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14. X-ray diffraction shows mainly quartz and plagioclase with small amounts of calcite, pyrite, and coffinite in the high-grade samples.
15. The age of the ore is not known with certainty; however, preliminary $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ measurements give discordant apparent ages of 81×10^6 to 150×10^6 years (K. R. Ludwig, personal communication).
16. We calculated the dose by summing the decay energies of the ^{238}U series and multiplying this by the number of decays since 160×10^6 years ago, based on the present uranium content.
17. The rad is a unit of radiation dose and corresponds to the absorption of 100 erg/g (equivalent to 6.24×10^{13} eV/g).
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26. Measurements of several other ore samples, not related as suites, also show this effect (J. S. Leventhal and I. Friedman, unpublished data).
27. The data can also be fitted to a power function $\delta^{13}C = 32.98\ U^{-0.06}$ with $r = .93$. Neither of these equations has a physical significance.

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Behavioral Competition: A Mechanism for Schedule Interactions

Abstract. *Rats pressing a lever for food reinforcement showed large positive-contrast effects when provided with the opportunity for a competing wheel-running response. Positive and negative behavioral contrast may reflect reallocation of competing interim and terminal responses between schedule components following changes in the reinforcement conditions in one component.*

The level of operant behavior that a given rate of reinforcement will maintain in a given situation is usually affected by the amount of reinforcement obtained in other situations. A much-studied example of this dependence is behavioral contrast (*1, 2*). The standard demonstration of contrast involves food-reinforced key-pecking by pigeons at two distinct visual stimuli presented in alternation (multiple schedule). If reinforcement for pecking at one stimulus (the changed component) is discontinued, responding to the other (the unchanged component) usually increases (positive behavioral contrast). Conversely, if pecking at one stimulus is reinforced more frequently, rate of responding to the other (unchanged) stimulus decreases (negative behavioral contrast).

The necessary and sufficient conditions for contrast have not yet been fully defined. The best generalization is that contrast results from changes in relative reinforcement rate (*2*). In recent years, several interpretations of contrast have been offered that depend upon the phenomenon of autoshaping: the elicitation, presumably by mechanisms related to Pavlovian conditioning, of food-related behaviors (specifically key-pecking by pigeons) in the presence of, and often directed at, stimuli that predict food (*2–4*). For example, Staddon (*3*) proposed that key-peck contrast results because pecking is an induced terminal response that typically occurs in the presence of stimuli that predict food. The stimulus in the unchanged component of a multiple variable-interval schedule is made more predictive when food delivery in the changed component is abolished. Hence pecking is likely to be facilitated (positive contrast). Conversely, if an instrumental response incompatible with pecking (such as treadle-pressing) is chosen, the facilitation of pecking by the contrast manipulation may interfere with the instrumental response, yielding a decrease in response rate (negative induction). These and other predictions of what has come to be termed "additivity theory" have been generally confirmed, and the adequacy of the contrast manipulation to produce autoshaping has been independently demonstrated (*2, 5*).

Despite these successes, additivity theory has its limitations. For example, it offers no straightforward account of negative contrast. Moreover, recent demonstrations have shown that it is possible to obtain positive contrast with responses such as treadle-pressing by pigeons and bar-pressing by rats that are not in any sense induced by food-related stimuli (*6, 7*).

There is a commonsensical mechanism that may contribute to contrast effects, which seems to have escaped attention despite its simplicity. It relates to constraints imposed by limitations of time on the animal's ability to engage in different activities. In any periodic-food situation it is possible to identifiy two mutually exclusive classes of activity, one class related to food reinforcement (terminal responses) and a complementary class (interim responses) (*8, 9*). There is evidence that interim and terminal responses compete for the available time; the most obvious is the observation that an enforced decrease in one class of activities usually leads to an increase in the level of the other.

