypothesis testing. The FPE seems to reflect certain deficiencies and difficulties that human beings often exhibit in their processing of negative information and their use of "non-occurrence" as a cue.

Experiment 1

Method

Subjects. The subjects were 24 Haverford and Bryn Mawr undergraduates who consented to participate in the experiment. There were 12 FP and 12 FN subjects.

Materials. The test materials included 90 3-in. × 5-in. (7.6 cm × 12.7 cm) index cards, each containing four symbols approximately 2.5 cm in height and .6 cm apart, and a wooden screen behind which the experimenter could sit and present the cards through a rectangular cutout. The individual stimulus elements were six symbols (O, □, △, T, ☆, X), each of which appeared a total of 60 times over the 90-trial maximum length of a discrimination session. Each trial consisted of the presentation of a single index card containing four different symbols. The triangle was the distinguishing feature for all subjects and appeared only on *Good* trials for the FP group and on *Not Good* trials for the FN group. The other five stimuli appeared on the various cards in a non-systematic fashion.

Procedure. Each subject was shown the first card and then asked to read the instructions, which were as follows:

Contrary to what seems to be a prevalent conception of a psychological experiment on this campus, this is an experiment which *is* testing what it purports to.

THE TEST: There are 90 cards. Each card has 4 symbols (6 symbols are used in all). Some of these cards are *Good* and some are *Not Good*.

THE TASK: The cards will be presented one at a time, for 5 seconds each. Your task is (1) to guess whether each card is *Good* or *Not Good* (the experimenter will tell you after each card whether you are right or wrong), and (2) to guess, as soon as possible, the solution which reliably predicts whether a card is *Good* or *Not Good*.

It is *one* symbol and not the relationship between them which is important.

The experimenter will record the number of cards used to arrive at a solution, but will not tell you if your hypothesis is right or wrong until the experiment is over. It is expected that when a subject has found a solution he or she will use the remainder of the cards to check the validity of his or her hypothesis. Thanks very much for your cooperation.

When the subject had finished reading the instructions, the experimenter read them aloud and clarified any questions by rereading the relevant part of the instructions. Then the learning session began. If a subject failed to respond either "Good" or "Not Good" within 5 sec after presentation of a card, another card was immediately presented and no feedback was provided for the prior trial. If at any time during the task the subject offered an incorrect solution, the experimenter replied, "Okay, continue to test it out." The experiment was terminated either when the subject provided the correct solution or after all 90 cards had been presented. The cards were thoroughly reshuffled for each new subject.

Results and Discussion

In the data analysis, subjects who did not state the correct solution within the 90-trial limit were assigned a score of 90 trials. The mean number of trials required before verbalization of the correct solution was 17.8 for the FP subjects and 62.9 for the FN subjects, $F(1, 22) = 19.53$, $MS_e = 624.39$, $p < .001$. All 12 FP subjects eventually stated the correct solution (the maximum number of trials taken by any subject in that group was 61), whereas only 6 of the 12 FN subjects were able to do so. Thus, as in the animal research mentioned earlier, subjects had considerably more difficulty learning a discrimination in which the distinguishing feature was located on the negative, as compared to the positive, display.

To hold constant the total number of presentations of each of the six stimuli, trials containing the feature necessarily consti-

tuted 67% of the total number of trials in the experiment, that is, 60 out of 90 trials. This aspect of the procedure could possibly have introduced a bias in favor of the FP group. However, we will shortly describe several successive-discrimination experiments in which an equal number of positive and negative displays were presented to FP and FN groups and in which a robust FPE was still obtained.

Experiment 2

Experiment 1 revealed a highly significant FPE in college students exposed to a successive discrimination. Our next experiment employed a simultaneous discrimination, which might be expected to facilitate learning because subjects could concurrently compare the feature and nonfeature displays. Instead of using symbols as the stimulus elements, the discrimination was based on the presence of a particular letter in one of the two trigrams presented on each trial. For the FP subjects this trigram was the correct choice, whereas for the FN subjects it was incorrect.

Method

Subjects. The subjects were 32 undergraduates at Indiana University who participated in the experiment to fulfill a psychology course requirement. Sixteen subjects were placed on a FP procedure and 16 on a FN procedure.

Materials. The test materials comprised 60 3-in. × 5-in. cards, each containing two typewritten trigrams located side by side on the card. A wooden screen with a rectangular cutout allowed presentation of the cards by the experimenter. The potential stimulus elements in this experiment consisted of all of the (capital) letters of the English alphabet. For half of the FP or FN subjects, the feature was a vowel (the letter A), whereas for the other half it was a consonant (the letter T). In addition to the feature, which always appeared on one of the two trigrams, each of the other letters of the alphabet appeared equally often on the 60 cards in a random fashion, except that (a) actual three-letter words were not used as trigrams, and (b) no vowels (including Y) were used on the trigrams for subjects that had a consonant as the feature. The feature appeared equally often in the left, middle, or right position of the trigram containing it. Nonfeature letters could be repeated on the other trigram, but not within a given trigram.

Procedure. Each subject was read the following standard set of instructions:

I have here 60 file cards. Each card contains two trigrams. A trigram is a meaningless combination of

three letters. One of the trigrams on each card is *Good* and one is *Not Good*. Now there is nothing inherently *Good* or *Not Good* about a trigram except that a system was used which does differentiate them. Your task is to figure out this system—in other words, what makes a trigram *Good* or *Not Good*. Any questions?

I am going to show you the cards one at a time at a rate of one card every 5 sec. You tell me whether the left or right trigram is *Good*, and I'll tell you whether you were right or wrong. Finally, it is very important that you tell me as soon as you think you have a solution. I will not tell you whether it is right or wrong, but I will write it down and then we will continue the test. Any questions?

If a subject failed to respond "left" or "right" within 5 sec after presentation of a card, another card was immediately displayed and no feedback was given for the prior trial. If a correct solution was never provided by the subject, the experiment ended after 60 trials; otherwise, it ended when the subject stated the correct solution. In the absence of any statements by the subject, every 10 trials the experimenter asked the subject what hypothesis he or she was using. The cards were thoroughly reshuffled for each new subject. For the FP subjects the presence of the feature in one of the trigrams made it the correct choice, whereas for the FN subjects the correct trigram was the one without that particular letter.

Delayed feedback condition. After the preceding conditions had been tested, 18 additional naive subjects, drawn from the same subject pool, were used in an extension of the work. There were 8 FP and 10 FN subjects. The stimulus cards were the same as those used in the "consonant" groups just described; that is, the letter T was the feature for all subjects. Except for the fact that each card was removed from sight for 5 sec before the experimenter provided feedback about the correctness of the subject's last response, the procedure and general instructions were the same as those in the previous treatments.

Results and Discussion

In the data analysis, subjects who did not verbalize the correct solution within the 60-trial limit were assigned a score of 60 trials. The mean number of trials required before verbalization of the correct solution in the immediate-feedback condition employing a vowel as the feature was 33.0 for the FP group and 56.3 for the FN group, $F(1, 14) = 12.01$, $MS_e = 179.96$, $p < .01$; seven of the eight FP subjects were able to state the solution before the 60-card limit had been reached, whereas only one of the eight FN subjects was able to do so. For the comparable groups that had a consonant as the feature, the mean number of trials required before verbalization of the correct

solution was 34.6 for the FP group and 60.0 for the FN group, $F(1, 14) = 8.63$, $MS_e = 298.42$, $p < .02$; five of the eight FP subjects were able to verbalize the solution before the 60-trial limit, whereas none of the eight FN subjects was successful.

Once again, a powerful FPE was obtained in a discrimination task with adult humans. Realizing that the information required to solve the problem appears on negative displays is apparently very rare. In both the vowel and the consonant experiments, it was common for subjects in the FN groups to report that when they had just chosen the wrong trigram, they rehearsed only the other (correct) member of the pair. They focused on information contained in the positive trigram and ignored information contained in the negative trigram; however, the latter provided the only basis on which the discrimination could be learned.

