

MATCHING-BASED HEDONIC SCALING IN THE PIGEON

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Four slightly hungry pigeons chose between pairs of grains in a Findley concurrent choice procedure. For Condition I, choice involved hemp *versus* buckwheat; for Condition II, wheat *versus* buckwheat; and for Condition III, hemp *versus* wheat. In all conditions, frequency of reinforcement was arranged according to concurrent variable-interval variable-interval schedules. On the assumption that subjects matched their behavior and time distributions to those of reinforcer *value*, the choice functions obtained in Conditions I and II were transformed to yield estimates of values of hemp and wheat relative to buckwheat. These, in turn, provided predictions about behavior and time allocation in Condition III. In general, the predicted outcomes were close to those actually obtained. The results evidence the effectiveness of matching-based hedonic scales in the prediction of choice between qualitatively different reinforcers.

Key words: matching law, food preference, reinforcer quality, concurrent variable-interval schedules, pigeons

In his well-known assault on learning theories, Skinner (1950) considered the category of complex theories devoted to phenomena such as discrimination and choice. Regarding the latter, he urged a formulation in terms of differentiable concurrent responses, and illustrated its application in an experiment in which a pigeon's responding to either of two simultaneously available response keys was alternately extinguished and reconditioned. Subsequently, Ferster and Skinner (1957) described the typical performances for a variety of procedures involving choice between a pair of response alternatives, each associated with its own schedule of reinforcement. Such procedures fell under the rubric of concurrent schedules.

One of the concurrent schedule types reported by Ferster and Skinner—the concurrent variable-interval variable-interval (conc VI

VI)—has proven popular in operant studies of choice (see Catania, 1966; de Villiers, *in press*). An especially prominent example of its use is provided in an experiment by Herrnstein (1961). This study was germinal in the development of a general principle of action—the matching law (see Herrnstein, 1970, 1974). The basic finding can be expressed as an equation:

$$\frac{B_1}{B_2} = \frac{R_1}{R_2} \quad (1)$$

where B_1 and B_2 represent alternative behaviors (frequencies of a pigeon's responding to two concurrently available response keys) and R_1 and R_2 the frequencies of reinforcement on VI schedules associated with B_1 and B_2 respectively. (The value of VI schedule represents the arithmetic mean of its several component interreinforcement intervals. Thus, a VI 3-min schedule has an average interreinforcement interval of 3 min.) Equivalence between the ratio of behaviors and that of reinforcement frequencies was designated as "matching". Even though B_1 and B_2 were several-fold larger than R_1 and R_2 in their absolute magnitudes, the equivalence between the ratios was closely preserved over a wide range of conc VI VI pairs. The vitality of this finding is enhanced by the realization that it was quite possible for the ratio of reinforce-

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ment frequencies (as well as the total frequency of reinforcement) to remain unaltered despite substantial alterations in behavior allocation, *i.e.*, in the behavior ratio. Yet, regardless of considerable latitude in the ratio at which they could apportion their responding with no consequent diminishing of reinforcement, the subjects in Herrnstein's study displayed a consistent equalizing, or matching, to the reinforcement ratio.

This preservation of equality between distributions of behavior and reinforcement frequency has been demonstrated more recently in diverse experimental settings. These have involved, for example, (1) a continuous type of behavior—standing in place (Baum and Rachlin, 1969); (2) a topographically disparate response—treadle pressing by pigeons (McSweeney, 1975); (3) a large number of response alternatives (Miller and Loveland, 1974; Pliskoff and Brown, 1976); and (4) a naturally occurring aggregate of pigeons (Baum, 1974a). Matching has also been observed in human subjects (see, *e.g.*, Baum, 1975; Schroeder and Holland, 1969). Despite their diversity, all of these studies shared certain procedural invariants. They all utilized conc VI VI schedules. Each offered reinforcers that differed only in frequency of occurrence. They were identical in composition, quality, duration, amount, *etc.*

An alternate course in the effort to extend the generality of the matching law has centered on deviations from the basic reinforcement scheme: *e.g.*, (1) the use of concurrent interval schedules other than conc VI VI; (2) the use of differential reinforcement duration or amount; and (3) the use of qualitatively different reinforcers. Results in each area are instructive because, in demonstrating the limited applicability of Equation 1, they suggest a larger view of matching.

Studies by Nevin (1971) and Trevett, Davison, and Williams (1972) exposed animals to the choice between VI and fixed-interval (FI) schedules. In both cases, the results were best described by a power function:

$$\frac{B_1}{B_2} = a \left(\frac{R_1}{R_2} \right)^b \quad (2)$$

where a and b are empirically-derived constants. Comparison of Equations 1 and 2 reveals the former as a special case of the latter, where $a = b = 1.0$. In the studies by Nevin and

by Trevett *et al.*, the values of a often deviated from 1.0, while values of b were consistently less than 1.0. Similar findings had led previous authors (*e.g.*, Lander and Irwin, 1968; Staddon, 1968) to suggest that matching (as defined by Equation 1) be considered a special case of a more general power-law relationship between the ratios of behavior and reinforcement in concurrent procedures. In effect, this implies that matching is a relatively rare phenomenon, generable only by a certain narrow class of procedures (*e.g.*, concurrent schedules employing VI components).