Behavioral competition sets the stage for behavioral contrast in the standard two-component procedure. In the first (prediscrimination) condition, with equal reinforcement in both components, interim activities compete with terminal responses in both components, leading to an intermediate level of terminal responding in both. In the second (discrimination) condition, however, there will be no terminal responding in the changed component, as a result of the absence of reinforcement; hence interim responding is free to increase. With this reallocation of interim activity into the changed component, the level of interim activity in the unchanged component is likely to decrease, reducing its inhibitory effect on the measured (terminal) response. This results in disinhibition of terminal responses in the unchanged component, thus producing positive behavioral contrast. A similar, symmetrical account can be offered for negative contrast: an increase in reinforcement rate in the changed component increases instrumental responding in that component, thus displacing interim activities into the unchanged component and depressing instrumental responding there (*10, 11*).

We now describe a simple test of this theory using the standard contrast paradigm and an instrumental response, barpressing by rats, that has shown equivocal contrast in previous reports (*2, 5–7*). The key difference between this experiment and others is the explicit manipulation of opportunities for an interim activity (wheel-running) that is incompatible with reinforcement-related (terminal) activity.

Subjects were four male albino rats, approximately 120 days old, maintained on freely available food and 23.5 hours of

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water deprivation. Reinforcement was access for 3 seconds to a 1-ml mixture of equal parts of evaporated milk and water. Experimental sessions were conducted in a standard Skinner box measuring 29 by 24 by 17 (high) cm. At one end was a running wheel approximately 20 cm in radius, at the other a response bar, dipper feeder, and two 6-W stimulus lights. Each 40-minute session consisted of two alternating, 1-minute components, signaled by one or the other stimulus light.

After preliminary bar-press shaping, with access to the wheel blocked, the following experimental conditions were imposed. In condition 1 (prediscrimination), rats 1 and 2, with access to the wheel, and rats 3 and 4, with no access to the wheel, were exposed to a multiple variable-interval 60 seconds, variable-interval 60 seconds (mult VI 60 VI 60) schedule of bar-pressing for milk reinforcement. In condition 2 (discrimination), the schedule was changed to a multiple variable-interval 60 seconds, extinction (mult VI 60 Ext) schedule. Condition 3 was a return to the mult VI 60 VI 60 of condition 1. After responding stabilized in condition 3, conditions 1 and 2 were repeated, with animals interchanged. Thus each rat was exposed to all four conditions (wheel present or absent and mult VI VI or mult VI Ext).

The pattern of results was the same for all animals (Fig. 1). Comparison of bar-pressing in mult VI Ext with and without the wheel available reveals striking differences. With no wheel, there was only modest positive contrast: an average increase in bar-pressing of approximately 19 percent in the unchanged component. Bar-pressing persisted at a moderate level in the changed component. With the wheel available, however, all animals showed robust positive contrast: an average increase of approximately 145 percent. Bar-pressing in the changed component decreased to a low level. Concomitantly, wheel-running in the unchanged component decreased dramatically as it increased in the changed component.

The rate of bar-pressing was lower when the running wheel was available than when it was not (Table 1). The extent of contrast was directly related to the degree of suppression of bar-pressing by the introduction of the wheel: those animals showing greatest suppression (compare columns 2 and 3) also showing the largest contrast effects (compare columns 2 and 4).

These results support the response-competition hypothesis. The lower bar-press rate in the prediscrimination (mult VI VI) condition with the wheel available indicates competition between wheel-running and bar-pressing. The increase in wheel-running in the changed component in the discrimination condition, and the concomitant decrease in wheel-running in the unchanged component, indicate that the animals reallocated the measured interim activity in the predicted way. The large positive contrast effect in the wheel-available condition was due to a lower rate in the unchanged component in the prediscrimination phase rather than to a higher rate in the discrimination phase; this result is consistent with a disinhibition interpretation, as is the covariation between contrast and suppression effects (Table 1).

Table 1. Prediscrimination (mult VI-VI) bar presses per minute in the unchanged component with and without the running wheel available (left columns); and rate of bar-pressing during discrimination (mult VI Ext) with and without the wheel (right columns). Data are averages of 5 days of stable performance for each individual animal.

