JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1994, **61**, 107-112 NUMBER 1 (JANUARY)

SHORTCOMINGS OF THE BEHAVIORAL COMPETITION THEORY OF CONTRAST: REANALYSIS OF MCLEAN (1992)

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McLean (1992) presented significant data showing that the occurrence of behavioral contrast in a multiple schedule was correlated with shifts in the frequency of reinforcers from a second source between components of the schedule, and interpreted his results as showing that contrast was due to changes in the degree of response competition within the constant component of the multiple schedule. Reanalysis of his data shows that there was an effect of reinforcement in the alternative component of the schedule independent of the shifts in reinforcers between components. Thus, the effect of relative rate of reinforcement cannot be ascribed, at least entirely, to the mechanisms proposed by the behavioral competition theory of contrast.

Key words: behavioral contrast, behavioral competition theory, relative rate of reinforcement, multiple schedules, key peck, pigeon

Behavioral contrast is said to occur when the response rate during one component of a multiple schedule, with a constant rate of reinforcement, is inversely related to the reinforcement rate in the alternative component of the schedule. One hypothesis to explain this effect, first proposed by Hinson and Staddon (1978) and elaborated by Staddon (1982) and McLean and White (1983), is behavioral competition theory. Its major tenet is that behavior during the constant component of the schedule is not affected directly by reinforcement during the alternative component; instead, this behavior is affected indirectly, in that this reinforcement causes reallocation of extraneous reinforcers between components. Accordingly, behavior during a given component of the multiple schedule is to be understood entirely in terms of the matching law, in that the response rate is determined by the proportion of the total number of reinforcers during the target component obtained from the constant schedule, where the total number of reinforcers is the sum of the schedule-produced reinforcers and the reinforcers from alternative, unmeasured behavior. The rate of these reinforcers from the unmeasured behavior is not constant but may be reallocated between the components of the multiple schedule, depending on the relative richness of the schedule values in each component. When a high rate of scheduled reinforcement occurs in the alternative component, behavior maintained by that high schedule value competes strongly with the unmeasured behavior, which results in fewer reinforcers being obtained by the unmeasured behavior. The unmeasured behavior then becomes more likely during the target component of the schedule, thus providing greater response competition. Conversely, when a low rate of reinforcement occurs from the schedule in the alternative component, the unmeasured behavior occurs at a high rate during the alternative component. This in turn causes the unmeasured behavior to decrease during the constant component, producing less competition with the schedule-maintained behavior during this component. Thus, response rate during the constant component is inversely related to the reinforcement rate from the schedule during the alternative component, but only because the alternative rate of reinforcement is directly related to the number of reinforcers received during the target component from the unmeasured behavior.

McLean (1992) has recently provided significant evidence supporting the behavioral competition theory of contrast by simulating, with explicit schedules of reinforcement, the presumed properties of the reinforcers obtained from the normally unmeasured behaviors. During both components of a multiple schedule, defined by keylights on one response key (the "main key"), a collection of different schedules operated for a second, "extra" key, including several different lean variable-inter-

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This research was supported by NSF Grant BNS-9010323. Requests for reprints should be addressed to Ben A. Williams, Department of Psychology, University of California, San Diego, La Jolla, California 92093-0109.

val (VI) schedules, a variable-ratio (VR) schedule, and a signaled VI schedule. McLean found that the obtained number of reinforcers from this collection of schedules did indeed vary between the two components of the multiple schedule, with the number of extra-key reinforcers received in the target component with the constant schedule directly related to the schedule value on the main key in the alternative component. The contrast effect with respect to main-key responding was then interpreted as the result of the increased competition *within* the constant component from the reinforcers from the extra key.

Although the reallocation of extra-key reinforcers obtained by McLean (1992) is entirely consistent with behavioral competition theory, these effects do not provide unambiguous evidence in favor of the theory because the direction of causality is uncertain. As noted by McLean, it remains unclear whether the contrast effects with respect to the constant schedule were due to the reallocation of extra-key reinforcers, or whether the reallocation of extra-key reinforcers was due to the contrast effect. His data show only that there is a reciprocal relation between the schedule value in the alternative component and the number of reinforcers obtained from the extra key during the constant component. The correlation between the two measures allows no determination of whether the contrast effect or the reallocation effect is fundamental. It is also possible that the dynamics of the two effects are at least partially independent.