A multiplicative power-law relationship has emerged from experiments that examined the effects of joint variation of reinforcement frequency and duration or amount (see, *e.g.*, Fantino, Squires, Delbruck, and Peterson, 1972; Schneider, 1973; Todorov, 1973). This relationship is expressed by the following equation:

$$\frac{B_1}{B_2} = c \frac{R_1^a D_1^b}{R_2^a D_2^b} \quad (3)$$

where a and b are empirically determined exponents for reinforcement frequency and reinforcement duration (or amount) respectively, and c is an empirically determined coefficient. In most cases, the values of a exceeded those of b , *i.e.*, reinforcement rate was a more influential determinant of choice than duration or amount of reinforcement. In addition, values of a were often displaced from 1.0—their theoretical value according to Equation 1.

Baum (1974b) argued for the following view: if matching is taken as a standard, departures from matching have their basis in nuances of experimental method. Once these are detected and controlled, matching will be restored. Baum also mentions an alternative tack: matching obtains wherever choice-making occurs, and any apparent deviations from matching indicate a need for adjustment in the measurement of those variables that identify the reinforcement alternatives. Moreover, such deviations may provide the empirical basis for a rule of remeasurement.

Several authors (Baum, 1973a; Herrnstein, 1971; Killeen, 1972; Rachlin, 1971) have proposed a generalized form of the matching relation in terms of reinforcer *value* (V). This quantity represents a composite evaluation of the several variables that are relevant contribu-

tors to a reinforcer. Killeen's formulation considers each of these contributions as a separate function and the resultant V as their concatenation. Thus, the ratio of values for two reinforcers may be written as follows:

$$\frac{V_1}{V_2} = \frac{f(R_1)}{f(R_2)} \cdot \frac{g(A_1)}{g(A_2)} \cdot \frac{h(I_1)}{h(I_2)} \cdot \frac{j(X_1)}{j(X_2)} \quad (4)$$

where $f(R)$, $g(A)$, $h(I)$, and $j(X)$ represent separate functions for the variables of reinforcement rate (R), amount (A), and immediacy (I), and any other dimension (X). The precise form of each function may be ascertained empirically.

When viewed from the perspective of reinforcer value, matching finds simple expression:

$$\frac{B_1}{B_2} \text{ or } \frac{T_1}{T_2} = \frac{V_1}{V_2} \quad (5)$$

where V_1/V_2 is defined by Equation 4. Time matching, *i.e.*, matching between the ratio of amounts of time spent responding for the pair of reinforcers and the ratio of values, would be indicated by replacing B_1/B_2 with T_1/T_2 .

This approach to matching may be illustrated through reference to an investigation of yet another reinforcement variable—quality. Hollard and Davison (1971) gave pigeons the opportunity to select between rather divergent sources of reinforcement—a grain (wheat) and electrical stimulation of the brain. These were available on conc VI VI schedules. That their results exhibit deviations from matching between response ratios (or time ratios) and ratios of reinforcement rates is not surprising. A stable preference for one of the items would exert a systematic response bias (and/or time bias) toward the favored alternative. In fact, Hollard and Davison observed sizeable preference for wheat in all of their subjects. Using measures of the quality of each item based on deviations from matching, they showed their results to be consistent with Equation 5.

The large number of studies reviewed here points to the conclusion that matching is an intrinsic property of behavior in choice situations. Reports of "mismatching" pale in the light of a redefinition of matching based on the concept of reinforcer value. In each instance, however, the transformations essential to reveal matching have been "postdicted", *i.e.*, their determination has been *ex post facto*.

Much of the efficacy and potency of the principle of matching predicated on the notion of reinforcer value resides in its predictive ability. For example, consider the case of an animal confronting two different food items—A and B—available on conc VI VI schedules. Just as in Hollard and Davison's (1971) study, it should be possible to scale the quality of A with respect to B and then, if necessary, to transform reinforcement frequencies in order to reveal matching as characterized by Equation 5. In a second condition, the same conc VI VI schedules are retained. Now, however, a new food item—C—is introduced in place of A. From the results of these first two conditions, the qualities of A and C may be scaled with respect to B. At this point, it becomes possible to predict the outcome in a third condition where the animal is given direct choice between items A and C. Again, the same conc VI VI schedules are in effect. The actual formula for predicting the resultant behavior (or time) allocation in the third condition follows from an algebraic combination of the matching equations produced by the first two conditions. Thus, since

$$\frac{B_1}{B_2} = \frac{V_1}{V_2}$$

and

$$\frac{B_2}{B_3} = \frac{V_2}{V_3}$$

then

$$\frac{B_1}{B_2} \cdot \frac{B_2}{B_3} = \frac{V_1}{V_2} \cdot \frac{V_2}{V_3} \quad (6a)$$

and, through cancellation,

$$\frac{B_1}{B_3} = \frac{V_1}{V_3} \quad (6b)$$

Time allocation (T_1/T_2) can be predicted in identical fashion.