Rat	Prediscrimination		Discrimination	
	Wheel	No wheel	Wheel	No wheel
1	5	23	19	30
2	11	20	25	24
3	12	21	28	25
4	25	32	35	34

The competition hypothesis accounts for reported difficulties in obtaining large contrast effects with rats and a lever-press response. In periodic food situations, pigeons show vigorous interim activities such as pacing, head-turning, and wing-flapping that compete with the instrumental (terminal) response of pecking (*11*). However, in similar situations, in the absence of appropriate supporting stimuli such as a running wheel, a water bottle, or objects to chew or sand to dig in, rats show much less interim activity (*12*). Past contrast experiments with rats have not provided such stimuli, so that only small contrast effects (comparable to those in our no-wheel condition) are to be expected.

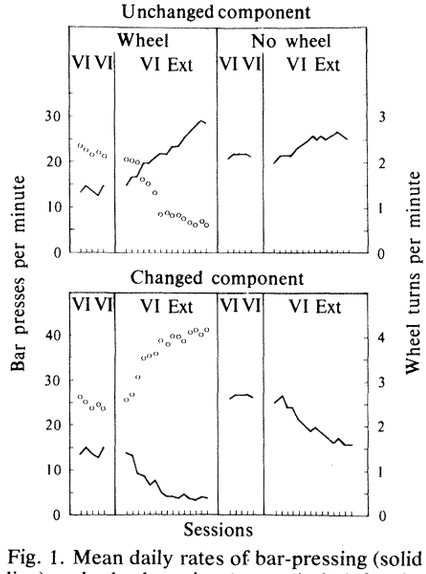

Fig. 1. Mean daily rates of bar-pressing (solid line) and wheel-turning (open circles) for the four animals in the changed and unchanged components in each of the four conditions.

Contrast effects with food-reinforced instrumental responses that are not biologically related to food (such as treadle-pushing by pigeons) may also be smaller because such responses tend to occur at a relatively low rate and hence compete less with interim activities than do food-related instrumental responses (such as key-pecking), which typically occur at high rates. Unlike additivity theory, the response-competition hypothesis does not preclude contrast with such nonelicited responses.

Several experiments have shown little or no contrast (even with pigeons and a pecking response) if the changed component is shifted to a free-food variable-time (VT) schedule, rather than to extinction (no food). This might seem surprising, since pecking is reduced by the VT schedule, and experiments have shown that the stimulus associated with the VT component has inhibitory properties (that is, a suppressive effect on the instrumental response) (*6*, *13*). However, VT schedules induce terminal (and interim) responses that are as vigorous as those produced by response-contingent (VI) schedules, although they may differ topographically (*11*). Hence a shift from VI to VT in the changed component does not permit the animal to reallocate interim responses from the unchanged to the changed component. Consequently, no disinhibitory increase in the terminal (instrumental) response in the unchanged component is to be expected. The inhibitory property of the VT stimulus is explained by competition between the terminal response induced in the VT component, which is under the control of the VT stimulus, and the terminal (instrumental) response in the VI component, which is under the control of the VI stimulus. Moreover, this inhibitory effect is likely to be less than that produced under comparable conditions by the stimulus associated with extinction in the changed component [compare with (*6*, *13*)] because the VT terminal response and the VI terminal (instrumental) response are likely to share common elements, since both are food-related (*14*).

Contrast has sometimes been inter-

preted as due to a "change for the worse" in the changed component, to a change in relative value (*15*). Our results are not consistent with this hypothesis since, if wheel-running has any value at all for the animal, the change from VI to Ext in the changed component will entail a smaller reduction in the value of that component with the wheel available than without.

The relation between the response-competition hypothesis and additivity theory is not yet clear. Both involve competition: between interim and terminal responses in the first case, between incompatible instrumental and induced terminal (Pavlovian) responses in the second. The induction of Pavlovian terminal responses by contrast manipulations, however, may itself be attributable (wholly or in part) to reallocation of terminal and interim behaviors between the two schedule components according to the mechanisms here described.

