JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1973, 19, 345-349 NUMBER 2 (MARCH)

SHARED ATTENTION IN PIGEONS[1]

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Two pigeons performed a three-key matching-to-sample task. The comparison (side key) stimuli were either solid colors or white lines. The sample (center key) stimuli were either compounds (white lines on colored grounds) or elements (white lines on black grounds on some trials, and solid colors on other trials). Sample stimuli were presented for nine sample stimulus durations ranging between 0.04 and 5.00 sec. Within each daily session, both compound and element samples were presented at each sample duration in a random sequence. Compound samples controlled matching responses less effectively than did element samples at all sample stimulus durations.

A problem central to the experimental analysis of behavior is the discovery of the conditions under which stimulus control is established and maintained. Organisms have been said to "attend" to stimuli that control behavior (*cf.* Skinner, 1953). When only a fragment of the total stimulus array controls behavior, attention has been described as "selective" (Mackintosh, 1965; Ray, 1969; Sutherland and Mackintosh, 1971).

Born and Peterson (1969) described stimulus control by elements of a compound stimulus as falling along a continuum, ". . .ranging from exclusive control by one element, running through equal control by both elements, and finally terminating with exclusive control by the second element" (p. 441). If the extremes of this continuum are synonymous with *selective* attention, then the midpoint, where control by both elements is equal, may be labelled *shared* attention. Stimulus control under conditions of shared attention has not received extensive empirical treatment, although the extremes of Born and Peterson's continuum might be best understood as departures from shared attention. This paper is addressed to the problem of how stimulus control by each of the elements of a compound stimulus is affected when responses to both of the elements have been reinforced.

[1]This research was supported by USPHS grant MH12485 and FR-7006 Biomedical Support grant to D. A. Riley. The first author was supported by USPHS Predoctoral Traineeship MH10878. The authors thank R. C. Hipple and D. A. Riley for constructive advice and critical reading of the manuscript, and E. R. Hafter for computer programming assistance during the early stages of this research. Reprints may be obtained from W. S. Maki, Jr., Department of Psychology, University of California, Berkeley, California 94720.

METHOD

Subjects

Two adult White Carneaux pigeons had served in an immediately preceding experiment (Maki and Leuin, 1972). This prior experience consisted of 50 consecutive sessions of post-acquisition performance of a matching-to-sample task in which the stimuli, apparatus, and reinforcement contingencies were the same as those described below. Each bird received its full daily ration of food in the experimental chamber. This procedure maintained each bird at about 85% of its free-feeding weight.

Apparatus

The experimental chamber, located in a sound-attenuated room, was a Grason-Stadler E3125A-300 research chest divided by a stimulus panel. The panel contained three Polacoat "Lenscreen" pigeon keys (Lehigh Valley No. 121-16) aligned horizontally behind circular openings 1 in. (2.5 cm) in diameter. The food hopper (Lehigh Valley No. 114-10) was behind a 2.5 by 3.25 in. (6.5 by 8 cm) opening located 3.25 in. (8 cm) below the center key. The keys, which were spaced 3.5 in. (9 cm) apart and located 8 in. (20 cm) above the floor of the chamber, required a force of 18 g (0.18 N) for actuation. The interior of the chamber was painted flat black and contained no houselight. Masking noise and ventilation were provided by a fan.

The stimuli were projected directly onto the keys from the rear of the panel by three Grason-Stadler No. A502-2A inline projectors with viewing screens removed and containing standard Grason-Stadler No. 151 stimulus patterns and GE No. 1820 lamps. Each projector was constructed to project a solid white disk, a solid red disk, a solid blue disk, three white vertical lines on a black ground, or three white horizontal lines on a black ground. Stimulus compounding was achieved by simultaneously lighting two lamps, which produced white lines superimposed on colored grounds. A Digital Equipment Corporation PDP-8/L computer was programmed to schedule reinforcement, control stimulus presentation, and report data over an on-line teletypewriter.