This matching-based predictive approach, which is analogous to a psychophysical method known as cross-modality matching (see Stevens, 1966; Cross, 1974), was incorporated in the present study. Within a simple concurrent procedure, pigeons were given a choice between two different kinds of grains. Later, one of the grains was replaced by a third kind. Using the transformations generated by these two conditions, it was possible to estimate reinforcer value for the two grains not pre-

viously paired. Predictions based on these estimates were then compared with the data obtained in the final condition, wherein subjects actually confronted choice between the third pair of grains. Close agreement between the actual and predicted outcomes would constitute strong evidence not only for the existence of matching in choice situations where reinforcers are qualitatively different, but would also underscore the reliability of matching-based hedonic scaling.

The present experiment included two procedural features designed to enhance discriminability of the alternative reinforcers—a lengthy changeover delay (COD), and the maintenance of subjects at close to their free-feeding weights. Baum (1974*b*) and de Villiers (*in press*) have discussed studies which suggest that a brief COD may obscure differences in reinforcement frequencies on conc VI VI schedules. Young (1973) reviewed findings which indicate that preferences are more sharply evinced under conditions of mild rather than severe deprivation. Since pigeons' grain preferences can be rather subtle even in the free-feeding state (see Brown, 1969), maintenance at a typical level of deprivation (*e.g.*, 80% of free-feeding weight) might eliminate preferences altogether.

The present study also included control procedures that permitted evaluation of effects due to asymmetries inherent in the apparatus. In this way, the contribution of qualitative differences between grains would be isolated from other factors influencing choice.

METHOD

Subjects

Four adult male White Carneaux pigeons (254, 255, 452, and 43) were maintained at approximately 95% of their free-feeding weights.² All had previous experience with simple concurrent procedures involving choice between different grains.

²A pilot study had exposed the same subjects to choices between different pairs of grains in a similar procedure. The animals were maintained at close to their free-feeding weights by supplementing their session intake with various mixtures of grains. These contained only those grains present in the choice situation, grains never presented in the situation, or a mixture of the two. Results showed no differential effects on preference as a function of supplement composition.

Apparatus

A wooden sound-proofed box, 83 by 57 by 57 cm, enclosed the experimental chamber—a modified aluminum picnic cooler. The chamber was partitioned by an aluminum panel (28 cm wide by 33 cm high), which contained two response keys and a pair of feeder apertures. The space occupied by the subjects measured 33 by 33 by 28 cm. A houselight was mounted overhead in the right rear corner of the enclosure. White noise was used to mask exterior sounds and was delivered through a small speaker located behind the front panel.

The response keys were centered in the panel one over the other. Each was 2 cm in diameter and was operated by a force of at least 0.15 N. The center of the upper (CO) key was 4.5 cm from the top of the panel. Below the CO key and separated from it by 4.5 cm was the response key. Both keys were transilluminated by dc lamps (Chicago Miniature No. 1829). The color of the CO keylight was white; that of the response key either green or red. A relay mounted behind the panel provided response feedback.

Access to two standard grain magazines was provided through a pair of circular apertures (5 cm in diameter) located in the lower half of the front panel. The center of each aperture was 11 cm from the floor of the chamber and 6 cm from the nearest side wall. The left-hand grain magazine was associated with the green keylight; the right-hand magazine with the red.

The experiment utilized electromechanical programming and recording equipment, which was located in an adjacent room.

Procedure

The experiment contained three conditions (I to III). Each was identified by the contents of the two grain magazines. In Condition I, subjects could choose between hemp and buckwheat. (See Levi, 1957, for nutritional profiles of these and other grains used in the experiment.) These were available in the following series of conc VI VI pairs, each pair being a component in each conduction (I to III): VI 1.5 VI 3.0, VI 3.0 VI 1.5, VI 6.0 VI 1.2 VI 2.0 VI 2.0, and VI 1.2 VI 6.0. In Condition II, wheat replaced hemp. In Condition III, animals chose between hemp and wheat. The sequence of conc VI VI schedules was identical in each condition.

The conc VI VI schedules were arranged according to a procedure first introduced by Findley (1958). A response on the CO key had two effects: it changed the color of the response-key light, which was alternated between red and green, and initiated a 6-sec COD. This meant that pecks on the response key would not produce a scheduled reinforcer until at least 6 sec had elapsed since the last changeover. Associated with the colors of the response-key light was a pair of conc VI VI schedules, as well as a type of grain. The schedules were constructed by randomizing a progression of intervals suggested by Fleshler and Hoffman (1962). Twelve intervals comprised each schedule and their arithmetic mean designated the schedule value (VI 1.5, VI 3, etc.). The particular pairs of VI values were chosen to maintain a constant total rate of reinforcement across components.

Animals were studied in daily sessions that terminated after 50 reinforcements had occurred. Reinforcement consisted of a 3-sec presentation of a grain magazine. During that time, key pecks were not recorded, nor did they produce feedback. The houselight and keylights were darkened during reinforcement. Delivery of either grain also interrupted the operation of two timers, which were used to record the total time a subject spent in the presence of the green keylight and the red keylight, respectively.

Within each condition, a conc VI VI schedule remained in effect until the distributions of responses and time between the two keys had stabilized, *i.e.*, until they displayed no directional trends. Typically, this required 20 to 25 sessions.

RESULTS

The results for each of the four subjects are summarized separately in the Appendix. The data averaged across subjects are considered here. The data were drawn from the last five sessions in each component.