Since it appeared that subjects failed to take into account information contained in the negative trigram, we next examined a condition that we thought might increase the probability of the FN subjects' utilizing such information: The stimulus card was removed from sight after the subject's choice, and feedback was delayed for 5 sec. Under these circumstances it seemed reasonable to expect that FN subjects would be more likely to rehearse and retain material contained in the negative display, if they had selected it, than was the case in the previous experiment when feedback was immediate and both trigrams were still visible at the time of feedback.

However, introduction of delayed feedback had virtually no effect on the magnitude of the FPE. The mean number of trials required before a statement of the correct solution was 22.3 for the FP group and 52.0 for the FN group, $F(1, 16) = 11.70$, $MS_e = 336.34$, $p < .01$. Seven of the 8 FP subjects solved the problem before the 60-trial limit had been reached, whereas only 2 of the 10 FN subjects were successful.

Experiment 3

The foregoing experiments involved stimuli whose common, irrelevant elements

were varied from trial to trial, and were selected from a fairly large set of potential items (5 items in the symbol discrimination used in Experiment 1, 19–25 items in the trigram discrimination of Experiment 2). In contrast, animal work on the FPE (but see our Experiment 7) has employed elements common to the positive and negative displays that were essentially identical from trial to trial (e.g., the static, unchanging physical aspects of the illuminated pigeon key itself; the presence of stars on a display). In two pairs of treatments with human beings, we next used a set of displays that came closer to the animal paradigm: One or two particular letters appeared on every trigram. The first pair of treatments involved a simultaneous discrimination, as in the prior work with trigrams, whereas the second pair of treatments employed a successive discrimination, as in the prior work with symbols. Would the FPE in human beings begin to disappear as the properties of the stimulus displays presumably became more and more similar to displays used with nonhuman subjects, and would the required discrimination therefore be simpler?

Method

Simultaneous discrimination. Sixteen Indiana University undergraduates participated in the study to fulfill a course requirement. The stimulus materials, the instructions, and the procedure were identical to the standard consonant-trigram discrimination described in Experiment 2, except that all trigrams, *Good* and *Not Good*, contained the letter J, which could appear in any position within the two trigrams. The feature was the letter N for all subjects.

Successive discrimination. Fifteen Indiana University undergraduates were exposed either to a FP discrimination procedure ($n = 8$) or to a FN discrimination procedure ($n = 7$) in which only one trigram appeared on each of the 102 cards (the size of the cards was 3 in. \times 2½ in. (7.6 cm \times 6.4 cm) in this work). Subjects were instructed that the trigram appearing on a given card was either *Good* or *Not Good*, and that their task was to discover the rule differentiating these categories. Each of the trigrams was composed of the same two letters (R and B) appearing randomly in any position within a trigram, and a third letter that was either the feature (T) or one of the 17 other consonants. Subjects had a maximum of 102 trials in which to discover the solution. In contrast to the successive discrimination of Experiment 1, an equal number of positive and negative displays were presented to all subjects.

Results and Discussion

The inclusion of an identical letter on both trigrams in the simultaneous-discrimination procedure did not reduce the magnitude of the FPE compared to the effects of similar treatments in Experiment 2. The mean number of trials to a correct solution was 22.0 for the FP subjects and 50.0 for the FN subjects, $F(1, 14) = 10.79$, $MS_e = 290.57$, $p < .01$. All eight FP subjects correctly stated the solution within the 60-trial limit, whereas only two of the eight FN subjects did so.

A substantial FP superiority was also obtained in the successive-discrimination arrangement. Subjects who did not verbalize the correct solution within the 102-trial limit were assigned a score of 102 trials. The FP subjects required a mean of 40.6 trials to discover the solution and the FN subjects 79.3 trials, $F(1, 13) = 5.28$, $MS_e = 1057.02$, $p < .04$. All eight FP subjects provided the correct solution, whereas only three of the seven FN subjects were successful. Thus, even though two of the three letters appearing on all trigrams did not vary, a significant FPE still occurred. Worth highlighting is the fact that the feature appeared as the "other" letter 51 times, whereas the remaining 17 consonants appeared as the other letter only three times each on the 102 cards. Despite this large difference, a majority of the FN subjects did not notice the significance of the feature.

An interesting point in connection with the successive-discrimination procedure and results involves the fact that FN subjects were exposed to a much smaller set of different negative displays (always R, B, and the feature) than were FP subjects (whose negative displays contained R, B, and one of the 17 other nonfeature consonants). Norton et al. (1971) hypothesized that learning how to respond on S- trials is the crucial aspect of discrimination learning, and they therefore suggested that FN learning was more difficult than FP learning for their human subjects because five different negative displays occurred in the former case and only one in the latter. Obviously, their hypothesis could not en-

compass the present findings. Hearst (1971) has cited a variety of animal studies, often with inconsistent findings, that are relevant to this point.

To summarize our trigram experiments, a large FPE was obtained with vowel or consonant features, immediate or delayed feedback, simultaneous or successive presentations of the positive (*Good*) and negative (*Not Good*) displays, and the inclusion of either zero, one, or two unvarying letters on the trigrams.

Experiment 4

An important characteristic of the performance of subjects in prior experiments showing a FPE has been "sign-tracking" behavior (see Hearst, 1978; Hearst & Jenkins, 1974). In most experiments with pigeons and young children, subjects contact (peck or touch, respectively) the stimulus element bearing the highest positive correlation with the reinforcer. FP subjects contact the feature; FN subjects contact an element or elements common to all stimulus displays. Such responses, which are not required for reinforcement, appear to reflect the subject's perception of which aspect of the environment it considers the "cause" of the reinforcer. Responding directed toward the feature facilitates learning in the FP problem because the feature is present only on positive trials. However, responding directed toward a common stimulus in the FN case retards or prevents acquisition of the discrimination between positive and negative displays, since such a stimulus appears on both types of displays. This directed tracking of positively predictive stimuli may reflect a basic stimulus-outcome learning process.

Contact responses were not appropriate to the tasks in our first three experiments. Experiments 4 and 5 used an apparatus, built in collaboration with Dexter Gormley, that presented symbols on four keys and required subjects to make manipulatory responses to the keys. This apparatus, similar to those typically used with pigeons (see Experiment 7), was modified to provide feedback to the subject by the dis-

play of points on a counter. By asking human subjects to press anywhere on the four-key display whenever they expected responding to add to their point total and not to press whenever they expected responding to cost them points, we hoped to observe both a FPE and sign-tracking behavior (e.g., pressing of the feature in the FP case and pressing of a common stimulus element in the FN case).

In addition to permitting the measurement of sign tracking, the use of a highly controlled situation in which feedback consisted of the gain or loss of points on a counter rather than verbal statements from the experimenter could resolve some potential difficulties in our earlier experiments. Demonstration of a strong FPE under the automated conditions would help (a) to eliminate the possibility that subtle cues from the experimenter had in some way influenced the prior results and (b) to reduce the likelihood that our specific instructions had strongly biased the subjects toward focusing on *Good* displays and disregarding *Not Good* displays.

Method

Subjects. The subjects were 12 undergraduates from Indiana University whose participation in the experiment fulfilled a course requirement. There were 6 FP and 6 FN subjects.

Apparatus. An aluminum discrimination panel (approximately 35-cm square), designed also to fit a standard Lehigh Valley Electronics pigeon chamber, was constructed. It included a row of four spatially contiguous, translucent plastic response keys, each approximately 4-cm square, on which individual symbols (circle, triangle, square, cross) could be displayed by means of four rear-mounted miniprojectors (Industrial Electronic Engineers Series 10, fitted with film No. 10-758 and illuminated with No. 1820 lamps). The projected symbols were about 2.5 cm in height and width, and were adjusted to be approximately equal in intensity. Depression of any key operated a microswitch connected to an electro-mechanical counter.

