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Accounting for Behavioral Contrast: Recent Interpretations

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ACCOUNTING FOR BEHAVIORAL CONTRAST:

RECENT INTERPRETATIONS

by

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IN REMEMBRANCE ...

"... One lesson that history teaches is that civilization seems to advance only upon the faltering footsteps of individual creativity.

"If we try to think of things in ways no one else has ever done before, we may eventually shatter the illusion that all things worthy of accomplishment have already been tried."

- Ron L. Snyder

These words, often spoken by my beloved son to his associates and to myself have served quite frequently to influence thoughts and to enhance accomplishment.

For Randolph Brill, they inspired the creation of the Panaroma of the Seven Seas at the Brookfield Zoo which now stands as a living memorial to Ron. This, in turn, reflects the guidance and inspiration of Dr. Carl Cheney, Dr. Robert Tarte, and others who were responsible for shaping my son's philosophy.

For me, they offer the realization that by being the very best of which I am capable, by using well my own gift of creativity, I become part of something much larger than myself: the march of mankind seeking to fulfill a destiny of truth and knowledge in the further advancement of civilization.

Marlena (Synder) Dorr

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ABSTRACT

Accounting for Behavioral Contrast:

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Behavioral contrast has been interpreted as a function of either (1) the reduction of frequency of reinforcement in one component of a multiple schedule or (2) the suppression of responses in one component regardless of reinforcement frequency.

These explanations are discussed in terms of their adequacy in accounting for several recent experimental results. Two alternative explanations are considered.

First, contrast is interpreted as a function of the relative summation of excitatory and inhibitory effects of stimuli.

Second, contrast is discussed as a possible function of a switch from a response-reinforcer contingency to a stimulus-reinforcer contingency as seen in auto-pecking. Both avenues are considered promising in terms of accounting for behavioral contrast.

(36 pages)

INTRODUCTION

The control of an organism's behavior can often be interpreted as resulting from an interaction of several different schedules of reinforcement. In operant conditioning studies, distinct behaviors can be brought under the control of distinctive stimuli each of which is related to its own schedule of reinforcement. Such an arrangement is called a multiple (MULT) schedule (Ferster & Skinner, 1957 p-503). Performances on each schedule within a MULT can be either the same as they would be if the schedule were operating by itself (Ferster & Skinner, 1957), or they can operate differently. Reynolds, (1961b) referred at any difference between the effects of a single schedule and its operation in a MULT as an interaction effect. He examined one interaction effect in some detail in his use of pigeons. He found that when one component of a MULT was changed from an intermittent schedule of positive reinforcement to extinction, (EXT), the rate of responding not only dropped in the EXT component, but concommitantly increased in the unchanged component. This increase in the unchanged component is in contrast to the decrease in the EXT component. Herein lies the central definition of behavioral contrast; if, during changes in multiple schedules, the rate in the unchanged component increases and the rate during the changed component decreases, positive contrast is demonstrated. Conversely, if the rate in the unchanged component decreases while the rate in the changed component increases, negative contrast is said to

occur. Positive and negative then only refer to the component that is manipulated and not to rates.

Contrast phenomena has attracted interest because it appeared to contradict Hull's (1943) notion of stimulus generalization during successive discrimination learning. Responding in the presence of one stimulus should be positively correlated to response rate in the presence of another stimulus. When the rate drops in the presence of the EXT stimulus, it should also drop during the unchanged component, according to Hull. Such a result would also be consistent with Skinner's (1938) definition of induction.

This paper reviews behavioral contrast and related areas which have attempted to isolate variables responsible for the phenomenon. The major examination of data will be restricted to experiments performed since 1968. The reader is directed to Freeman (1971) for a comprehensive review of contrast research prior to that time. First, a brief overview of the development of the concept of behavioral contrast is presented. This is followed by a discussion of the major controversy in the area, concerning the relative contributions of reinforcement frequency versus response suppression. It is suggested that this controversy was the result of an inadequate formulation of the original question. That is, the effects of reinforcement density and response suppression may affect different "micro-aspects" of the contrast phenomenon. Unless these aspects are specifically examined, no adequate answer to the controversy is available.

One example of such a "micro" analysis is that of Malone and Staddon (1973), who found several possible changes in rate if the

"local contrast" following presentation of stimuli in a generalization experiment was examined. In fact, their results question the entire concept of behavioral contrast since the changes in rate they found could be adequately explained in terms of generalization gradients.

The thesis of this paper in regard to the controversial effects of reinforcement frequency versus response suppression is that a combination of inhibition and excitatory functions "sum" together to produce changes in response rates. This notion is due to Rachlin (1973) and Malone and Staddon (1973). The function of reinforcement frequency is only one of many factors which may influence the "value" of a particular stimuli. The summation is always relative, depending upon the environmental conditions. In other words, both reinforcement frequency and response suppression may or may not operate in any contrast experiment, with their influences masking each other, depending upon which is having the most effect.