In Figure 1, the heavy lines depict functions relating the logarithms of ratios of the geometric means of responses at the two alternatives (B_g/B_r) to the logarithms of the geometric means of reinforcement frequencies for the alternatives (R_g/R_r). The subscripts indicate the color of the response key—green (g) or red (r). The grain associated with a green response

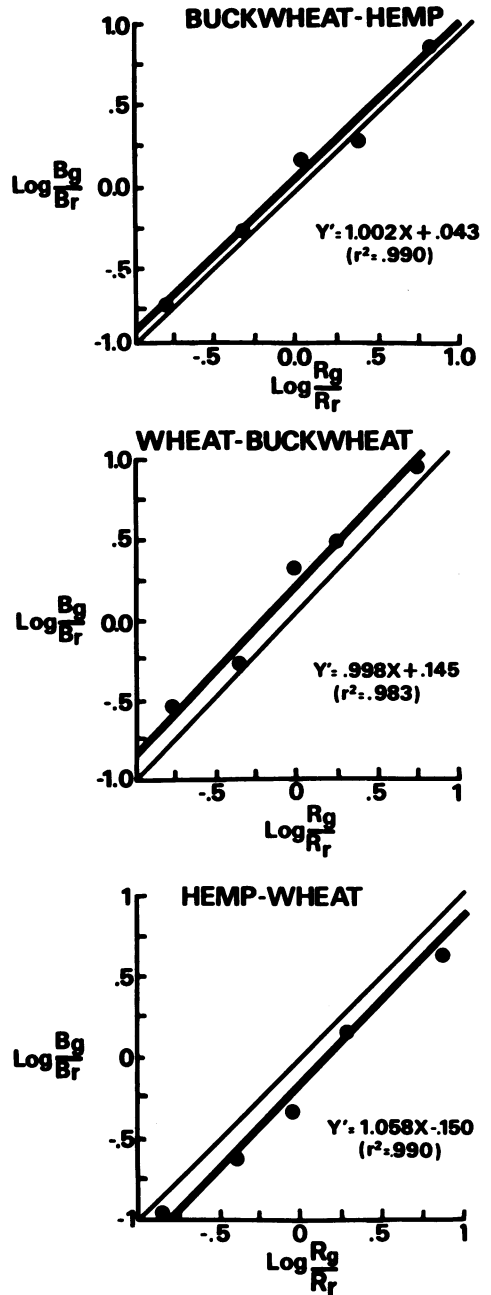


Fig. 1. Data averaged across the four subjects. For the three conditions of the experiment, the ratios of logarithms of responses to the two alternatives—green (g) and red (r)—are shown as functions of the ratios of logarithms of reinforcements received. The points represent geometric means over the last five sessions of each component. The heavy lines were drawn through the points by the method of least squares. The corresponding regression equations and the coefficients of determination (r^2) are shown in the lower right-hand portion of each graph. The diagonal represents matching.

key appears as the left member of the pair above each graph. The heavy lines were fitted to the data by the method of least squares. The equations for the linear regressions and the coefficients of determination (r^2) are also shown. The light diagonal line represents matching between responding and reinforcement frequencies.

Figure 2 shows similar functions relating the logarithms of ratios of the geometric means of times spent in the presence of the two alternatives (T_g/T_r) to the logarithms of the geometric means of corresponding reinforcement frequencies.

In Figures 1 and 2, preference for one of the available alternatives is indicated by the value of the y-intercept of the regression line. Whenever the intercept is positive, it indicates a preference for the alternative in the numerator of the behavior or time ratio. A negative intercept signals preference for the alternative in the denominator. A value of zero signifies indifference between the two items. Thus, in Figures 1 and 2, near-indifference between buckwheat and hemp is indicated in the top-most graph; the middle graphs depict a preference for wheat over buckwheat. In each figure, the bottom graphs show that wheat was preferred to hemp.

These findings conform with the principle of weak stochastic transitivity (see Coombs, Dawes, and Tversky, 1970):

$$P(x,y) > 0.5 \text{ and } P(y,z) > 0.5 \\ \text{imply } P(x,z) > 0.5 \quad (7)$$

where $P(x,y)$, $P(y,z)$, and $P(x,z)$ are the probabilities of preferring item x to item y , item y to item z , and item x to item z , respectively. If $P(x,y) > 0.5$, then a preference for item x over item y is indicated. In the present case, this is equivalent to the statement that the quality ratio for x and y (Q_x/Q_y) is greater than 1.0. If, as in Figures 1 and 2, $P(\text{wheat, buckwheat}) > 0.5$ and $P(\text{buckwheat, hemp}) > 0.5$, then it follows that $P(\text{wheat, hemp}) > 0.5$. The graphs for Condition III verify such an outcome for the averaged data. In only one case (Bird 254), was there a violation of weak stochastic transitivity.

Predictions of the outcomes in Condition III were made on the basis of the regression equations obtained in Conditions I and II. (Recall the procedure suggested by Equations 6a, b.)