Procedure

The sample stimuli, presented on the center key, were of two types, elements and compounds. Element sample stimuli consisted of a single color or a set of lines. Compound sample stimuli were composed of lines superimposed on a colored ground. The comparison stimuli were never compound stimuli. Either the two colors or the two achromatic sets of lines appeared as comparison stimuli. When the sample stimulus was only a color, the comparison stimuli were also colors. When the sample stimulus was only a set of lines, the comparison stimuli were also lines. When the sample stimulus was a compound, the comparison stimuli were either the two colors or the two sets of lines.

Each trial commenced with the illumination of the center key by white light. A peck on the center key resulted in the immediate replacement of the white light by a sample stimulus. After a specified time, and independently of pecking, the center key was darkened and the side keys were immediately illuminated by comparison stimuli. A correct response (match) was defined as a peck on the side key containing the color or line orientation that appeared in the sample. Correct responses immediately darkened the side keys and resulted either in reinforcement followed by a 5-sec timeout, or a 5-sec timeout alone. Incorrect responses (errors) did not immediately darken the side keys. When an error was committed, the offset of the comparison stimuli was delayed by 2 sec; then, the side keys were darkened for 5 sec. During both the 2-sec delay following an error and during the 5-sec timeout, pecks were neither effective nor recorded.

Reinforcement consisted of access to mixed grain for 2 sec during the early phases of the experiment, and later, for 1.8 sec. Within each session, 50% of the correct responses were reinforced according to a variable-ratio (VR 2) schedule constructed in the following manner. The computer was programmed to keep running totals of the number of trials (N_t) and the number of trials in which reinforcement was available (N_a). During any given trial, if N_a was within the inclusive boundaries defined by $N_t/2 \pm 1$, reinforcement was randomly made available with an expected probability of 0.50. If N_a exceeded $N_t/2 + 1$, reinforcement was not available; if N_a was less than $N_t/2 - 1$, reinforcement was always available.

Both birds received 10 blocks of six daily sessions. Each session consisted of 64 warmup and 256 test trials. During the first day of each block, sample stimulus duration was fixed at 5 sec, the original training duration. The 5-sec training sessions were included to forestall any detrimental effects of prolonged testing at short stimulus durations. During each of the remaining five sessions, sample stimulus duration was 2.56 sec during warmup trials and varied during test trials (0.04, 0.08, 0.12, 0.16, 0.24, 0.32, 0.64, 2.56 sec). Test trials were randomized with regard to the position of the correct comparison stimulus, order of sample durations, and number of elements in the sample. The randomization procedure had the restrictions (for both element and compound sample stimuli) that there were eight test trials per day at each sample stimulus duration and that each of the four stimuli (red and blue disks, and vertical and horizontal line orientations) appeared as correct matching alternatives with equal frequencies.

RESULTS

Figure 1 summarizes both birds' performances on color- and line-orientation matching. Within each panel of Figure 1, per cent correct matching as a function of sample stimulus duration is presented separately for compound and element sample trials. Data collected during the 256 daily test trials were averaged over sessions. Thus, each point is based on 400