A hole 8.5 cm below the keys was cut to attach a grain magazine in pigeon experiments, but for the human work a second, galvanized-sheet-metal mask was placed over the whole aluminum panel, and only those parts needed for the human experiments were left exposed. A slot (1.5 × 4.5 cm) was cut through the mask, in the grain magazine location, to permit mounting of a modified calculator readout panel (Commodore Minuteman MM3R), which pro-

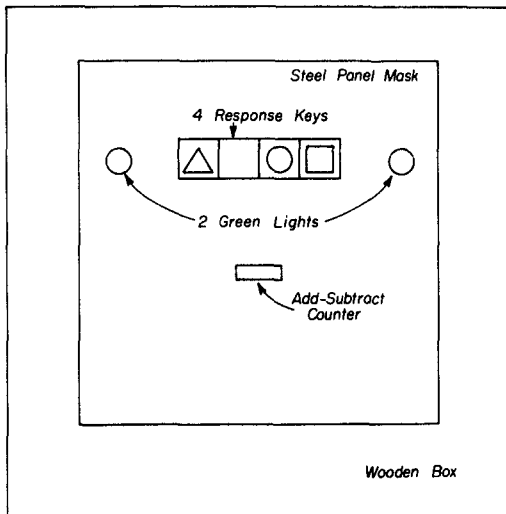


Figure 1. Schematic diagram of the discrimination panel used for human beings in Experiments 4 and 5, and with the replacement of the add-subtract counter by a grain magazine, for pigeons in Experiment 7. (See text for additional details.)

vided feedback to human subjects by adding or subtracting points dependent on the subject's responses to the row of keys. For use in Experiment 5, two additional miniprojectors were mounted flush behind two 2.3-cm-diameter circular holes approximately 4 cm to the left and right of the row of response keys; these two circles could be illuminated with green light. Figure 1 presents a sketch of the front panel as it appeared to the subject.

The entire panel, fronted by the mask, slipped into a grooved metal channel on the face of a box made of .5-in. (1.3 cm) painted plywood. When in use, the apparatus was connected to relay circuitry situated in an adjacent room. The programming of stimulus displays, intertrial intervals, and the addition or removal of points on the counter—as well as the recording of the frequency and location of key presses—was all accomplished automatically by the relay circuitry.

Procedure. Each subject was allowed time to read the following instructions before the experimenter himself read them aloud and answered any questions:

You are about to view a series of displays. Each display consists of three symbols and a blank space. These displays are divided into two categories: *Correct* and *Incorrect*.

When a *Correct* display appears, you will receive 5 points for pressing anywhere on this display. On the other hand, you will lose 5 points if you press anywhere on an *Incorrect* display.

No points will be added or subtracted if you do not press.

Your task is to gain as many points as you can by *pressing* the correct displays and by *not pressing* the incorrect displays.

After the subject had indicated that he or she understood the instructions, the experimenter left the room and started the discrimination-learning session, which for each subject consisted of 144 5-sec trials separated by 7.5-sec intertrial intervals. Each trial involved presentation of a four-element display containing three of the four possible symbols (circle, triangle, square, or cross) and a blank unilluminated key. Each of these elements could appear in any position on the display, but on a particular trial each key was illuminated with an element different from those on the other keys. The first phase of the experiment lasted for 72 trials, 36 of which contained the feature and 36 of which did not. The feature was the circle for half of the subjects and the triangle for the other half, counterbalanced across FP and FN subjects. The other three (nonfeature) symbols were presented randomly but equally often. The counter was set at zero at the beginning of each session. Subjects received 5 points, awarded at the end of a trial, for pressing *any* key during presentations of S+ displays, and they lost 5 points at the end of a trial for pressing *any* key during presentations of S- displays. The sequence of S+ s and S- s was irregular, with the constraints that no more than three consecutive trials of the same type could occur and that each block of 12 successive trials must contain 6 S+ s and 6 S- s. Several different sequences were composed, and different subjects in each group received different sequences.

After these initial 72 trials, a reversal phase was run in which the FP subjects were transferred without any warning to the FN discrimination involving the same feature, whereas the FN subjects were transferred to the corresponding FP discrimination, for 72 additional trials. After the total of 144 trials was completed, the subjects were asked to state the basis for their discriminative responding, to indicate why they pressed where they did, and to offer any other comments they might have on the experiment.

Results and Discussion

The data for each subject were grouped into blocks of 12 trials for purposes of plotting group learning curves. Figure 2 shows the FP versus FN group median discrimination ratios (total responses to S+/total responses to S+ and S-) over the two phases of the experiment, original learning and reversal.

After the first block of 12 trials, FP subjects performed consistently better than FN subjects and soon achieved a high level of discriminative performance, which was maintained over the last 4 blocks of the first experimental phase. The FP subjects required a mean of 3.0 blocks before their first attainment of a discrimination ratio of 1.0, whereas FN subjects required a mean

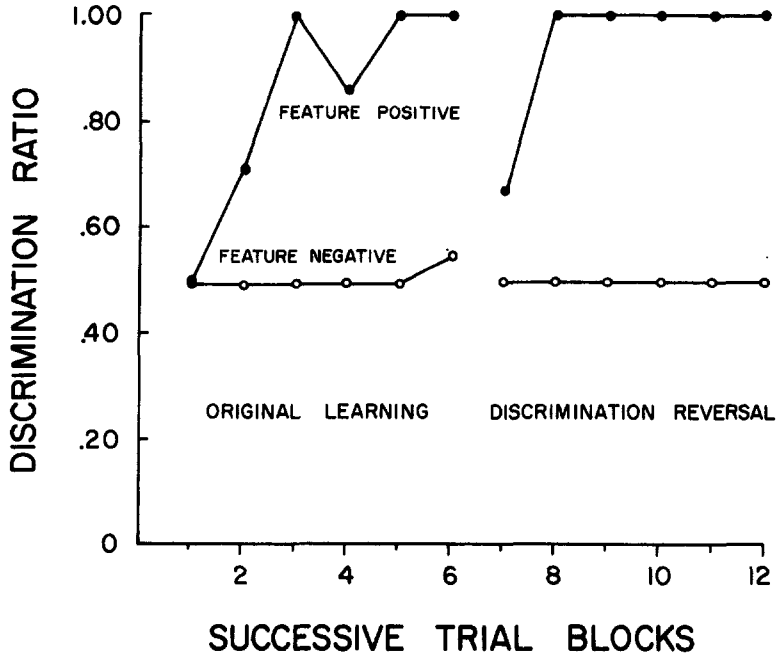


Figure 2. Group median successive-discrimination ratios (proportion of responses on positive trials relative to responses on all trials) over 12-trial blocks for the feature positive (FP) and feature negative (FN) groups of Experiment 4. (After the sixth block, FP subjects were transferred without warning or interruption to the FN procedure [but are still indicated by solid circles], whereas the FN subjects were transferred to the FP procedure [but are still indicated by open circles].)

of 5.7 blocks, $F(1, 10) = 9.14$, $MS_e = 2.33$, $p < .02$; subjects never reaching the 1.0 ratio were assigned a score of 6 blocks in these calculations. Five of the six subjects in the FP condition eventually attained a ratio of 1.0, whereas only one subject in the FN condition ever did better than .71 during a single trial block; this subject achieved a 1.0 ratio during both the fifth and sixth blocks.

All five subjects who had learned the FP discrimination in the first phase successfully reversed their strategy and mastered the FN discrimination within the first two blocks of the reversal phase. On the other hand, only one or two of the subjects who were switched from FN to FP showed any evidence of learning the FP discrimination. The subject who had eventually learned the FN discrimination in the first phase performed very erratically during the reversal phase (achieving a discrimination ratio of 1.0 during the second, third, and fifth trial blocks, but ratios of only .33 and .66 during

the fourth and sixth blocks, respectively); another subject, who had not learned the FN discrimination in the first phase, performed at a chance level for the first five blocks of the reversal phase and then displayed a 1.0 ratio during the last block. This overall result is typical of other (unpublished) feature-reversal experiments with human subjects conducted in our laboratory. Once subjects on procedures analogous to those described in this article have failed to learn within 50 or 60 trials, it is unlikely that a correct solution will ever be achieved, even if they are subsequently placed on a much easier (e.g., FP) discrimination.