This review also examines the suggestion of Gamzu and Schwartz (1973) that contrast is possibly the reflection of a shift in stimulus control from a response-reinforcer contingency to a stimulus-reinforcer contingency. The data for this kind of explanation is not yet persuasive and may be more parsimonious than the "summation of values" explanation. (However, both the stimulus control shift and the relative values explanations account for many different contrast-producing procedures.) The review therefore includes some auto-pecking literature in order to clarify Gamzu and Schwartz' (1973) suggestion.

In sum, this paper suggests two possible alternatives for the reinforcement frequency versus response suppression explanation of

behavioral contrast. First, a relative summation function of inhibitory and excitatory effects is suggested, and second, the shift from a response-reinforcer contingency to a stimulus-reinforcer contingency is postulated to account for contrast. The first explanation accounts well for "local" contrast (Malone & Staddon, 1973), while the second remains somewhat speculative. The question of whether both functions can operate at the same time or if they are mutually exclusive will remain moot until clarified through further research.

DISCRIMINATION TRAINING: EARLY DESCRIPTIONS OF CONTRAST

Verplanck (1942) trained rats to discriminate a black from a white runway leading to either a food filled or an empty box. During initial acquisition of the running behavior both conditions were rewarded. Verplanck reported an increase in running speed for the positively valued choice during discrimination training which later was reduced to pre-discriminational levels. Solomon (1943) reported a similar effect in jump-stand latencies as rats learned to discriminate one pattern from another on a goal box door. During training, latencies were shorter for the rewarded condition than they were before discrimination training was begun. Solomon did not discuss the latencies after the acquisition of the jump-stand discrimination.

These reports seem to demonstrate contrast between responses to positively and negatively valued outcomes. They appear to conform to Reynolds' (1961a) prescription for a reduction in the frequency of reinforcement in the presence of one stimulus relative to the reinforcement frequency during all of the stimuli which are controlling the organism's behavior. This kind of investigation represents a methodology not generally used in modern psychological research and yet indicates that discrete trial experiments offer another possible route of inquiry into the contrast phenomenon.

Contrast in operant discrimination was first described by Smith and Hoy (1954). They trained rats to discriminate a bright from a dim light and then reversed the reinforcement conditions. Under both acquisition

and reversal training for some of the rats, the response rates made in the presence of the positive stimulus were higher than those of control rats with no opportunity to respond to the negative stimulus. Herrick, Myers and Korotkin (1959) also reported increases in S^D rates during an operant discrimination acquisition between S^D and S^Δ. Also, Findley (1958) showed that the change in rate of responding during the presentation of one stimulus in a direction away from the rate on the other stimulus need not depend on extinction under the second stimulus (S^Δ). He demonstrated contrast on a VI 6 minute component of a MULT VIVI if the second component had a mean interval of greater than six minutes.

The first reference to these changes in rate of responding under differential stimulus conditions as illustrating "behavioral contrast" was in Reynolds' (1961a) dissertation, although the term was first suggested by Skinner (1938). Skinner used the term "induction" to describe changes in opposite directions. Reynolds also interpreted FI scallops in terms of the contrast between the never reinforced early part of the interval and the always reinforced latter part. However, Reynolds' (1961a) later investigation into the relative contributions of frequency of reinforcement and rate of responding to the development of contrast generated much more interest in the phenomenon than any of the previous reports.

Reynolds (1961a) attempted to clarify several questions about contrast in this paper. First, he showed that contrast occurred when S^Δ was replaced by a TO which immediately produced near zero responding. That is, a slow decline in responding in S- was not necessary for the

appearance of contrast. He also showed that if not responding during S- was reinforced intermittently (VI DRO), contrast did not occur. If the reduction of reinforcement in one component, rather than a low rate of responding, creates the conditions necessary for contrast in the other component, then Reynolds claimed that a DRO S- eliminates contrast by providing equal reinforcement in the S- condition. Since a slow decline in S- reinforcement density was not necessary for the appearance of contrast during S+, induction, which Reynolds felt had to work gradually, did not appear to affect its appearance. In other words, responding was reduced under S- without a corresponding decrease in reinforcement density, and contrast did not appear under S+. Reduction in relative density of reinforcement was therefore considered the necessary and sufficient condition for the appearance of contrast.

REDUCTION IN REINFORCEMENT VS. SUPPRESSION OF RESPONDING

Reynolds' (1961a) account of the relative contributions of reinforcement density and response rate to the development of contrast was re-examined using punishment of one response to produce contrast in an unpunished response (Brethower & Reynolds, 1962). A key peck was reinforced on a VI schedule during the presentation of two stimuli. In various phases of the experiment, punishment followed responses emitted in the presence of one of the stimuli. When the rate of punished responding was reduced, the unpunished responding changed in the opposite direction, exhibiting positive contrast. This procedure reduced response rates independent of reinforcement during the depressed component and still produced contrast. Nevertheless, Brethower and Reynolds were reluctant to abandon the reduced reinforcement explanation and were forced to postulate a "functional similarity" between punishment and a decrease in positive reinforcement.