An alternative method for assessing the adequacy of behavioral competition theory, beyond the demonstration of reallocation of extra-key reinforcers, is to determine whether the rate of reinforcement for main-key responding during the alternative component of the schedule makes a contribution to the contrast effect independent of the rate of reinforcement during the constant component from the extra key. According to behavioral competition theory, no such effect should occur, because the entire effect of alternative-component reinforcement is mediated by changes in the distribution between components of extra-key reinforcers. Thus, any independent effect of the alternative-component reinforcement would be inconsistent with behavioral competition theory.

To test this possibility, the data reported by McLean (1992) were fit by Equation 1, the model of contrast developed by Williams and Wixted (1986). In order to increase the degrees of freedom for purposes of statistical testing (see below), and because past work with the model has shown the free parameter, C, to account for very little of the variance, its value was set to zero. It is included here only because because of the conceptual derivation of the model.

$$B_{mc} = kR_{mc}/[(R_{mc} + aR_{ec} + bR_{mv}) \div (1 + a + b)] + C. \quad (1)$$

The model was derived from the general concept that response rate during the constant component is inversely related to the average rate of reinforcement in the entire schedule situation, where the different sources of reinforcement in the situation contribute differentially to the average according to different weights that are empirically determined. For example, sources of reinforcement concurrently present with the target behavior will presumably have a larger impact than those in the alternative component of the schedule, but each separate source of reinforcement makes its own independent contribution. Thus, the behavior to the main key during the constant component (B_{mc}) is a function of its own reinforcement (R_{mc}) relative to the weighted sum of the different sources of reinforcement in the situation (R_{ec} = the reinforcement from the extra key during the constant component, and R_{mv} = the reinforcement from the main-key schedule during the varied component). A separate term was not included for reinforcement from the extra key during the varied component, because that reinforcement rate was almost perfectly negatively correlated with the reinforcement rate from the extra key during the constant component, and thus for entirely statistical reasons could not account for any independent variance. Note that this model, unlike that of Herrnstein (1970), is not derived from the matching law, and is not subject to the criticisms of internal inconsistency elaborated by McLean and White (1983). Instead, the model is based on the assumption that alternative reinforcers produce an inhibitory effect on behavior generally, in a manner similar to that proposed by Catania (1973).

The critical test of behavioral competition is whether the weight given to reinforcers from the main key during the alternative component is significantly greater than zero. Behavioral competition theory states that any effect of the alternative-component reinforcement is entirely mediated by the reinforcers for the extra key during the constant component, so a separate term for reinforcers in the alternative component should be superfluous. Thus, Equation 1 should provide no better description than Equation 2, in which the term for main-key reinforcement during the alternative component is omitted:

$$B_{mc} = kR_{mc}/(R_{mc} + aR_{ec})/(1 + a). \qquad (2)$$

Table 1

Parameter values and variance accounted for (VAF) for the best fits to Equations 1 and 2. Standard errors of the parameter values are in parentheses.

Parameter	Pigeon			
	S-5	S-6	S-7	S-8
Equation 1				
k	49.8 (1.9)	60.2 (1.8)	72.1 (3.1)	68.3 (0.9)
a	0.70 (0.40)	0.31 (0.11)	0.31 (0.23)	0.18 (0.03)
b	0.29 (0.07)	0.08 (0.05)	0.17 (0.07)	0.11 (0.02)
VAF	93.0	79.9	65.5	95.7
Equation 2				
k	56.2 (2.0)	60.9 (1.7)	73.1 (3.4)	70.1 (1.8)
a	4.22 (4.08)	0.42 (0.13)	0.73 (0.43)	0.30 (0.08)
VAF	80.5	73.6	44.0	71.8

Table 1 provides the best least squares fits of the two equations for the data from all seven conditions of McLean's (1992) study for each of his 4 subjects. The critical observation is the value of *b*, which is greater than zero for all 4 subjects, and significantly so for 3 of the 4 subjects (all except S-6). Also evident from Table 1 is that the variance accounted for by Equation 1 is substantially greater than the variance accounted for by Equation 2 for all subjects, and substantially so for 3 of the 4 subjects (with S-6 again the exception). Given that Equation 1 contains one more free parameter than Equation 2, an *F* test was conducted on the pooled fits of the 4 subjects to determine if the additional variance accounted for by the extra parameter was significantly greater than would be expected by chance. The result was that the *F* value was statistically significant, $F(4, 16) = 3.26$, $p < .05$. Thus, the addition of the *b* parameter does significantly improve the fit of the data, which implies that the effect of the alternative-component reinforcement from the main key is not entirely mediated by the reinforcement from the extra key during the constant component.