With respect to sign tracking on feature-present trials, great variability occurred, and no reliable differences were obtained between the two groups in the percentage of total responses that were directed at the feature. During the debriefing of subjects after the experiment, several FP subjects reported that they had avoided pressing

directly at the feature. The reasons they gave differed; for example, one subject did not want the experimenter to know what strategy she was using and therefore she pressed only the rightmost key, another felt he was supposed to press only the blank key, and another decided that pressing two keys at once would determine whether points were awarded.

We decided to replicate the experiment, with the sole exception of shortening the trial duration from 5 to 2 sec. Perhaps if subjects had less time to think about their reactions they would be less likely to develop response-centered strategies like those just mentioned. Furthermore, Hearst and Jenkins (1974, p. 19) reported that shorter trial durations are more likely than long durations to produce a strong FPE in pigeons.

The subjects in this replication were 10 Indiana University undergraduates whose participation fulfilled a course requirement. There were 5 FP and 5 FN subjects, each of whom provided data for six blocks of original learning and six blocks of reversal, as in the prior experiment. The results once again revealed far superior performance by the FP subjects. The FP subjects required a mean of 1.8 blocks before their first attainment of a discrimination ratio of 1.0, whereas FN subjects required a mean of 5.8 blocks, $F(1, 8) = 42.11$, $MS_e = .95$, $p < .001$. All 5 FP subjects had attained a discrimination ratio of 1.0 by the last trial block of original learning, whereas only 1 FN subject showed any learning at all (this subject finally reached a 1.0 ratio during the last trial block). Paralleling the results in the reversal phase of the earlier experiment, only 2 of the former FN subjects (including the one that had eventually learned the FN task) mastered their new (FP) discrimination, whereas 4 of the 5 former FP subjects learned their new (FN) discrimination.

No systematic differences in percentage of total responses that were directed at the feature (sign tracking) occurred in this replication, just as in the prior study. Several subjects reported that they always responded to one particular key, regardless of the symbol on it, because this strategy

required less time than aiming their response at a particular symbol. Thus, although the replication did not produce any consistent sign tracking, it yielded additional evidence for the superiority of FP over FN learning in this situation. Worthy of reiteration is the fact that the intertrial (postfeedback) interval was 7.5 sec in these experiments, a much slower pacing of trials than in Experiments 1–3. Despite this greater opportunity for subjects to process trial-by-trial information, the FPE was still large.

Experiment 5

In other work with successive discriminations in the key-pressing arrangement (including some pilot research in which trials were not fixed in duration but were terminated by a single response of the subject, and in which only two symbols were presented on each trial instead of three), several subjects had concluded (despite the statement in the instructions that there would be both correct and incorrect displays) that they could successfully obtain five points on *all* trials—if only they pressed a certain symbol during each presentation of a combination of symbols that formed a particular display. There appeared to be some confusion on the subject's part between "displays" and the specific "symbols" forming a display. Consequently, we devised a new procedure, resembling to some extent a probability-learning task (see Estes, 1976), in which subjects had to guess whether a visual stimulus would appear after each trial: Regardless of the subject's behavior during the trial, two green lights were programmed to appear on both sides of the four-key display immediately following a S+ display, and not to appear after a S- display. Such an arrangement would presumably help to clarify the notion of a successive discrimination by making it clear that the visual stimulus was going to occur on only half of the trials, no matter what the subject did. Another advantage of this new arrangement was that it did not require our specifically mentioning *Good* and *Not Good* displays, or *Correct* or *Incorrect* displays—as was the case in all of the pre-

ceding experiments—since we could simply tell subjects to indicate by making a key press whether they thought the green lights would come on after a given trial.

Method

Subjects. The subjects were 12 Indiana University undergraduates whose participation fulfilled a course requirement. There were 6 FP and 6 FN subjects.

Apparatus and procedure. The apparatus and general procedure were similar to those in the key-pressing arrangements described in Experiment 4, with one important exception: Two green lights, one on either side of the four-key display (see Figure 1), were programmed to come on for 2 sec immediately after every S+ presentation. All displays lasted 5 sec, and the intertrial interval was 7.5 sec. The experimenter read the following instructions to the subject:

Your task is to learn to predict when the symbols will be followed by the green lights. Wait until the symbols appear—then if you think that they will be followed by the lights, press on the display [experimenter points to the whole display]. If you predict correctly, that is, if you press the display and then the lights come on, you will gain five points. If you press and the lights do not come on, you will lose 5 points [experimenter shows counter, set at zero, to the subject].

Remember, one half of the presentations will be followed by the lights, and one half of them will not. But this is not a guessing game—you can predict perfectly by using the symbols. Try to gain as many points as you can by pressing when you think that the lights will come on and by not pressing when you think that the symbols will not be followed by the lights. Thank you for your cooperation.

This is an experiment testing your ability to predict an outcome on the basis of visual cues. About every 10 sec three symbols will appear somewhere on this display [experimenter points to it]. The experiment is set up so that two green lights [experimenter points to them] will come on after exactly one half of these presentations.

Results and Discussion

As in Experiment 4, the results for each subject were grouped into blocks of 12 trials for purposes of data analysis. Figure 3 shows the FP versus FN group median successive-discrimination ratios (total responses to S+/total responses to S+ and

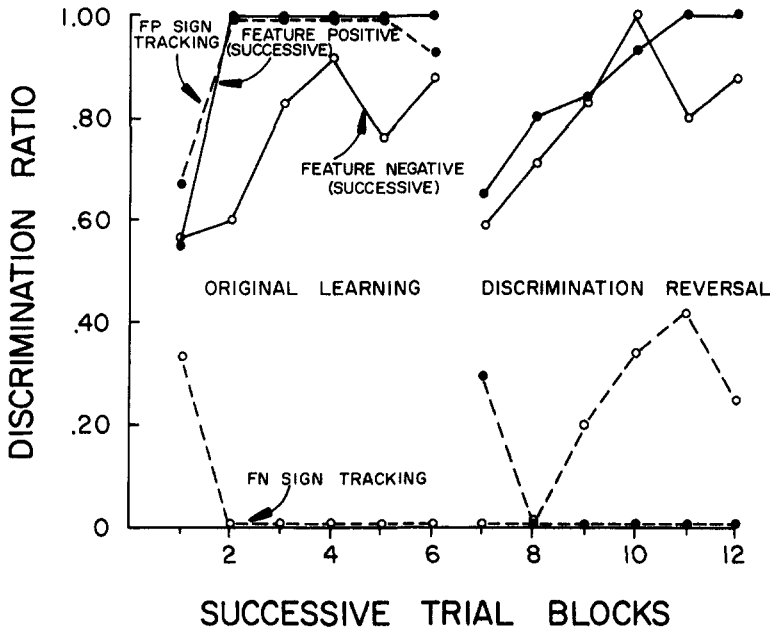


Figure 3. Group median successive-discrimination ratios (proportion of responses on positive trials relative to responses on all trials) and group median sign-tracking ratios (proportion of responses to the feature on feature-present trials) over 12-trial blocks for the feature positive (FP) and feature negative (FN) groups of Experiment 5. (After the sixth block, FP subjects were transferred without warning or interruption to the FN procedure [but are still indicated by solid circles], whereas the FN subjects were transferred to the FP procedure [but are still indicated by open circles].)

S—) over the two phases of the experiment. Also included on this figure are sign-tracking measures for each group (median ratio of total responses to the feature/total responses on all feature-present trials); ratios near 1.0 indicate that subjects are pressing the feature almost exclusively, whereas ratios near 0.0 show that subjects are pressing only some common element or elements of the display.