Later, Terrace (1966) attempted to explain the cause of contrast from an "emotional response" point of view. He proposed that the "aversiveness" of receiving no reinforcement for responding to S- produces the increase typically seen during S+. He showed that contrast declined over a two months period after pigeons learned a light discrimination. The "emotional" responses presumably declined in intensity over time, thereby producing the reduction in contrast. The main support for an emotional or "aversive S-" interpretation, however, came from his demonstration that contrast does not appear following errorless discrimina-

tion training (Terrace, 1966). Since there is no responding to an errorless S-, the organism does not react emotionally when no reinforcement follows S- in errorless training. Therefore, it would not be expected to react to S- as an aversive stimulus, producing contrast. Terrace (1968) later expanded this "reduced responses in an aversive S-" explanation to completely account for contrast, relegating Reynolds' (1961a) relative reinforcement density explanation to a "special case." Terrace (1968) pointed out that Reynolds' (1961a) VI DRO birds had originally been trained on a VI EXT schedule in which S- was the same in EXT as it was in DRO. He suggested that the development of not responding to S- during VI EXT may have facilitated the cessation of responding to S- in VI DRO.

The validity of Terrace's (1966, 1968) explanation of contrast rests heavily upon his assumption that an errorless S- does not possess aversive capabilities. However, his demonstration (Terrace, 1968) that contrast still results when the rate of reinforcement in both components is held constant and response rate is depressed in one component by DRL schedules, does provide evidence against Reynolds' relative density of reinforcement explanation.

RECENT DATA CONCERNING THE AVERSIVENESS OF AN S-

Later evidence regarding these conflicting interpretations of the sufficient conditions for the production of contrast contributed little to the controversy (Freeman, 1971). However, several recent papers have offered some important qualifications. Wessells (1973) used an auto-shaping procedure to teach pigeons an errorless discrimination between a green light S+ and a vertical white line S-. After the discrimination was learned, the S- was superimposed over the S+. Surprisingly, responses were markedly suppressed in this procedure. Also, new response acquistion was inhibited if the same S- were superimposed on a new S+ (red light). Wessells concluded that an errorless S- can be inhibitory. Terrace's (1966, 1968) argument rested on the assumption that the organism emits emotional responses to a normally learned S- and it becomes aversive, resulting in contrast. His demonstration that contrast did not occur with errorless discriminations lent support to that notion. Wessells (1973) points out that the depressed rate with the superimposed S- demonstrates contrast with an errorless discrimination, as well as demonstrating the inhibitory effect of an errorless S-.

A second experiment questioning the generality of Terrace's (1968) conclusions was reported by Taus and Hearst (1970). They trained pigeons to peck a disk for intermittent reinforcement during 30-second presentations of a stimulus. Blackout periods (BO) of from 0 to 30 seconds duration for different groups of pigeons were interpolated into

the sessions. In this experiment response rate was a direct function of the intervening blackouts. Clearly, the increase in response rate in this study following longer BO violates Terrace's (1968) conclusion that the development of such rate increases requires the occurence and decline of behavior during some other stimulus. Also, training with BO is analogous to errorless discrimination (Terrace, 1966) and yet contrast was demonstrated between S+ and BO. Terrace's main argument had rested on the demonstration that an errorless discrimination did not result in contrast.

Wessells' (1973) and Taus and Hearst's (1970) results should not be interpreted as negating completely the concept of the aversiveness of a traditionally learned S-. They simply show that the errorless learning procedure does not necessarily rule out behavioral contrast. In fact, Terrace (1974) has recently shown that a conventionally learned S- results in responses physically opposed to the required response in S+, for human subjects. His procedure required the subjects to pull a joystick toward themselves for reinforcement. When an S- appeared, they tended to push the stick away.

Errorless discrimination control subjects did not push the stick during S-. Terrace's notions about the aversiveness of S- are almost certainly valid, but they do not fully account for contrast.