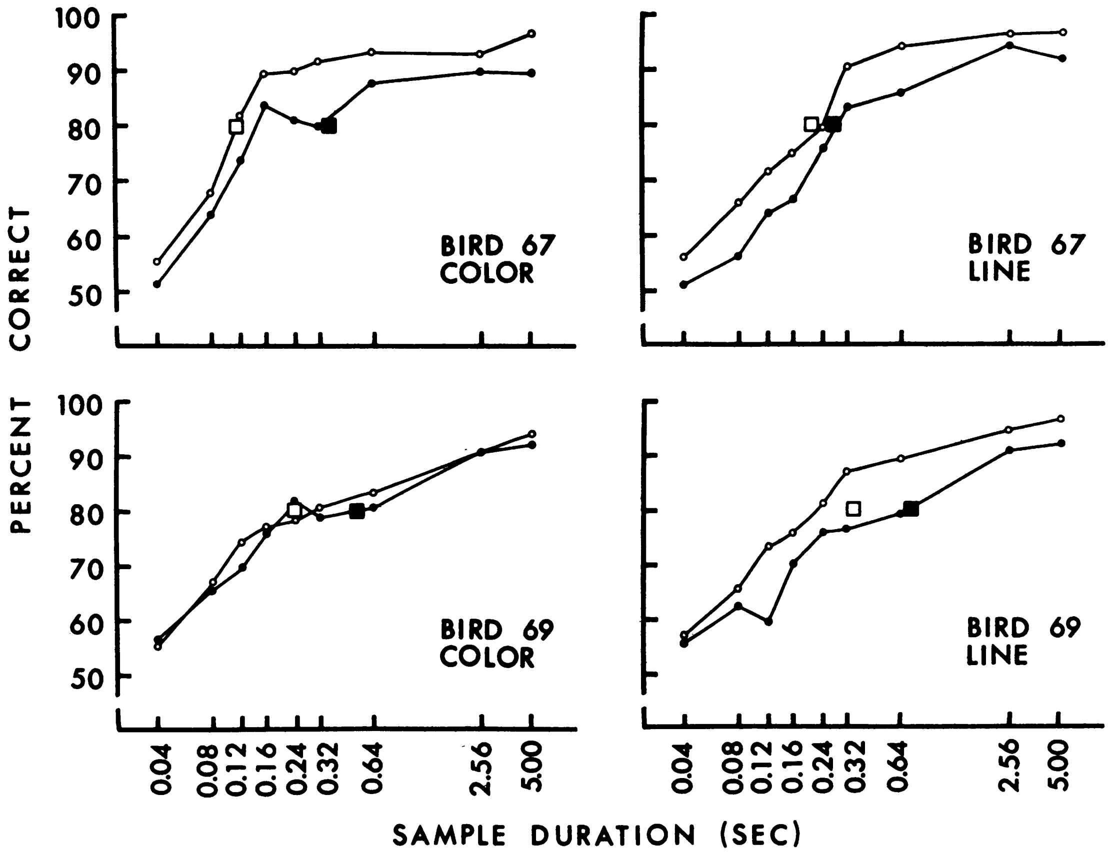

Fig. 1. Matching-to-sample performance as a function of compound and element sample durations. Data were obtained from each of two birds for color- and line-orientation matching. Open circles represent performance on element matching trials, and filled circles represent performance on compound matching trials. Open and filled squares are element and compound average sample durations obtained from 80% correct titrations (Maki and Leuin, 1972). Stimulus duration is plotted on a logarithmic scale.

trials, except for the 5-sec points, which are based on 640 trials.

Two main effects are clear. First, performance varied directly with sample stimulus duration. Second, at each sample stimulus duration, compound sample stimuli generally controlled responding less effectively (*i.e.*, there were more errors) than did element sample stimuli. These effects are similar for both dimensions. Figure 1 also shows the mean sample stimulus durations required to maintain 80% correct matching (Maki and Leuin, 1972). Those values are close to corresponding points on the functions obtained in the present study for both birds and both dimensions.

DISCUSSION

In this experiment, correct responses were dependent upon attention to both elements of a compound stimulus. The results suggest that the consequence of the sharing of attention among elements of a compound stimulus is the reduction of control by those elements. The same conclusion may be drawn from the results of two other experiments.

Blough (1969) presented compound stimuli that consisted of all combinations of seven colors ranging between 576 and 582 nm, and seven pure tones ranging between 3370 and 3990 Hz. Responses on a single key in the presence of the 3990 Hz–582 nm compound were intermittently reinforced. Stimulus control was measured along one dimension of the compound when nonreinforced stimuli from only that one dimension appeared and along both dimensions when nonreinforced stimuli from both dimensions appeared. These can be regarded as conditions of selective and shared attention, respectively. Blough found that stimulus control along a particular dimension was better when only that one dimension varied than when both dimensions varied.