It should be noted that Equation 2 is not the same quantitative formulation as that proposed by McLean and White (1983) as their basic equation underlying multiple-schedule behavior. Thus the difference between Equations 1 and 2 may not be regarded as a fair test of the behavioral competition theory. Based on their assumption that only interactions within a schedule component are responsible for different levels of behavior, they proposed Equation 3. Equation 3 is a variation of the familiar hyperbolic equation for simple response strength proposed by Herrnstein (1970), in which the term R_o represents the concurrently present reinforcers other than those contingent on the target behavior. The only variation is that two additional free parameters are added, the exponent *a* that allows the reinforcers to vary in effectiveness and the constant *b* that allows the effects of the reinforcement for other behavior to be differentially weighted relative to those contingent on the target behavior:

$$B_1 = kR_1^a/(R_1^a + bR_o^a). \qquad (3)$$

The relation of Equation 3 to Equation 2 is straightforward. With the exception of the exponents for the reinforcer terms (which are irrelevant to the present discussion because any such modification could be included in Equation 1 as well), the two expressions are equivalent, given that the only relevant source of other reinforcement is assumed to be that from the extra key during the constant component of McLean's (1992) experiment. The term $1 + a$ in the denominator of Equation 2 can be algebraically transferred to the numerator, thus producing a different value of *k*. The only substantive issue is whether the value of R_o in Equation 3 should be identified with the obtained rate of reinforcement from the extra key. One might assume that additional sources of reinforcement exist independent of the scheduled reinforcers on the extra key, in which case R_o should include two separate terms. It is critical to note, however, that the rationale of McLean's experiment depends on the reinforcers from the extra key being functionally similar to the unmeasured reinforcers. Thus, unmeasured reinforcers presumably also shift between components as a function of the change in schedule on the main key, in a manner similar to the reinforcers obtained from the extra key. This means that the measured reinforcers from the extra key should represent some constant fraction (p) of the total reinforcers separate from those produced via the main key, so that any additional reinforcement effects from the unmeasured reinforcers should be captured entirely by a different weight of the parameter b. That is, if the true value of R_o is R_{ec} plus the unmeasured reinforcers (R_u), and R_u is some fraction of R_{ec}, the following must hold:

$$R_O = R_{ec} + R_u,$$

$$R_u = \mathrm{p}R_{ec},$$

$$R_O = (1 + \mathrm{p})R_{ec} = bR_{ec}.$$

Thus, despite their apparent differences, Equations 2 and 3 are formally equivalent, and the difference in the fits of Equations 1 and 2 provides a direct test of the validity of the basic assumptions of the behavioral competition model.

Other Arguments Against Behavioral Competition

The preceding analysis shows that contrast effects cannot be explained entirely in terms of the idea of reallocation of extraneous reinforcers between the constant and varied components of the schedule. This does not imply that there is no effect of the reallocation of reinforcers from the extra key, in that contrast effects may result from several different mechanisms. However, other considerations suggest that the general notion of behavior competition is a poor candidate for an explanation of any significant amount of the contrast effect. As noted by McLean (1992), the fact that contrast in three-component schedules occurs primarily in the constant component preceding the varied component (Williams, 1981; Williams & Wixted, 1986) cannot be explained easily by behavioral competition theory, at least some versions of which (Staddon, 1982) predict the opposite pattern of effects. It is also the case that behavioral competition theory states that the size of the contrast effect is constrained by the rate of reinforcement obtained from extraneous reinforcers. Given that the rate of such reinforcers with pigeons as subjects is typically very low (e.g, 3 to 10 reinforcers per hour; see Herrnstein, 1970) whereas the reinforcer rates from the response-contingent schedule are much higher, this means that the maximum size of the contrast effect should be very small. For example, with a VI-1 min schedule in the constant component of a multiple schedule, approximately 60 reinforcers per hour will be delivered from that schedule. Assuming that the rate of extraneous rate of reinforcement is 10 reinforcers per hour, this means, according to the matching law, that the actual rate of responding controlled by the schedule will be 6/7 of the maximum rate. Then, if all of the extraneous reinforcers are reallocated to the varied component of the schedule when its schedule is changed to extinction, then the maximum response rate in the constant component would be 7/7, or an increase of 16%. Because contrast effects are often much larger than this value (in the range of 30% to 100% increases in response rate), the reallocation of extraneous reinforcers between components cannot explain the rate increase.