MULTIPLE DEPENDENT VARIABLES

It may be that neither Reynolds' nor Terrace's alternative explanations for contrast have dealt adequately with the phenomenon. Terrace's (1966, 1968) demonstrations that contrast occurs when relative frequency of reinforcement remains constant and other variables are manipulated, plays havoc with Reynolds' (1961) suggestions. On the other hand, Terrace's conclusion has difficulty with Wessells' (1973) and Taus and Hearst's (1970) results. Apparently neither Reynolds nor Terrace has been able to achieve the upper hand in their explanations of the phenomenon. Perhaps the reason for the inadequacy of both approaches is that they both have concentrated on the search for some single property of reinforcement schedules that can account for all instances of contrast. The search has been unsuccessful for two reasons. First, contrast, can be shown when the relative frequency of reinforcement in two components of a multiple schedule is constant. This was shown by Terrace's (1968) demonstration of contrast with shock in one component and Reynolds and Limpo's (1968) paper which shows contrast with DRL in one component, holding reinforcement equal in both components. Second, contrast cannot be a sole function of unreinforced responding since it appears when a VI component is alternated with a time out (Taus & Hearst, 1970).

The first papers which reported empirical data supporting the notion that there may be multiple variables at work in the production of behavioral contrast were Bloomfield (1966) and Nevin and Shettleworth

(1966). Bloomfield (1966) demonstrated two "types" of contrast (reviewed below) and Nevin and Shettleworth (1966) showed that the rates of responding during one component were different depending upon the relative reinforcement rate of the preceding component. In their experiments investigating contrast, Malone and Staddon (1973) made use of a distinction first proposed by Nevin and Shettleworth (1966) regarding the permanence of contrast effects. As stated above, Nevin and Shettleworth found that the pattern of responding in one component of a multiple VI schedule were dependent upon the relative reinforcement frequency during the immediately preceding component. If the relative reinforcement frequency of the preceding component was low, responding was high during the first part of the next component and gradually declined. If the relative frequency of reinforcement in the preceding component was high, responding was depressed at the beginning of the next component. They referred to these effects as positive and negative transient contrast, respectively. Nevin and Shettleworth then went on to show that these effects were not dependent upon changes in response rates in a preceding component. They did this by reproducing the effects without any responding being necessary in the preceding component.

There is some controversy regarding the accuracy of the term "transient" in this sense. The effect does appear at an intermediate stage of training but it has also been reported during steady state performance during multiple fixed interval schedules (Staddon, 1969). Therefore, "transient contrast" may or may not be transient across sessions. Malone and Staddon (1973) refer to effects which are

transient within components as "local contrast," thereby separating the effect from those that persist across sessions in multiple FI. Their local contrast may then appear in two forms: (1) "positive local contrast," which may be an overall increase in responding during one component or as a gradual decrease, (2) "negative local contrast," which can be either depressed overall responding or a gradual increase during one component.

In order to separate the various functional relationships among the effects described above, Malone and Staddon (1973) developed a procedure which enabled them to assess both behavioral and local contrast among presentations of stimuli forming a generalization gradient. Pigeons were trained to peck a key with eight different possible orientations of a line focused on the key. The experimental sessions consisted of reinforcements for responding only to the vertical (90^{o}) orientation while all other orientations (6^{o} to 78^{o}) were not reinforced. This condition corresponded to a VI EXT schedule. Generally, the shift from training (VI VI) to VI EXT produced increased responding to the S+ (90^{o} line stimuli), an instance of behavioral contrast.

Negative local contrast was shown when the response rate during a 78^{o} stimulus, for instance, was preceded by a 90^{o} stimulus (S+). That is, it increased. When a 78^{o} presentation was preceded by an 18^{o} stimulus, responding was initially elevated and decreased gradually (positive local contrast). Also, overall levels of responding were higher when an orientation was preceded by one more distant from 90^{o} and lower when the preceding orientation was 90^{o}. Therefore, the preceding stimulus influenced both the pattern and overall level of responding

during a subsequent presentation. Malone and Staddon concluded that this experiment showed that "although the average response rate in a stimulus on a generalization gradient is a function of its distance from S+, the preceding stimulus presentation can influence both rate and pattern of responding during an individual presentation." These authors point out that the change in response rate during a particular stimulus could be either a contrast effect, a generalization effect, or both. There is no way to decide which is the better alternative. Behavioral contrast could have been occurring only between the 90° stimulus and the stimulus most unlike it (6°), and increased rates in 78° and 68° would then be due to generalization from S+. Conversely, generalization from the 6° stimulus would explain decreases in response rates in the 18° and 30° stimulus conditions.

A second experiment in this report was conducted to establish a baseline for assessing local contrast effects. Since their first experiment had suggested that contrast effects are relative to the response rate in the preceding stimulus, it is important to identify differences in response rates relative to a baseline. Contrast due to responding in the preceding stimulus was compared to contrast due to other stimuli by presenting one stimulus condition followed by either the same condition or a different one. This experiment showed that there were no differences in behavior due to presentation sequence. Responding was elevated over baseline when the preceding stimulus was further removed from S+ and was depressed when the preceding stimulus was nearer S+. The "pattern" of responding was similar to the first experiment. For instance, positive local contrast occurred during the

90° stimulus when preceded by 54° or 18° and in 54° when preceded by 18°.