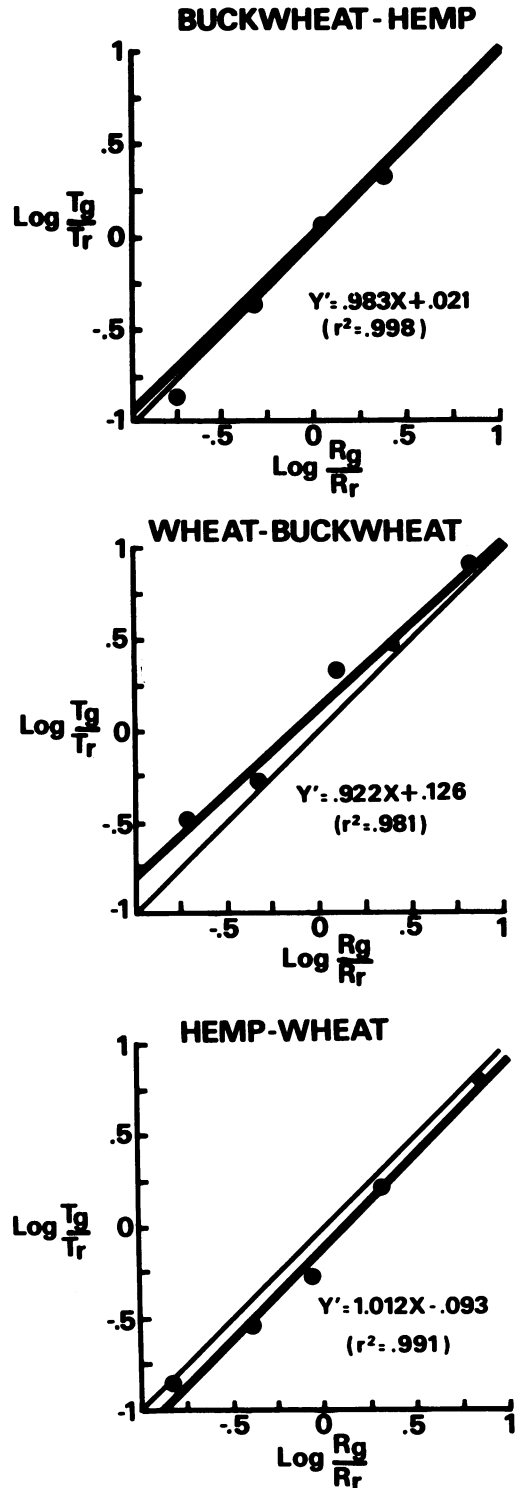


Fig. 2. Time allocation versus reinforcement ratios for the averaged data. See Figure 1 for further description.

First, the value ratios for those conditions were obtained using the following formula:

$$\frac{V_g}{V_r} = \frac{Q_g}{Q_r} \left(\frac{R_g}{R_r} \right)^a \tag{8}$$

where Q_g and Q_r are derived measures of the qualities of items g and r and R_g and R_r are the frequencies of those items. (As previously noted, the ratio of qualities was made equal to the antilogarithm of the y -intercept.) The value of the exponent a was determined by the slope of the regression line. Table 1 shows the quality ratios and values of a for each subject, as well as for the averaged data, in each experimental condition.

After estimates of the values of hemp (V_h) and wheat (V_w) had been obtained relative to buckwheat, they were inserted into Equation 6b to produce estimates of B_h/B_w . Estimates of T_h/T_w were produced in an identical manner.

Figure 3 provides a graphic view of the propinquity between the predicted logarithms

of the behavior ratios and those actually obtained. The accuracy of predictions for logarithms of time ratios is also displayed. The diagonal lines represent the locus of perfect agreements between actual and predicted outcomes. Congruence between the two may be further represented by a statistic—the mean absolute deviation from the diagonal. Table 2 offers a summary of that statistic for each subject as well as for the averaged data.

The left-hand columns in Table 2 indicate that behavior ratios were predicted with roughly the same accuracy as time allocation ratios. For two birds (254 and 43), behavior ratios were more accurate; for the other two (255 and 452), predictions of time allocation were superior. If one considers just the averaged data, however, the picture is impressive (see Figure 3). Here, there is near-perfect prediction for ratios of both behavior and time.

Estimates of the qualities of hemp and wheat relative to buckwheat were obtained in Conditions I and II (see Figures 1 and 2 and Table 1).

Table 1

Values of $\frac{Q_g}{Q_r}$ and a for Original Functions and Functions with $a = 1.0$

Subject	Condition					
	I		II		III	
	$\frac{Q_h}{Q_b}$	a	$\frac{Q_w}{Q_b}$	a	$\frac{Q_h}{Q_w}$	a
	Behavior Data					
254	0.867	0.619	1.521	0.700	1.218	0.871
	0.891	1.000	1.445	1.000	1.188	1.000
255	0.463	0.946	1.259	1.113	0.473	1.139
	0.457	1.000	1.259	1.000	0.457	1.000
452	2.013	1.062	1.531	1.091	0.725	1.163
	2.042	1.000	1.549	1.000	0.741	1.000
43	0.806	1.312	1.321	1.102	0.630	1.032
	0.819	1.000	1.349	1.000	0.617	1.000
Average	0.906	1.002	1.396	0.998	0.708	1.058
	0.905	1.000	1.398	1.000	0.699	1.000
	Time Data					
254	0.807	0.680	1.500	0.878	0.977	0.932
	0.813	1.000	1.445	1.000	0.989	1.000
255	0.676	0.906	1.132	0.939	0.632	1.017
	0.692	1.000	1.122	1.000	0.631	1.000
452	1.542	1.039	1.600	1.026	1.021	1.177
	1.549	1.000	1.622	1.000	1.023	1.000
43	0.841	1.256	1.172	0.870	0.667	0.926
	0.871	1.000	1.148	1.000	0.676	1.000
Average	0.953	0.983	1.337	0.922	0.807	1.012
	0.955	1.000	1.348	1.000	0.805	1.000

Table 2

Mean absolute deviations between predicted and obtained logarithms of behavior and time ratios.