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10. The minimal condition for the contrast prediction is that an increase in the time available for the competing activity (that is, the time in the changed component made available by the abolition of food-related activities in that component) reduces its competitive effect on the terminal response in the unchanged component. This is just the well-accepted behavioral equivalent of the economic law of diminishing marginal utility [H. Rachlin and B. Burkhard, *Psychol. Rev.* **55**, 22 (1978); J. Allison, M. Miller, M. Wozny, *J. Exp. Psychol. General*, in press]. A formal account of the competition hypothesis, applied to the generalization-gradient peak shift and inhibitory gradients, as well as to contrast, is given in J. E. R. Staddon [in *Operant-Pavlovian Interactions*, H. Davis and H. M. B. Hurwitz, Eds. (Lawrence Erlbaum, Hillsdale, N.J., 1977), pp. 103–131]. This account assumes for simplicity that competition can be represented by a system of linear equations, but many quantitative models are compatible with the general idea. An account invoking terminal-interim competition has recently been offered for local contrast effects by P. Killeen [in *Advances in the Experimental Analysis of Behavior*, M. Zeiler and P. Harzem, Eds., vol. 1, in press]. The terminal-interim distinction was originated by Staddon and Simmelhag (*11*) and was reviewed, with emphasis on interim activities and interim versus terminal competition, by Staddon (*9*). The utility to the animal of stimuli that allow it to allocate interim and terminal activities efficiently has been suggested by L. Green and H. Rachlin [*J. Exp. Anal. Behav.* **27**, 255 (1977)]. J. F. Rand [*ibid.* **25**, 103 (1977)] has shown that pigeons allocate interim activities preferentially to the unreinforced stimulus in successive discrimination.
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Emotions Are Expressed More Intensely on the Left Side of the Face

Abstract. *Pictures of human faces posing six distinct emotions (plus a neutral expression) and their mirror reversals were split down the midlines, and left-side and right-side composites were constructed. Subjects judged left-side composites as expressing emotions more intensely than right-side composites. The finding indicates hemispheric asymmetry in the control over emotional expression in the face.*

Anecdotal and experimental evidence has suggested that the left and right sides of the face are physiognomically asymmetrical (*1*). On the basis of case studies, Wolff (*1*, *2*) proposed that the right side of the face is consciously expressive and "public," while the left side of the face is more inhibited and "private." Furthermore, Wolff claimed that the right side of the face is perceived as more similar to the whole face than the left side is. Although the first proposition has never been examined experimentally, the second has (*3*, *4*). In such studies the procedure has been to split photographs of a full face and its mirror reversal down the midline to construct composite photographs of the face, one made up of the left side and one made up of the right (Fig. 1).

Generally, the right-side composite face is judged more similar to the original face than the left-side composite (*4*). However, these studies failed to obtain judgments of the similarity of the composites to a mirror reversal of the original face. Gilbert and Bakan (*3*) demonstrated that when this condition is included, subjects judge whichever side of the face appearing more to their left to be more similar to the whole face than whichever side appears more to their right. They concluded that judgments of facial asymmetry in expression are determined by biases of the perceiver rather than by asymmetry in actual ex-

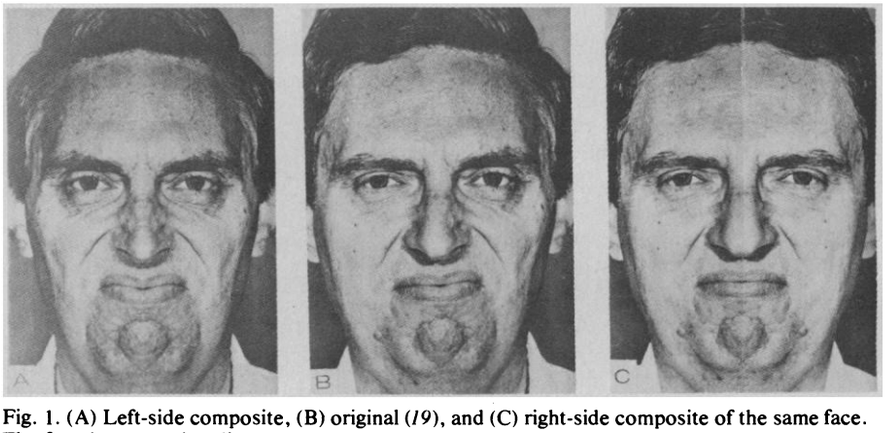

Fig. 1. (A) Left-side composite, (B) original (*19*), and (C) right-side composite of the same face. The face is expressing disgust.

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