Summarizing these experiments, stimuli correlated with higher average response rates depressed responding during a subsequent stimulus (negative local contrast), while stimuli correlated with a lower average rate of responding produced an elevation in response during a subsequent stimulus (positive local contrast). However, there was some evidence that this relationship between average response rates and local contrast may hold only during steady state performance.

RELATIVE VALUES OF DISCRIMINATIVE STIMULI

The results of Malone and Staddon's (1973) experiments could be interpreted in terms of a Pavlovian induction model proposed by Nevin and Shettleworth (1966). Accordingly, the stimuli in the maintained generalization gradient made up of the vertical and slanting lines became relatively excitatory or inhibitory. The relative reinforcement associated with each stimuli presumably enhanced excitation following an inhibitory stimulus (i.e., 18^{o}) and enhanced inhibition following an excitatory stimulus (i.e., 84^{o}). However, this interpretation requires that the same stimulus be <u>both</u> inhibitory and excitatory. Responding in 90^{o} following 66^{o} was always high at first and then decreased. When 66^{o} preceded 6^{o}, the response rate began at a low level and then increased. The 66^{o} stimulus was therefore both excitatory and inhibitory, depending upon the following stimulus. The functional predeterminations of local contrast are therefore no "absolutely" related to the excitation or inhibition of preceding stimuli, but they are relative to the value of the preceding stimuli.

The response rate of an animal in a contrast experiment may then be interpreted in the following way. First, the animal "orders" the stimuli according to their value. For instance, the VI component in Reynolds' (1961b) experiment is of more value than the EXT component. The punishment stimuli in Terrace (1968) is of less value than the DRL stimuli without punishment. The average response rates of the animal during each of these stimuli may reflect this ordering of values. Since

any of these stimuli are capable of exerting both excitatory and inhibitory effects (Malone & Staddon, 1973) on the other stimuli, an interaction analogous to the "neutral unit" summation of Bekesy (1967) takes place. Farthing (1974) has shown that the neural unit analogy may be relevant to his results. He trained pigeons on a discrimination involving twelve line tilts from vertical to horizontal. The six tilts running clockwise from vertical were S+, while the remaining six were S-. The pigeons responded at the highest rate to the S+s which were nearest the S-. Contrast was therefore greater with small than with large stimulus differences, just as in sensory lateral inhibition systems.

The implications for further studies of contrast and generalization seem clear. Discrimination learning is not adequately described as the acquisition of excitatory properties by some stimuli and inhibitory properties by others. A more satisfactory account is that stimuli exert both excitatory and inhibitory effects, depending upon their current value to the organism. In this sense, any single stimulus must exert its control within a broad spectrum. The relative correlation with greater or lesser valued outcomes will determine the organism's reponse. Baum (1974) has discussed this notion in terms of a "correlated law of effect" which attempts to account for all behavior as a ranking of values.

Bloomfield (1966, 1967, 1969) has developed the concept of value interaction in behavioral contrast with several experiments. He (Bloomfield, 1966) required a period of no-responding during S- for pigeons on a MULT VI EXT. Under these conditions a high "peak rate" of

increased responding to S+ appeared during the early stages of training while the pigeons learned to avoid prolonged exposure to S-. The peak rate of contrast was correlated with the total number of responses to S- during this period. During the later stages of training, the high rates of responding to S+ declined to a stable level which was still above baseline. Bloomfield explained these two levels of contrast as resulting from a differential "punishment" contingency. He suggested that S- can be more or less aversive depending upon its total temoral relation to S+, and the more aversive it is, the more contrast appears.

Bloomfield pointed out that Brethower and Reynolds (1962) reported a similar result. They shocked pigeons in one component of a MULT VI3 VI3 and found that the rates of responding in the unpunished component rose proportionally to the intensity of the electric shock. Bloomfield considered the response produced non-reinforcement period in his experiment functionally similar to the response contingent shock in the Brethower and Reynolds procedure. The assumption of similar ties between punishment and S- are in agreement with Amsel's (1958, 1962) notions of the effects of "frustrative non-reward." That is, the longer an S- remains in effect, the more "frustrated" the pigeons become and engage in higher rates of frustration produced behavior, in this case, the "peak" rates of responding during S+. Of course, the "punishing" aspects of S- are precisely what Terrace (1968) identifies as the sole source of contrast effects.