In Blough's paradigm, stimulus control was always measured with a compound stimulus, the elements of which often elicited competing behaviors (*e.g.*, 582 nm—"peck", 3770 Hz—"no peck"). Hence, it may be argued that strong control by one dimension obscured control by the other dimension. The matching-to-sample paradigm presented here avoids such problems; when measuring control by an element of a compound stimulus, other elements from other dimensions that may control competing behaviors are at least nominally removed. Using this paradigm, Maki and Leuin (1972) "titrated" sample stimulus duration to maintain matching performance at 80% correct. Compound matching titrations yielded longer duration estimates than did element matching titrations. This was true of both color- and line-orientation matching for each of the two birds (see Figure 1).

The particular contribution of the present experiment is the finding that when reinforcement contingencies are arranged so that responding is controlled by individual, unidimensional stimuli, control by each of those stimuli is attenuated when they comprise compound stimuli. It appears that the degree of control exerted by one element of a compound is reduced when other elements present in the compound also control behavior. This rule of stimulus control, which describes behavior in a shared attention task, also describes behavior in selective attention tasks, *i.e.*, at the extremes of Born and Peterson's (1969) continuum. The presence of an element that strongly controls behavior may reduce the control that can be exerted by other elements of a compound; alternatively, in the absence of strong stimulus control by one element, other elements of the compound may come to control behavior.

The most general case of the rule states that the degree of control exerted by one element of a compound stimulus is inversely related to the stimulus control exerted by other elements of the compound. Mackintosh (1965), using a different terminology, proposed essentially this same rule. The rule has two points that recommend it. First, it relates stimulus control by one element of a compound to control by others. Second, it describes the outcomes of a large variety of experiments (Sutherland and Mackintosh, 1971).

One problem for an experimental analysis of attention is the determination of the training conditions that locate an experimental outcome along a continuum like that of Born and Peterson. Unequal control by elements of a compound stimulus places a given experiment toward one or the other extreme of the continuum; equal, or nearly equal, control by both elements locates the experiment towards the middle. Born and Peterson (1969), Johnson and Cumming (1968), and Reynolds (1961) all obtained unequal control by two elements of a compound stimulus in the presence of which responding was reinforced. Nearly equal control was obtained in the present experiment, and by Blough (1969) and Maki and Leuin (1972).

Some of the rules for establishing stimulus control by the elements of a compound stimulus seem clear. For instance, one method of ensuring unequal control by elements of a compound is to give extra training with one element alone (Johnson and Cumming, 1968). The design of the present experiment ensured nearly equal control by elements in a compound by explicitly reinforcing responses to each element as it appeared in compound. Simply reinforcing responses in the presence of a compound stimulus does not ensure equal control by both elements, nor does it even allow a prediction of the element that can come to control behavior (Ray, 1969; Reynolds, 1961). The foregoing suggests that the features of an organism's environment that receive its attention are at least partly determined by the contingencies of reinforcement. This suggestion is reminiscent of ". . .the conception of attention as something to be taught rather than something immutable to be measured" (Ray, 1972, p. 293).

REFERENCES

Blough, D. S. Attention shifts in a maintained discrimination. *Science*, 1969, **166**, 125-126.

Born, D. G. and Peterson, J. L. Stimulus control acquired by the components of two color-form compound stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 437-442.

Johnson, D. F. and Cumming, W. W. Some determiners of attention. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 157-166.

Mackintosh, N. J. Selective attention in animal discrimination learning. *Psychological Bulletin*, 1965, **64**, 124-150.

Maki, W. S., Jr. and Leuin, T. C. Information processing by pigeons. *Science,* 1972, **176,** 535-536.

Ray, B. A. Selective attention: the effects of combining stimuli which control incompatible behavior. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 539-550.

Ray, B. A. Strategy in studies of attention: a commentary on D. I. Mostofsky's *Attention: contemporary theory and analysis. Journal of the Experimental Analysis of Behavior,* 1972, **17,** 293-297.

Reynolds, G. S. Attention in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1961, **4,** 203-208.

Skinner, B. F. *Science and human behavior.* New York: Macmillan, 1953.

Sutherland, N. S. and Mackintosh, N. J. *Mechanisms of animal discrimination learning.* New York: Academic Press, 1971.

Received: 25 March 1972.
(Final Acceptance: 5 October 1972.)