Subject	Predictions Based on Behavior Ratios	
	Using Original Values of <i>a</i>	
	Using <i>a</i> = 1.0	
254	0.429	0.295
255	0.341	0.146
452	0.227	0.250
43	0.330	0.106
Average	0.076	0.073
	Predictions Based on Time Ratios	
254	0.642	0.241
255	0.089	0.088
452	0.078	0.087
43	0.626	0.117
Average	0.060	0.058

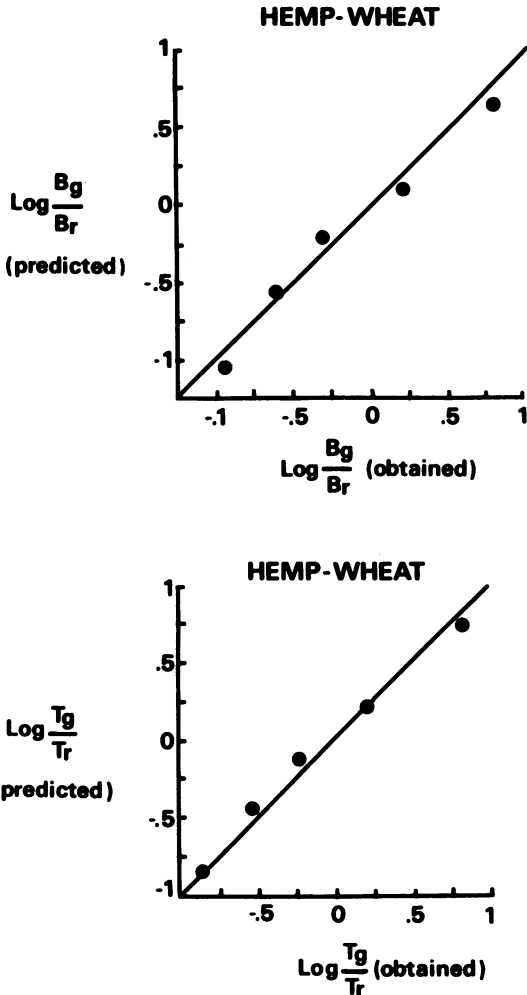


Fig. 3. For the averaged data, the upper graph indicates the closeness of fit between predicted logarithms of the behavior ratios (hemp versus wheat) for Condition III and those actually obtained. The diagonal represents matching. The lower graph gives similar results for the logarithms of time ratios.

Using these estimates, a scale of grain quality may be constructed. With the quality of buckwheat arbitrarily set at 10 units (the name for the quality unit is left undesignated), the measures of quality for hemp and buckwheat are simply determined by the ratios Q_h/Q_b and Q_w/Q_b . Figure 4 shows a pair of scales constructed in this manner—one based on the averaged behavior measures and the other on averaged measures of time allocation. Obviously, either hemp or wheat could serve in place of buckwheat as the standard for the scale. Despite a different standard, the relative

positions of the items would remain unchanged.

Estimates of V_h and V_w were obtained using empirically derived values of *a*—the exponent for reinforcement frequency. Suppose, however, that *a* were held constant at a value of 1.0—its theoretical value (see Equation 1)—and a new best-fitting intercept were found. Would the estimates of V_h and V_w based on the altered functions be better or poorer as predictors? Table 2 shows the quality ratios (Q_g/Q_r) when the value of *a* was constrained at 1.0 within each condition. The results shown in the right-hand column of Table 2 offer a clear demonstration that prediction is often substantially enhanced by the assumption that *a* = 1.0. This is most clearly shown in the predictions for Bird 43. Part of the reason for the predictive imprecision of the bird's original functions may lie in the sizeable differences between the slopes of those functions (see Table 1). Such differences can grossly over-inflate the predicted value ratios, particularly if one of the slopes is greater than 1.0 and the other substantially smaller than 1.0. The differences between the slopes of the functions for Bird 43 in Conditions I and II were larger than those for any other subject.