Later, Bloomfield (1967) rewarded pigeons on a MULT VI EXT in which the stimuli changed every two minutes, to produce behavioral contrast. He then changed the conditions of the experiment so that the stimuli

changed only between sessions. That is, one hour sessions of reinforcement and non-reinforcement occurred on alternate days. Under these conditions, responding to S+ still increased above baseline, but the increase disappeared during the session. Bloomfield concluded that S- had an "excitatory" effect that appears each time S- precedes a reinforcement session with S+, but as responses to S+ are reinforced, the effect disappears. Therefore, behavioral contrast occurs for the first few minutes of S+ only, and should be regarded as an excitatory effect of the change in reinforcement frequency from one component to another, superimposed on a VI baseline rate. His account of contrast as one interaction of positively valued stimuli (excitation) versus negatively valued stimuli (inhibition), allows the response rate in a preceding component to become the organisms' "yardstick" to measure these values. The value of the preceding component is therefore, a relative measure and may cause positive contrast in one situation and negative contrast in another situation. Thus, some of the conflicting data concerning the independent variable responsible for contrast may be clarified. Behavioral contrast becomes a complex summation of excitatory and inhibitory influences, with many interactions possible. The major dependent variable becomes the reduction in value of one MULT component, and <u>any</u> method which reduces it will work.

AUTOPECKING AND BEHAVIORAL CONTRAST

Gamzu and Schwartz (1973) first suggested that an association might exist between autopecking and contrast. Autopecking is the appearance of fairly high rates of key pecking by pigeons when a stimulus is presented on the key for a few seconds before response-independent food presentations. Brown and Jenkins (1969) first demonstrated the phenomenon and Williams and Williams (1969) showed that autopecking occurs even when such key pecks prevent food presentation.

Gamzu and Schwartz (1973) used multiple schedules where two or more successive component schedules are associated with different stimuli. They compared schedules in which the components differed with schedules in which they did not. The food presentations in their experiments were always associated with a particular stimulus but were not contingent upon key pecks. The reinforcers were delivered on a variable time (VT) schedule. For instance, when one component of a multiple schedule was VT 33-sec and the other was extinction, the pigeons key pecked during VT (positive stimulus) but hardly ever during EXT. However, when both components were the same (e.g., MULT VT 33-sec VT 33-sec), rates of key-pecking in both were considerably reduced. The high rates during VT in the MULT VT EXT schedule satisfy the definition of behavioral contrast, particularly when compared to the rates during MULT VT VT.

In summary, Gamzu and Schwartz propose that the transition from MULT VI VI to MULT VI EXT involves the introduction of a stimulus-reinforcer contingency. The effect of this contingency is to channel

onto the key the "reflexive" pecks which, during baseline, have been occurring off the key. The effect of this change is to increase the number of key closures. Gamzu and Schwartz further speculated that the stimulus-reinforcer contingencies, and thereby, behavioral contrast, occur whenever stimuli are associated with different conditions of reinforcement.

A possible objection to the idea that reflexive pecks are occurring off the key during MULT VI VI was expressed by Westbrook (1973). He pointed out that multiple schedules that separate the components with blackouts provide the basis for the development of stimulus-reinforcer contingencies even during MULT VI VI. However, no data is currently available on this question.

Gamzu and Schwartz suggested that the contrast seen in the usual contrast experiment consists of a combination of instrumental responding which is appropriate to the schedule in effect, and "extra" responses which appear in response to the stimuli which have been correlated with the richer component. This "switch" from a response-reinforcer contingency is a kind of "instrumental-plus-autopecking" effect. This additive function is temptingly simple but may result in changed topography as well as an increase in rate of response. Schwartz and Williams (1972) attempted to differentiate auto-shaped versus instrumental key pecks of pigeons in terms of short and long IRT durations. No clear differences were apparent in their study. However, Blough (1963) analyzed the IRTs of pigeon pecks under several different schedules of reinforcement. He found that the frequency of very short IRTs was not affected by the different schedules. They appeared at a fairly constant

rate regardless of the schedule in effect. Perhaps these short IRT pecks represent the "reflexive" responses to which Gamzu and Schwartz (1973) refer.

The instrumental plus auto-shaped formulation seems to account for any contrast experiment where the instrumental responses are similar to those which appear in an auto-pecking procedure, that is pecking at a lighted key. In terms of the "relative values" suggestion above, any situation which is relatively more highly valued by the organism excites reflexive pecking which is then directed at the response key. The two suggestions may not be mutually exclusive, as long as the response comprises both operant and critically similar reflexive components.

However, the question of the universal applicability of the instrumental plus auto-pecking explanation cannot be assessed until it can be demonstrated that contrast does not appear when the two responses are separated. Such a demonstration may be impossible. Once an instrumental contingency has been established, the "auto-excitation" effect would probably be expressed through instrumental modality. When response independent food presentations are paired with auditory stimuli, pigeons peck at the air (Rachlin, 1973). Whatever the organism happens to be doing is therefore likely to be affected by the auto-pecking excitation.