The most important criticism of behavioral competition theory comes from the observation that the size of the contrast effect does not depend upon the behavior actually maintained by the reinforcement schedule in the varied schedule, but rather upon the rate of reinforcement per se. The rationale behind the reallocation of reinforcers between components is behavioral competition. Thus, during the baseline conditions in which the varied component of the multiple schedule has a high rate of scheduled reinforcement, the behavior controlled by this scheduled reinforcement provides strong competition with the unmeasured behavior that produces the extraneous reinforcers, causing it to occur at a low rate. Then, when the schedule during the varied component is changed to extinction, responding controlled by the schedule is eliminated, so that the unmeasured behavior that produces extraneous reinforcers is free to increase to a high rate, which then causes it to shift from the constant component to the varied component, thus producing the contrast effect in the constant component. The problem with this account is that shifts in reinforcement rate during the varied component need not be correlated with any change in the level of behavior. This is exemplified best when a multiple VI variable-time (VT) schedule is changed to multiple VI extinction (EXT). Because there is no operant response required in the VT component, there should be little competition with the unmeasured responses that produce the extraneous reinforcers. The extraneous responses that normally occur during the constant VI component of the schedule should move into the VT component during the baseline phase of the experiment, so that during baseline training the operant rate during the VI component of a multiple VI VT should be higher than the corresponding rate in a multiple VI VI. Further, when the VT is changed to EXT, there should be little change in the degree of competition in the varied component, so there should also be little change in the response rate in the constant VI component. Thus, contrast effects with a multiple VI VT should be substantially smaller than with a multiple VI VI, when both are changed to multiple VI EXT. To the contrary, however, interactions with the two schedules appear to be basically similar (e.g., Halliday & Boakes, 1974).

This fundamental criticism of the behavioral competition theory has been addressed by Staddon (1982), who argued that the response contingency may be irrelevant to the amount of operant behavior (or "terminal behavior") that occurs, because some evidence suggests that the rate of such behavior is similar, regardless of the response contingency (Staddon & Simmelhag, 1971; but see Fenner, 1980, for contrary data). He thus assumes that the degree of competition from "terminal" behavior with the behavior producing the unmeasured reinforcement is necessarily correlated with the frequency of scheduled reinforcement, regardless of the constraints imposed by the particular schedule. But this assumption is severely challenged by experiments in which a multiple VI signaled VI schedule is changed to a multiple VI EXT schedule, where again the contrast effects that are observed are independent of the changes in the response rate in the varied component (Williams, 1980). In such schedules, pecking occurs in the signaled VI component only when the signal is present. Given that pecking is assumed to be functionally similar to other, unmeasured, forms of terminal behavior, the dynamics of pecking should serve as an index of all of the terminal behavior that is occurring. That is, all behavior is nonreinforced when the signal is absent, so whatever mechanisms discourage pecking in the absence of the signal also should discourage any other operant (terminal) behavior. Key pecking seems to be the most likely form of terminal behavior in the absence of the signal because it is reinforced in the presence of the signal, and there is no greater disincentive for pecking in the absence of the signal than for any other type of terminal behavior. To argue that behavior other than pecking is maintained in the absence of the signal thus requires the invention of a new category of behavior with its own separate functional properties that are designed solely to salvage the behavioral competition theory.

In conclusion, the evidence for an account of behavioral contrast in terms of behavioral competition is weak. McLean (1992) does provide a demonstration that reinforcers from other sources do move between components of a multiple schedule as predicted by the theory, but his data still reveal an effect of reinforcement in the alternative component of the schedule that is not mediated by this reallocation effect. Most important, the theory fails to deal with critical aspects of the findings of behavioral contrast, the most important being that the controlling variable is changes in relative rate of reinforcement independent of changes in the level of behavior maintained by the reinforcement.

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Received February 4, 1993
Final acceptance July 28, 1993