Figure 5 shows the averaged changeover frequencies for Conditions I to III as a function of the logarithms of behavior ratios or time ratios in each condition. The frequencies are the arithmetic means determined over the last five sessions of a component. The figure is consistent in displaying an inverted U-shape in

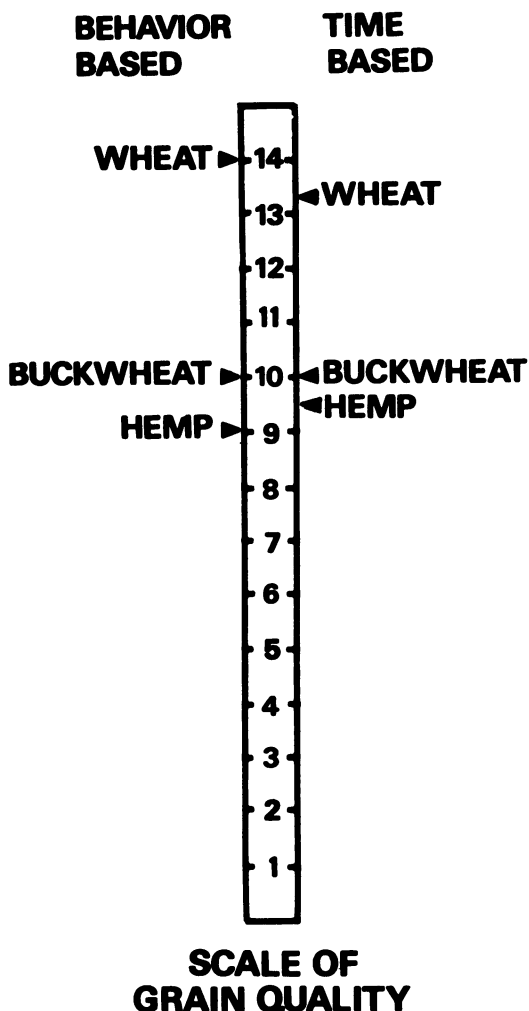


Fig. 4. Two empirically derived scales of grain quality. The quality of buckwheat served as the standard for each scale and was assigned an arbitrary value of 10 units. The scale on the left was derived from the averaged data for behavior allocation; that on the right is based on averaged time allocation data. See text for details of the derivation procedure.

these changeover functions. There is also a tendency for the functions to be centered over the zero point on the abscissa.

A few additional findings are mentioned in conclusion. Examination of the data for each subject in the last five sessions of each component indicated that, with few exceptions, all subjects maintained a fairly high, constant overall rate of responding across and within conditions. This suggests that the overall rate of reinforcement varied only slightly within the experiment. Moreover, at no time did the

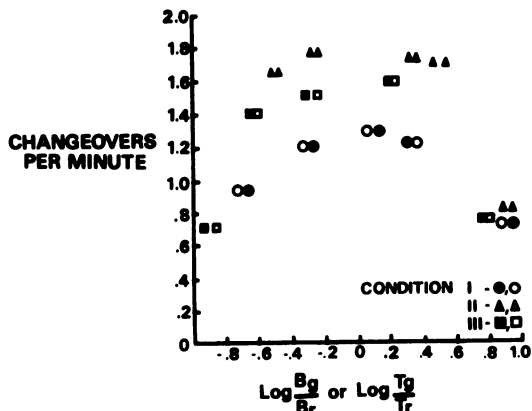


Fig. 5. Rate of changeover appears as a function of logarithms of behavior ratios (filled figures) or logarithms of time ratios (open figures) for Conditions I to III. The points represent across-subject arithmetic means obtained from the last five sessions of each component.

cumulative records for the animals suggest satiation within sessions.

Generally, the subjects required little supplementary feeding after sessions, *i.e.*, food obtained within a session was usually sufficient to maintain the animals at their 95% free-feeding weights. After Condition III ended, the subjects' free-feeding weights were calculated. In no case were there appreciable departures from the free-feeding weights determined before the experiment.

DISCUSSION

In general, prediction was improved when the slopes of the original choice functions were constrained to a value of 1.0 (see Table 2). This finding suggests that departures from slopes of 1.0 were not particularly significant, and may simply reflect measurement error. Taken as a whole, the present results provide support for the efficacy of matching-based hedonic scales in the prediction of choice between qualitatively different reinforcers.

The magnitudes of the preferences observed in the present study (see quality ratios in Table 1) were not as large as those observed by Hollard and Davison (1971). This may be at least partially attributable to the fact that the reinforcers used by Hollard and Davison (wheat *versus* electrical brain stimulation) differed more in quality than did the items used in the present study. It should be noted that

Hollard and Davison's experiment contained no procedure for evaluating the extent of position bias. Thus, it is unclear whether the preferences they observed could be solely attributed to qualitative differences between the reinforcers. The comparison of estimates of reinforcer quality between the two studies is further complicated by differences in procedure. Although both experiments employed conc VI VI schedules, only the present study allowed the VI schedules to operate independently. Hollard and Davison's use of a "forced-choice" technique (see Fantino *et al.*, 1972) may have resulted in reduced estimates of preference. Finally, it should be noted that the slopes of the choice functions in both studies were quite similar. It is also important to note that the similarity between the response-derived and time-derived choice functions in the present study provides counter evidence for Todorov's (1973) suggestion that response and time allocations are affected differently by the distribution of reinforcements.