Keller (1974) attempted to separate operant and elicited pecks occurring in multiple schedules by moving the component stimuli to a second key, upon which pecks had no effect. In this experiment, the operant key stimulus was constant regardless of the reinforcement schedule in effect. He used both two and three component multiple schedules

and he compared single-key and two-key procedures. Kelley found that the conditions which produced contrast with the single-key procedure reduced responding to the operant key in the two-key procedure. That is, the rate of responding on the operant key decreased in both components (induction). The rate of responding on the component key increased during S+, showing behavioral contrast.

The rationale of this study was that while operant pecks were assumed to be directed to wherever they produce reinforcement, the elicited pecks would be directed toward the stimuli which is paired with reinforcement. Keller's (1974) results seem to confirm these assumptions. He concluded that there is a class of pecks elicited by and ordinarily directed to a stimulus associated with a high rate of reinforcement when that stimulus alternates with an extinction stimulus. Since contrast did not occur on the operant key, this study supports the suggestions of Gamzu and Schwartz (1973) that behavioral contrast is a result of "added (reflexive) elicited pecks" to a baseline of induction. However, since Keller (1974) did not make use of a change-over response between the two keys, his results may have been contaminated by some superstitious responding during the S+ component.

Rachlin (1973) has suggested that the autopecking effect may help explain negative contrast in either of the following two ways. First, just as an excitatory effect may "add" autopecking to normal instrumental responses, it may subtract from responding during an S-. Alternatively, the autopecking effect might excite one kind of response during S+ and another kind of response during S-. The latter response might

simply interfere with responding to the key. Therefore, both positive and negative contrast may be accounted for.

If added autopecks explain behavioral contrast, the question immediately arises as to how contrast in experiments with organisms and responses which are not so amenable to auto-shaping procedures can be explained. Since bar pressing in rats is less likely to appear in an auto-shaping procedure, can contrast with rats be a similar function of "added presses?" Bernheim and Williams (1967) and Pear and Wilkie (1971) both employed rats as subjects in behavioral contrast investigations. The former study examined running wheel performance, the latter was a bar-pressing experiment. In both studies positive contrast did occur in some subjects, but not in others.

Westbrook (1973) provided further comparative data on the occurrence of positive behavioral contrast by examining its appearance under two conditions of responding for pigeons. He trained one group of pigeons to peck a key for food reinforcement while a second group was trained to press a bar with their feet. When the procedure was shifted to a VI EXT MULT schedule, positive contrast occurred with pigeons that key pecked. However, negative induction occurred with those that bar-pressed. The absence of contrast in the bar-pressing group could not be ascribed to any lack of response inhibition in this group, because negative generalization gradients were U-shaped in a second experiment. Westbrook suggested that the inhibitory after-effects of an S- may be limited to the response which has the highest probability of emission in the experimental situation. That is, the key peck response may be

particularly sensitive to inhibitory after-effects while the bar-press response is not.

Westbrook's (1973) view may be seen as lending a special status to bar-pressing in pigeons. According to his formulation, contrast doesn't occur in bar-pressing pigeons because this response is affected differently from key-pecking by inhibitory stimuli. This view is the opposite side of the Gamzu and Schwartz (1973) coin, since they propose that operant key pecking is a special response, which summates with "reflexive" pecks to produce contrast. Whichever response is the "special" one seems less important than the fact that contrast depends upon the operant chosen for pigeons. Hemmes (1973) showed that the same pigeons would show contrast during key-pecking and induction (or no change) during foot treadle operation. Her demonstration is persuasive evidence that the conditions necessary for the production of behavioral contrast, in pigeons, involve the operant chosen. In fact, Rachlin (1973) reports that contrast may be a phenomenon restricted to the pigeon key-pecking paradigm. He cites many studies in which induction, the opposite of contrast, is reported for species such as rats and dogs in MULT schedules. Of course, contrast has been reported in other species than the pigeon, including humans (Waite & Osborne, 1974). But Rachlin simply points out that the phenomenon may be most pervasive in pigeons.

As noted above, contrast was most clearly demonstrated when the stimuli associated with the component schedules are located on the response key. These conditions are similar to those in which autopecking and negative automaintenance are obtained. In fact, autopecking does

not appear unless the stimulus is located on the response key (Wasserman, 1973). These findings raise the question as to whether contrast should only occur when the stimulus is on the key when the response is restricted to automaintenance. Redford and Perkins (1974) studied groups of pigeons on both MULT VT EXT and MULT VT VT schedules. In order to assess the differences between autopecking and response contingent reinforcement, the food deliveries for the birds were yoked to that of two other groups of birds which were responding under VI EXT and VI VI schedules. That is, both groups received comparable reinforcement, but one group was autopecking while the other was receiving food contingent upon their responses. For one group in each condition the stimuli associated with the components were located on the response key. The second group had the stimuli non-localized (i.e., bright and dim houselights).