Although FN learning in this experiment was better than in our prior experiments, Figure 3 once again demonstrates a clear superiority of the FP over the FN group during original learning. The FP subjects required a mean of 1.5 blocks before their first attainment of a successive-discrimination ratio of 1.0, whereas FN subjects required a mean of 3.5 blocks, $F(1, 10) = 5.22$, $MS_e = 2.30$, $p < .05$.

Interestingly, clear evidence of sign tracking was obtained in this experiment. Figure 3 indicates that subjects in the FP group contacted the feature on a very high proportion of the trials on which it was present, a ratio much greater than the chance level of 25% or 33% (depending on whether the blank key is considered one of the elements of the display). During original learning, four of the six FP subjects pressed the feature virtually 100% of the time after the first block of trials. On the other hand, FN subjects rarely pressed the feature; five of the six subjects never again responded to the feature after the second block of original-learning trials. The difference between FP and FN groups in mean sign-tracking ratios over the entire six blocks of original learning was significant, $F(1, 10) = 9.80$, $MS_e = .09$, $p < .02$, as well as over the final three blocks, $F(1, 10) = 10.92$, $MS_e = .11$, $p < .01$. These results are similar to those obtained in pigeon experiments (see, e.g., our Experiment 7), since FP subjects confined their responses mainly to the feature, and FN subjects mainly to the other symbols.

Although during the reversal phase the original FP subjects performed somewhat better on their subsequent (FN) successive discrimination than did the FN subjects transferred to the FP discrimination—a trend in the same direction as in Experi-

ment 4—the group differences were not large in this experiment. Since only one of the six subjects in the FN group was not performing reasonably well at the end of original learning, their good transfer in the next phase is perhaps not too surprising; apparently, once the significance of the feature is noticed, transfer to either FP or FN learning proceeds efficiently in human beings. Figure 3 also shows that the sign-tracking ratio decreased in the new FN group (solid circles) as they learned the discrimination, whereas it increased in the new FP group (open circles)—a change exhibited by five of the six individual subjects in the respective groups; there was a crossover in the tracking ratios of the two groups during the reversal phase. Thus, when the feature signaled that the green lights would come on, subjects had a relatively strong tendency to press it, even though pressing any key on positive trials was an equally effective indicator of their prediction about the green lights. When the feature signaled the absence of green lights, subjects pressed it infrequently.

The effects displayed in this experiment (a significant FPE, and correlated changes in sign tracking) were more like those observed in pigeon experiments than were the outcomes of our prior experiments with humans using the apparatus of Figure 1. However, we cannot state with any confidence which aspects of the instructions or procedure are responsible for the clear-cut sign-tracking results obtained here as compared to Experiment 4.

Experiment 6

In a final experiment with human subjects, we made some radical changes in material and procedure, not only to examine further the generality of the FPE but also to assess the importance of certain aspects of the reinforcement procedures implemented in our earlier work. First of all, we wanted to use stimulus materials closer to everyday objects than the trigrams or symbols employed in the prior work; in the present experiment, line drawings of boats, houses, and locomotives served as the stimuli. More importantly, we wondered

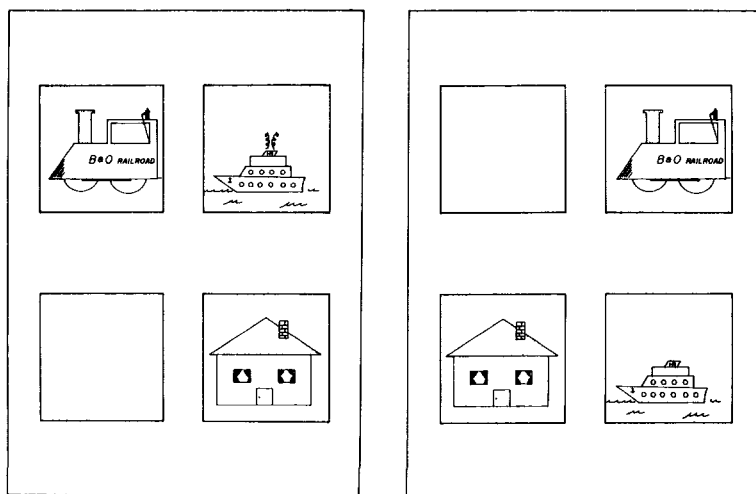


Figure 4. Examples of feature (left) and nonfeature (right) displays in the smokestack experiment (Experiment 6). (All displays included four quadrants, three containing pictures and the fourth blank. On feature displays, "smoke" [two spiral lines] rose from the chimney or smokestack of one of the pictures, as in the upper right quadrant of the left display. Only one type of display was presented on any trial, i.e., a successive-discrimination procedure was in force throughout the experiment.)

whether the instructions and reinforcing outcomes in the previous studies, especially Experiments 4 and 5, had failed to make it sufficiently clear to subjects that correct performance on negative trials of a successive discrimination was as critical as correct performance on positive trials. Perhaps subjects had felt it was more important to gain points than to avoid losing points, or to predict the occurrence of a light than to predict its nonoccurrence, and it seemed possible that such interpretations by the subjects could have played a role in the FPE.

In the present experiment a single poker chip was delivered not only for correct predictions about the occurrence of a light but also for correct predictions about the nonoccurrence of a light. In other words, all FP and FN subjects could receive equivalent, explicit reinforcement on every trial, feature and nonfeature, for appropriate responding. Furthermore, once the experiment began, the experimenter did not speak until the subject had appeared to reach a solution; in addition, the instructions did not imply any particular focus, since *Good* and *Not Good* trials were not mentioned. The stimulus materials were, in a way, more similar to those used in pigeon experiments than had been the case in every

one of the prior studies described in this article: All of the stimulus elements remained the same from trial to trial, except for the presence or absence of a small distinctive feature. Contrariwise, in Experiments 1–5 the common elements had varied from trial to trial.

Method

Subjects. The subjects were 16 Indiana University undergraduates who participated to satisfy a psychology course requirement. There were 8 FP and 8 FN subjects.

Apparatus and materials. The displays were drawn on 48 8½-in. × 11½-in. (21.6 cm × 29.2 cm) sheets of paper, which were divided into four quadrants (see Figure 4 for examples of displays with and without the feature). Three of the quadrants on each display contained pictures, and one quadrant was always blank. The three pictures on each display comprised drawings of a house, a boat, and a locomotive. Each of these pictures occurred an equal number of times in each of the four quadrants. The feature was the presence of "smoke" (two spiral lines) rising from the chimney or smokestack in one of the pictures on a sheet. Smoke appeared on 24 of the sheets, and was equally paired with the house, boat, or locomotive.

The experimenter sat behind a wooden screen that contained a light and a rectangular cutout for presenting displays. In front of the screen, facing the subject, was a small metal console with two levers. One lever was labeled *Yes—light* and the other *No—*

light. Standard poker chips were used to provide feedback to the subject after each correct response.

Procedure. The subject was seated at a table and was read the following instructions while he or she looked at an example of a FP or FN display:

I'm going to show you a series of displays. A display is a sheet of paper divided into four quadrants, and three of these quadrants contain pictures.

Some of these displays will be followed by a red light [experimenter points to it], and some of them will not be followed by the light. Your task is to learn how to predict, from the displays, whether the light will or will not follow.

I will show you one display at a time, and you must respond within 5 sec. Press the right lever (Yes—light) if you think that the light will follow or the left lever (No—light) if you think that the light will not follow. I will give you a poker chip for every correct prediction.

If the subject had no questions, the experimenter began presenting a random sequence of feature and nonfeature displays, one every 5 sec. Half of the displays were followed by a flash of red light and a new display, whereas the other half were followed only by a new display. All responses were manually recorded by the experimenter. Whenever the subject made five consecutive correct predictions, the experimenter asked the subject whether he or she had a solution. If the answer was not correct, the subject was instructed to continue to test his or her hypothesis. The experiment terminated when the subject reported the correct solution or after a maximum of 96 trials, that is, twice through the sequence of displays.