Predictions of response and time allocation in Condition III of the present experiment were based on estimates of value (see Equations 6a, b) that were empirically derived. That is, in order to predict performance when choice involved hemp and wheat, it was first necessary to estimate the qualities of hemp and wheat *vis-a-vis* a third item (buckwheat) and to determine appropriate transformations on the frequencies of hemp and wheat when they were paired with that item. It should be obvious, though, that the direction of prediction, *i.e.*, from Conditions I and II to Condition III, was arbitrary. Predictions could just as well have been made in other directions: from Conditions I and III to Condition II, or from II and III to I. In each case, the accuracy of predictions would have been similar to that for the original.

The results depicted in Figure 5 are comparable to those from previous studies of time allocation (Baum, 1973*b*, 1975). They suggest that animals' rates of switching between alternatives tend to be highest when responses or time are distributed evenly between the alternatives. Changeover rates show monotonic declines from the maximum as choice favors one or the other of the alternatives.

In sum, the present study provides further evidence that the operant procedure offering simple concurrent alternatives can be a power-

ful tool in elucidating the factors that influence choice. Moreover, the procedure provides measures that may be used to predict choice.

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APPENDIX

Summary of Results for Individual Subjects
 (Entries are sums over the last five sessions of each component)

<i>Component</i>	<i>Responses to Green</i>	<i>Responses to Red</i>	<i>Time at Green (min)</i>	<i>Time at Red (min)</i>	<i>Reinf. Green</i>	<i>Reinf. Red</i>	<i>Change- overs</i>
<i>Bird No. 254</i>							
CONDITION I							
A	6940	3538	213.03	77.69	176	74	400
B	4366	6731	121.92	185.57	79	171	557
C	3470	8305	78.62	199.49	40	210	526
D	6238	4748	171.82	113.48	132	181	483
E	7569	2306	219.93	66.52	212	38	253
CONDITION II							
A	12051	4226	196.64	66.13	173	77	669
B	6108	8396	104.93	155.77	87	163	686
C	5496	9094	85.87	182.39	47	203	869
D	10119	5207	196.46	93.10	131	119	935
E	13640	2560	241.31	31.71	217	33	363
CONDITION III							
A	9009	3942	183.74	95.37	167	83	569
B	4690	7921	86.84	176.75	83	167	650
C	2716	9221	45.43	228.20	36	214	301
D	6007	5642	133.29	149.66	125	125	632
E	10083	1603	242.81	44.99	214	36	257
<i>Bird No. 255</i>							
CONDITION I							
A	8650	1935	250.57	86.04	182	68	181
B	7832	7075	144.05	195.77	88	162	369
C	2882	6081	82.85	237.15	41	209	238
D	16864	4509	211.42	88.98	136	114	358
E	17758	1014	262.07	24.15	224	26	120
CONDITION II							
A	12834	4926	182.86	98.97	172	78	572
B	4415	11069	83.91	192.70	76	174	460
C	3355	16812	51.56	224.96	35	215	399
D	4175	2700	214.15	145.56	132	118	302
E	13158	1250	254.84	36.75	214	36	217
CONDITION III							
A	5592	6438	141.02	148.29	157	93	402
B	1826	15191	44.61	249.00	61	189	220
C	1213	21699	25.44	270.67	26	224	142
D	3793	18204	75.29	212.34	106	144	358
E	12974	2496	238.12	43.45	217	33	193

APPENDIX *continued*

<i>Component</i>	<i>Responses to Green</i>	<i>Responses to Red</i>	<i>Time at Green (min)</i>	<i>Time at Red (min)</i>	<i>Reinf. Green</i>	<i>Reinf. Red</i>	<i>Change-overs</i>
<i>Bird No. 452</i>							
CONDITION I							
A	8024	9372	153.68	137.51	165	85	465
B	3807	17754	67.39	254.41	68	182	194
C	882	14527	22.20	255.67	32	218	165
D	4615	12318	96.43	294.23	112	138	380
E	10147	2961	224.96	52.09	212	38	336
CONDITION II							
A	12684	2106	255.06	48.29	190	60	265
B	6135	7627	134.39	151.89	87	163	478
C	2154	13605	45.92	239.79	31	219	208
D	9986	3774	220.96	79.87	143	107	492
E	11182	1092	261.36	25.14	220	30	165
CONDITION III							
A	9699	3047	215.69	64.13	179	71	433
B	3550	11987	80.96	195.38	76	174	416
C	1184	14455	31.46	255.04	36	214	161
D	4798	7781	131.69	154.21	121	129	363
E	10015	1674	254.32	23.98	221	29	205
<i>Bird No. 43</i>							
CONDITION I							
A	12015	5591	193.85	88.46	167	83	416
B	4795	11884	75.09	209.95	73	177	388
C	1118	13450	25.31	258.44	32	218	156
D	13029	6881	175.14	133.05	129	121	428
E	18562	1013	267.36	17.30	219	31	139
CONDITION II							
A	10940	3386	196.93	78.36	174	76	401
B	4081	13359	60.81	218.65	72	178	313
C	4513	14613	86.76	196.39	46	204	408
D	15066	4804	208.27	83.44	147	103	373
E	12401	1372	243.69	44.33	218	32	184
CONDITION III							
A	7457	7238	159.93	142.23	162	88	439
B	3056	17034	47.91	234.07	68	182	227
C	1853	16380	38.74	246.68	31	219	210
D	3970	10782	83.30	198.46	111	139	377
E	7214	1092	251.74	45.97	221	29	215