The results of this experiment clearly showed that contrast could be obtained with an autopecking procedure. Both the VI EXT and VT VI birds responded more often during the positive stimuli when the stimuli were on the key. The results of Gamzu and Schwartz (1973) were thereby confirmed and extended to a yoked procedure. However, the more important result was that the birds pecking on the MULT VI EXT with houselight stimuli did not show contrast. This result is in agreement with Rachlin (1973) who suggested that stimuli must be correlated with the key for optimum contrast. The birds in the VT EXT condition with houselight stimuli maintained high rates at some intermediate point, making it unclear whether contrast was obtained or not. The maintenance of responding by the VT EXT houselight birds was curious since Wasserman

(1973) had shown that autopecking was restricted to stimuli localized on the response key, but the question the experiment was intended to answer (whether contrast is shown during automaintenance when stimuli is not localized on the key) was clearly answered. The methods of Redford and Perkins and Keller (1974) should be considered useful in determining answers to other questions about contrast. For instance, the technique of employing different stimuli with each component for several multiple schedules could be used to determine whether or not contrast continues for extended periods of time. The decrement in contrast over time could be partitioned into the different stimuli conditions. Also, this technique could be extended to different species to determine (1) optimal auto-shaping procedures, and (2) whether contrast can be demonstrated in these species using auto-shaping plus instrumental interpretation.

SUMMARY

How may we account for behavioral contrast? To answer this question it is necessary to review and point out which traditional explanations do not adequately account for all the criteria established for the phenomenon, and suggest some current ideas and data which appear to more satisfactorily describe the necessary and sufficient conditions which produce the behavior.

Neither Reynolds' (1961) concept of the reduction of reinforcement density, not Terrace's (1968) suppression of responding formulation fully account for all the instances of behavioral contrast. The studies which demonstrated the inadequacy of the first explanation were Terrace (1968) and Reynolds and Limpo (1968), who showed that contrast can appear when the relative frequency of available reinforcement in all components of a multiple schedule is constant. The second explanation was questioned by the Taus and Hearst (1970) study which showed that contrast cannot be a sole function of reinforced responding since it appears when a VI component is alternated with a time out.

The work of Nevin and Shettleworth (1966), and Bloomfield (1969) demonstrated different types of behavioral contrast. Their results suggest that one reason for confusion between alternative accounts was that contrast is really several slightly different kinds of behavior, each determined by different sets of contingencies. Malone and Staddon's (1973) demonstration that the same stimulus can produce either positive or negative local contrast lends credence to the ideas of

Bloomfield (1969) and Baum (1974) about the values of stimuli to organisms. According to these explanations, events which reduce the overall value of one component of a multiple schedule, with respect to the other component, will result in behavioral contrast. Response suppression and reinforcement frequency reduction are functionally equivalent in that their aversiveness reduces the value of one component and increases response rates in the other in accordance with the suggestions of Amsel (1962). In his terms, the lower-valued stimulus is "frustrative" and leads to excitation of behavior in the presence of the unchanged stimulus.

Except for questions of operational definition, the determinants of value reduction are irrelevant. They include such things as suppressed responding, reduction in reinforcement frequency, response contingent shock, or distance from S+ on a generalization gradient. Value reduction is one component produces inhibition of responding and a corresponding enhancement of value responding in the other component. An important qualification is that excitation as shown by increased responding in S+ may be temporary or "local," depending upon particular conditions of the experiment.

The "relative values" explanation appears to account for contrast in pigeons, but since behavioral contrast is rarely observed in other animals, can the phenomenon be considered a general outcome of value manipulation? At this time, the answer must be a qualified "no." Not only is contrast limited to pigeons, but it appears to be further constrained to their key-pecking response only (Hemmes, 1973). The work of Gamzu and Schwartz (1973), Redford and Perkins (1974), and Keller

(1974) seems to indicate that the key-pecks which pigeons add to their baseline behavior, in a contrast experiment, are elicited responses, which are not under reinforcement schedule control (Blough, 1963). Therefore it is unlikely that procedures which use arbitrary operants will have much success in producing contrast. That is, when an operant is chosen which is not related to the native food gathering behavior of an organism, responses are less likely to be elicited by stimuli associated with food. Of course, any further demonstrations of contrast in humans may force qualifications to this statement, but the bulk of the comparative work supports it (Rachlin, 1973).

The explanation of behavioral contrast as a function of changes in value in the components of a multiple schedule may require that some modifications be made in the definition of contrast. Reynolds (1961a) had defined behavioral contrast as a change in response rate in one component of a multiple schedule in a direction opposite to a rate change in the other schedule. If a lessening of the value of one component produces contrast in the other component, perhaps positive contrast should be re-defined simply as an increase in S1 rates as an effect of decreasing reinforcement in S2, or suppressed responding in S2, or whatever procedure is used to lower its value. Negative contrast would then be defined as a decrease in S1 response rates as an adjunct of increasing the value of S2 by some specific method.

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