Results and Discussion

Subjects who did not state the correct solution within the 96-trial limit were assigned a score of 96 trials. The mean number of trials required before verbalization of the correct solution was 28.0 for the FP subjects and 85.3 for the FN subjects, $F(1, 14) = 14.13$, $MS_e = 927.96$, $p < .01$. Seven of the eight FP subjects eventually provided the correct solution, whereas only one of the eight FN subjects was successful.

Thus, a powerful FP superiority occurred in this experiment even though drawings of familiar objects served as stimuli, and even though the same tangible reinforcer (a poker chip) was delivered for correct predictions about either the occurrence or nonoccurrence of a light. Like the pigeon experiments of Jenkins and Sainsbury (1969, 1970), the common elements of the displays, although varied in location, were the same

from trial to trial, and the obtained FPE was quite analogous to that observed in pigeons. Since Experiments 1–5 had involved common elements that varied from trial to trial, we wondered whether pigeons would still show a FPE under those relatively complex conditions. Therefore, in a final experiment we attempted to move in the opposite direction from the rest of the work described here and to demonstrate that results for human beings would also hold for pigeons.

Experiment 7

This experiment returned to the four-key discrimination apparatus of Experiments 4 and 5 but employed the nonhuman species most commonly used in previous studies of the FPE (see the review in Hearst, 1978). Except for substitution of a grain magazine for the add–subtract counter, the general method of Experiments 4 and 5 was followed as closely as possible. The common elements appearing on the display were varied from trial to trial, unlike in prior pigeon work, and this complication might make even the FP task too difficult for pigeons. However, if a clear FP superiority continued to appear under these new circumstances, it would not only extend the generality of the earlier pigeon findings—our major goal in the experiment—but might also reduce the plausibility of certain alternative explanations of the human findings. For example, a clear FPE in this pigeon study would strengthen the implication from Experiments 1–6 that the particular instructions given to our human subjects, or other experimenter–subject interchanges occurring during the experiments (e.g., interruptions for statements about hypotheses being tested by the subject), were not necessary for the phenomenon. Furthermore, partly as a *tour de force*, we hoped to show that pigeons would behave like human beings in a situation that seemed to us very similar for both organisms.

Method

Subjects. Sixteen experimentally naive female White Carneaux pigeons, maintained at 75% of their free-feeding body weights, served in the study. Birds

were housed individually in a constantly illuminated room with water always available. There were 8 FP and 8 FN subjects.

Apparatus. The discrimination panel that had been used for human subjects in Experiments 4 and 5 (see Figure 1) was removed from its old setting and placed in a standard Lehigh Valley Electronics pigeon chamber. Just as in the human work, four response keys were available on which different symbols (circle, triangle, square, cross) could be displayed. The only major change from the human arrangement was the replacement of the add-subtract counter by a grain magazine, which was illuminated with white light during the 3-sec periods when grain was accessible. A white noise remained on continuously in the experimental room and masked external sounds. A dim house light providing general chamber illumination went on in the experimental box at the beginning of a session and stayed on until the total of 48 daily trials had been completed. Programming and recording equipment was located outside the experiment room.

Procedure. All birds were initially given 2 consecutive days of magazine training. On the first day, the experimenter held the subject's head in the lighted magazine aperture and allowed it to eat for 5-10 sec. The bird was then given 6-12 additional grain presentations at times controlled by the observing experimenter, followed by approximately 30 3-sec reinforcements delivered automatically according to a 30-sec variable time schedule. On the second day all birds received approximately 30 more reinforcements according to the automatic schedule.

After completion of magazine training, all birds were assigned randomly to either the FP or FN group. Discrimination training for both groups began on the next day. For all subjects, every trial involved a 5-sec illumination of any three of the four keys, each with a different symbol on it; the fourth key remained unilluminated as in the human work. A session consisted of 48 trials separated by intertrial intervals averaging 30 sec. Half of the trials were positive and were followed immediately by a 3-sec grain delivery, and half were negative and were never followed by grain. Thus a classical conditioning procedure (discriminative autoshaping; see Hearst & Jenkins, 1974) was used, and trial outcomes were never affected by the subject's responding (as was also the case for the colored lights in Experiments 5 and 6 involving humans).

The symbol that served as the feature was different for different subjects in the FP and FN groups; two birds in each group had the circle as the feature, two had the square, two the triangle, and two the cross. The three nonfeature (common) symbols for a given subject appeared 40 times each during a daily session, 10 times on each of the four different keys; a particular nonfeature symbol thus occurred on 16 of the 24 trials containing the feature, as well as on all 24 trials without the feature. The sequence of positive and negative trials was irregular, with the constraint that no more than 3 consecutive trials of the same type could occur. Different daily sequences of positive and negative trials were composed, and each

subject was exposed to them in a random order. The experiment lasted 30 sessions, scheduled every day of the week.

Results and Discussion

By the second or third day of training, almost every subject had begun to peck at the four-key display on a large majority of the trials. This outcome is typical of pigeons placed on autoshaping procedures: Subjects approach and contact signals positively correlated with grain delivery, even though these responses are not required for reinforcement.

Figure 5 shows mean discrimination-learning curves for the FP and FN groups; subjects that had been assigned different symbols as their feature are pooled for each group. Two measures are plotted in the figure for both the FP and FN subjects (see also Figure 3). One measure represents learning of the *successive* discrimination (positive vs. negative displays); it is the ratio of the total number of responses on any key during presentations of the 24 daily positive trials to the total number of responses on any key during all 48 daily trials. The other measure (*sign tracking*) traces the development of the discrimination between common and feature symbols within displays containing the feature and is calculated by dividing the total number of responses to the feature key by the total number of responses to all displays containing the feature. No data points are plotted for Day 1 in Figure 5 because a number of subjects made very few or no pecks during their first session.

Figure 5 exhibits a powerful FP superiority, analogous to that obtained from pigeons in many experiments in which the common elements remain identical from trial to trial, unlike this experiment. Typically, the individual FP subjects soon began to peck almost exclusively at the feature on positive trials (see the sign-tracking ratios) and then stopped pecking on negative trials (see the successive-discrimination ratios). On the other hand, all of the FN subjects soon stopped pecking the feature on negative trials (very low sign-tracking ratios) but continued to peck common features on both

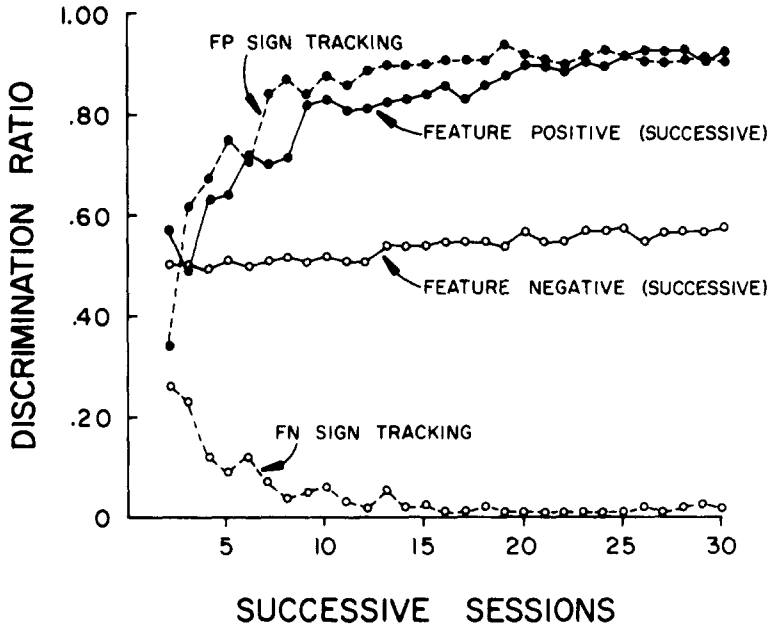


Figure 5. Group mean successive-discrimination ratios (proportion of pecks on positive trials relative to pecks on all trials) and group mean sign-tracking ratios (proportion of pecks to the feature on feature-present trials) over 30 sessions of training for the feature positive and feature negative pigeons of Experiment 7.

positive and negative trials throughout the 30 days of the experiment. The fact that the mean successive-discrimination ratio for the FN subjects was eventually closer to .60 than to the baseline of .50 that would be expected if there were no learning of the successive discrimination can be primarily attributed to certain aspects of our procedure for equally distributing the four symbols across the four key locations during daily sessions. Recall that a particular nonfeature symbol occurred on all 24 trials without the feature as well as on 16 trials containing the feature. About half of the FN subjects began to peck almost exclusively at one particular nonfeature symbol, and by doing so at an approximately equal rate whenever that symbol appeared, they could achieve successive-discrimination ratios of about .60 without learning any discrimination (since 24 of the 40 daily trials contained that symbol).

We also analyzed the results in terms of measures similar to some of those used in Experiments 1-6 with human beings. The FP subjects required a mean of 12.8 ses-

sions before they first achieved a successive-discrimination ratio of at least .90 in a single session. Seven of the eight FP subjects eventually reached this value, and with one slight exception they never fell below it during the remainder of the experiment. None of the eight FN subjects ever achieved better than a .65 ratio during a single session, and none of them ever performed consistently above .60. These group differences in the number of sessions required to attain a .90 ratio were highly significant, $F(1, 14) = 23.62$, $MS_e = 50.39$, $p < .001$; in these calculations subjects never achieving the .90 ratio were assigned the maximum possible score of 30 sessions.

The data in Figure 5 demonstrate all of the essential features of the results for pigeons reported by Jenkins and Sainsbury (1969, 1970) and Hearst (1975, 1978), who used unchanging common features. It is somewhat surprising that variation of the common features from trial to trial did not seem to have much effect on the extent of the FPE and the properties of sign-tracking behavior. The pigeon data concerning the

FP superiority also closely resemble the results reported for human subjects in Experiments 1-6.

General Discussion

These experiments have demonstrated a powerful feature-positive effect in a variety of tasks involving adult human subjects. When two displays can be discriminated only on the basis of the presence versus absence of a single feature, most subjects acquire the discrimination readily if this feature appears on displays associated with a positive event (gain of points; illumination of a light; assignment to the *Good* category). On the other hand, subjects perform poorly if the distinctive feature appears on displays associated with a negative event (loss of points; nonoccurrence of a light; assignment to the *Not Good* category); they either fail to learn the discrimination at all or take a relatively long time to acquire it.

We have shown the broad generality of the FPE in human beings by obtaining a feature-positive superiority in tasks involving simultaneous or successive discriminations, immediate or delayed feedback, different kinds of features (letters; shapes; details of pictures), and large differences in the size and nature of the set of potential irrelevant (common) elements that could appear on displays. Furthermore, because the FP superiority was still large despite variations in the nature of the feedback presented, in the length of the intertrial (post-feedback) interval, and in the details of experimental instructions, it seems unlikely that the phenomenon depends on very specific characteristics of our instructions or procedures.

Although a robust FPE was obtained under a wide variety of experimental instructions, it is certainly true that more specific instructions or pretraining can remove or reduce the FPE in human beings. For instance, Newman (Note 1), in extensions of our Experiment 1, found that telling all subjects that "something about each of the *Good* cards makes them *Good*" preserves the FP superiority, whereas telling all subjects that "something about each of the *Not Good* cards makes them *Not*

Good" reverses the standard effect (FN subjects do as well as typical FP subjects, i.e., in Experiment 1, and FP subjects do as poorly as typical FN subjects). Similarly, in a rare comparison of the complementary concepts based on the presence versus absence of a single feature (affirmation vs. negation), Neisser and Weene (1962) found that the absence of a certain letter in a consonant string was somewhat *easier* to use as a positive stimulus than was the presence of the letter. Their instructions, which emphasized that only the presence or absence of particular letters mattered, and that the absence of a letter could be as important as its presence, probably facilitated performance of their "FN" subjects. All of these results parallel demonstrations that subjects specially trained with "nonexamples" may focus on the absence of a stimulus attribute to quickly learn some concepts from negative instances alone (Davidson, 1969; Toppino & Johnson, 1974).

In composing our instructions, we attempted to equate the basic conditions under which different species are tested for FP versus FN learning by giving our human subjects only minimal instructions. They received no advance information about (a) the relevance of the presence versus absence relation and (b) the number of specific elements or attributes that might be relevant (except for the subjects in Experiment 1, who were told that only one symbol was important in solving the problem). Our use of relatively open-ended, nondirective instructions was intended to produce a learning situation resembling those occurring in natural environments.

Many prior experiments in human concept learning have demonstrated that in the absence of instructions or training to the contrary, subjects tend to concentrate on positive rather than negative instances of the events they are monitoring (see, e.g., Bruner, Goodnow, & Austin, 1956). Post-experimental protocols strongly suggested that our subjects adopted such a "positive focus." Even when equivalent reward (i.e., the experimenter's response "right!" in the successive discriminations of Experiments 1 and 3; a single poker chip in Experiment

6) was given for appropriate responding to both kinds of instances, subjects devoted most of their attention and rehearsal to stimulus elements presented on positive rather than negative displays.

A subject's focus seems clearly determined by the *presence* of an outcome event. In our experiments the positive displays were denoted by the explicit presence of grain, the occurrence of a light, the addition of points on a counter, or the verbally mediated symbolic presence of the criterion quality (*Good* or *Correct*). In contrast, negative displays were denoted by the absence of these events (i.e., no grain, no light, the loss of points on a counter, *Not Good* or *Incorrect*). It follows from this analysis that if displays are differentiated by neutral labels (i.e., if the outcome is neither the presence nor the absence of one event, but the presence of Event A or the presence of Event B), then subjects would "focus" on both categories. Pilot work in our laboratory suggests that if the neutral categories *Blue* and *Green* are substituted for the category labels *Good* and *Not Good* in our Experiment 1, learning is faster and better than for FN subjects. The color labels *Blue* and *Green* probably represent the presence of two different outcome events rather than a polar psychological dichotomy based on presence versus absence (as would be the case for *Blue* vs. *Not Blue*).

Neumann (1974) has given a different interpretation to a similar finding. He compared the speed with which subjects partitioned stimulus displays as a function of whether the rule they were using was designated by neutral labels or by directional labels based on the presence versus absence of an outcome (i.e., a primary rule [cf. FP] or its complement [cf. FN]). He found that subjects using neutral labels learned at a rate intermediate between subjects using a primary rule and subjects using its complement. Neumann suggested that a random half of the subjects using neutral labels solve an analogue of the primary rule and the other half solve an analogue of the complement. However, if his interpretation is correct, the subjects using neutral labels should have exhibited much more variable performance than subjects using only the

primary rule or the complement. His subjects using neutral labels showed approximately the same degree of variability as subjects in the other conditions, and were probably using a single strategy, namely, monitoring the presence of two different outcome events. Correspondingly, the positive focus exhibited by subjects in our FPE experiments seems to reflect attention to those trials that are associated with the presence of a particular event, in contrast to the relative inattention devoted to trials associated with the absence of that event.

Our experiments complement several studies of concept formation that have indicated that attention to positive instances is important because subjects focus on the stimulus attributes *present* on those trials (see also Bourne, 1974). Haygood and Devine (1967) manipulated both the proportion and composition of positive instances of a concept based on two stimulus dimensions and found that learning was influenced primarily by the composition of positive instances. By varying the composition of positive instances through the use of nonconjunctive rules, these authors were able to demonstrate that learning was more dependent on whether positive instances contained both relevant attributes than on positive instances per se. In a similar paradigm, Bourne et al. (1976) demonstrated that learning a given bidimensional concept is easier when there is a relatively large differential in the frequency with which relevant and irrelevant stimulus attributes appear on positive instances of that concept. However, the direction of the frequency differential proved more important than its size: If on positive instances the relevant attributes were present more often than irrelevant attributes, the problem was easier than if the relevant attributes were more often absent (compare Conditions 1 and 2 in Bourne et al.'s, 1976, Experiments 2 and 4). In other words, the rate of learning was primarily determined by the ease with which subjects could locate the relevant attributes, which, in turn, depended on the degree to which relevant attributes appeared more frequently than irrelevant attributes on positive instances. The FP superiority shown in our Experiments 4, 5, and 7 also demon-

strates that the presence of the relevant attribute (feature) on positive instances is more important in learning the discriminations than is the differential frequency with which various stimuli appear on positive instances.

Human subjects' focusing on the stimulus elements *present* on trials on which an outcome is *present* parallels the sign tracking shown by our birds in Experiment 7 (see also Hearst & Jenkins, 1974, and the introduction to our Experiment 4). The pigeons directed approach and contact behavior toward those kinds of stimuli. The birds showed that they had monitored the frequency with which different stimulus elements appeared on positive trials because even before any clear discrimination between positive and negative displays began to appear, they responded differentially on feature-present displays: FP birds pecked the feature, whereas FN birds pecked some common stimulus. In both cases the birds were tracking stimulus elements bearing the highest positive correlation with the reinforcer. Similar patterns of directed responding were made by adult human beings in Experiment 5. Overt tracking responses are obviously not necessary for adult human beings to solve the discrimination problems (tracking did not reliably occur in our Experiment 4), but the use of more difficult tasks and more sensitive measures such as eye movements and fixations might yield evidence of the directedness of subjects' behavior toward specific stimulus elements. In any event the processes, if not their overt manifestations, by which both animal and human subjects identify relevant attributes and features, appear analogous with respect to their dependence on stimuli positively correlated with a particular outcome.

After the most predictive stimulus element has been identified, the nature of the learning and its reflection in performance differ for the two species. The humans presumably use the most predictive cue to generate or select a hypothesis based on the presence of that cue. When testing of the hypothesis leads to the solution of the problem, processes of verbal mediation permit the easy, flexible reversal of the rule.

For instance, the subjects in Experiments 4 and 5 who had mastered the FP discrimination were able to acquire a subsequent FN discrimination quickly. In contrast, pigeons that are switched to a FN discrimination after learning a FP discrimination show little, if any, eventual learning of the new problem; they act like naive FN subjects (Hearst, 1975). This result suggests that the FP performance of birds is controlled by specific external stimuli and not by rules that can be simply modified to handle new discriminations—a conclusion analogous to Kendler and Kendler's (1975) interpretation of species and developmental differences in discriminative transfer of other kinds. However, a factor probably involved in the effective use of rules in discrimination reversal by our human subjects is that they were informed or could infer that there was a *perfect* solution to the new problem, whereas the arrangements with young children and animals have not been designed to encourage such an inference.

In spite of possible differences in the nature of learning by different species, the powerful cross-species FPE demonstrated in our experiments suggests that discrimination learning based on the nonoccurrence of stimuli is a difficult task. Of course, human beings can learn on the basis of the nonoccurrence of stimuli if instructions focus their attention on the absence of the relevant cue, if they receive only trials in which the outcome is absent (e.g., Bourne et al.'s, 1976, Experiment 7), if only a limited number of hypotheses based on the presence of stimulus elements are possible (see Levine, 1966), and probably if the feature is very salient (see Hearst, 1978). But under conditions that seem to parallel many natural discrimination problems, the FPE illustrates that nonoccurrence is hard to use. In FP discrimination problems the *feature-present*, *outcome-present* trials permit the subject monitoring the frequency with which stimulus elements appear on positive trials to discover the correct contingency (or hypothesis) relating the feature and the outcome; *feature-absent*, *outcome-absent* trials can be used to test that hypothesis. In FN discrimination problems

the *feature-absent, outcome-present* trials misdirect the subject to a common stimulus (or to the wrong hypothesis), and *feature-present, outcome-absent* trials may (for human beings) disconfirm that hypothesis but do not lead to the selection of the correct one.

Although detailed analyses cannot be pursued here, there are several other effects obtained in studies of human information processing that deserve mention in connection with the FPE and the tendency of subjects to focus on information present during positive instances and to ignore information present during negative instances (see also Hearst, 1978). For example, even when subjects verbally report the details of both positive and negative trials in a probability-learning task, they still base their judgments primarily on the actual frequency with which an event is followed by a positive outcome, and not on the overall probability that the event is followed by that outcome (Estes, 1976). In similar fashion, subjects' estimates of the degree of contingency between an event and an outcome are determined mainly by the number of positive confirming instances (Jenkins & Ward, 1965; Ward & Jenkins, 1965).

Furthermore, in studies of the confirmation bias in human hypothesis testing, subjects concentrate on verification rather than disproof of alternative explanations; even in tasks in which cognitive capacities do not appear unduly strained, subjects overlook or disregard the importance of information indicating the nonoccurrence of a predicted outcome (Snyder & Swann, 1978; Wason & Johnson-Laird, 1972). Einhorn and Hogarth (1978) discussed "illusions of validity" prevalent in human subjects, and they showed how large amounts of positive feedback can lead to reinforcement of a nonvalid rule in subjects who do not attend sufficiently to instances in which their judgment was incorrect. The nonoccurrence of an action or prediction is so often discounted by subjects that Einhorn and Hogarth were pessimistic about attempts to overcome such "illusions" unless specific feedback is given that is designed to focus attention on disconfirming cases. Discussing distortions in attribution processes studied by social

psychologists, Ross (1977) employed examples from several sources, including impressions of personal dislike, to illustrate the failure of people to use information provided by the nonoccurrence of behavior or stimuli; he remarked that nonoccurrences are seldom as salient or as cognitively "available" to the potential attributor as are occurrences. He suggested that absences or nonoccurrences ought to be better noted and remembered when the subject is provided with a positive or active category label to apply to such instances.

The control of behavior by stimuli present on positive instances seems a pervasive and fundamental phenomenon in human beings and animals. We can speculate that the development and maintenance of this bias in processing information may not, as some writers (e.g., Bourne, 1974; Bruner et al., 1956) have suggested, be primarily derived from extensive past experiences of individual organisms and thereby represent a well-learned strategy for attacking a variety of problems, but could have originated in the evolutionary history of organisms capable of learning. The bias may have evolved as a result of attention to biological events critical to survival. Since these events are relatively rare, an organism that monitored their presence rather than or in addition to their absence would require a comparatively simple and economical set of physiological structures and processes. Furthermore, the subsequent learning and memory of associations between "neutral" environmental stimuli and biologically significant events would also very likely be based on the presence of those stimuli or on stimulus-outcome sequences; in nature the nonoccurrence of various stimuli is normally the prevailing state and transmits less information about other stimuli than would "occurrence." In an associative environment (see Björkman, 1966), a sufficient number of conjunctions of signals and outcomes occur to render unnecessary the development of a mechanism for explicitly monitoring the absence of contiguity between signals and outcomes. If it is accurate to state that organisms can more easily form associations between the occurrences of two events than between the nonoccurrence

of one event and the occurrence of another, then an additional principle might be added to the list of biological constraints on learning that have received so much recent attention (see, e.g., Hinde & Stevenson-Hinde, 1973).

The FPE can be regarded as a manifestation of certain widespread but often inappropriate information-processing strategies, and the procedures we devised to investigate it may represent fairly simple tasks for studying variables that could magnify, reduce, or even remove some of these inefficient or unsuitable forms of behavior. The pervasiveness of the feature-positive superiority across species, settings, and problems seems to call for additional research and thought on the phenomenon, which might proceed not only by manipulating intratask factors but also by analyzing more deeply the possibly different processes governing learning and performance in different species and human developmental levels.

Reference Note

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Received November 16, 1979

Revision received March 21, 1980 ■