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Specious Reward: A Behavioral Theory of Impulsiveness and Impulse Control

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In a choice among assured, familiar outcomes of behavior, impulsiveness is the choice of less rewarding over more rewarding alternatives. Discussions of impulsiveness in the literature of economics, sociology, social psychology, dynamic psychology and psychiatry, behavioral psychology, and "behavior therapy" are reviewed. Impulsiveness seems to be best accounted for by the hyberbolic curves that have been found to describe the decline in effectiveness of rewards as the rewards are delayed from the time of choice. Such curves predict a reliable change of choice between some alternative rewards as a function of time. This change of choice provides a rationale for the known kinds of impulse control and relates them to several hitherto perplexing phenomena: behavioral rigidity, time-out from positive reinforcement, willpower, self-reward, compulsive traits, projection, boredom, and the capacity of punishing stimuli to attract attention.

This article takes up the question of why organisms, particularly human beings, often freely choose the poorer, smaller, or more disastrous of two alternative rewards even when they seem to be entirely familiar with the alternatives. I call this kind of choice *impulsive,* although the word has also been used for behavior that is simply unpremeditated. The question of impulsiveness is one of the oldest on record—it is, after all, the subject of the story of Adam and Eve. It recurs in Homer in the story of Ulysses and the Sirens. Millenia of philosophical pondering and decades of scientific observation have left us with three rather poorly defined guesses about why people are so prone to this maladaptive behavior:

1. In seeming to obey impulses, people do not knowingly choose the poorer alternative but have not really learned the consequences of their behavior. Socrates said something like this. Those who hold this kind of theory prescribe education or "insight" as the cure for impulsiveness.

2. In obeying impulses, people know the consequences of their behavior but are impelled by some lower principle (the devil, repetition compulsion, classical conditioning) to act without regard for differential reward. Those who hold this kind of theory prescribe some means of exorcising the lower principle, such as abreaction or desensitization.

3. In obeying impulses, people know the consequences of their behavior, but their valuation of the consequences is innately distorted so that imminent consequences have a greater weight than remote ones. Those who hold this kind of theory prescribe devices

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that serve to commit future behavior to courses decided on well in advance.

Workers in the many disciplines that have studied impulsiveness—economics, sociology, social psychology, dynamic psychology, behavioral psychology, and behavior therapy—have generally labored in ignorance of their neighbors' work. This article first brings together some of the literature in these fields. An examination of this literature suggests that Theories 1 and 2 are not adequate to explain some situations in which subjects have been observed to choose the smaller of two rewards. Theory 3, which was first clearly formulated by Mowrer and Ullman (1945), is well documented but incomplete. It does not say how a subject is ever motivated to control impulses or why the conflict between impulse and control is not resolved like a simple choice. The additional explanation has been supplied by recent parametric choice experiments in animals, which suggest that the effectiveness of delayed reward declines in a curve with a marked upward concavity, so that preference between certain pairs of small–early and larger–later rewards can be expected to shift from the larger to the smaller reward simply as a function of elapsing time.

This hypothesis, that subjects' preferences can often be expected to change in a regular way over time in the absence of any new information about the alternatives, turns out to have great organizing power over what has been a mystifying body of data. It poses the problem of impulse control as a need to forestall the temporary effectiveness that some small rewards can be expected to acquire by virtue of their temporal position.

The latter part of this article discusses a laboratory situation and four kinds of human behavior that seem to involve the choice of poorer alternatives and devices to prevent this choice. The laboratory situation is "time-out" from positive reinforcement. In human beings, the use of a relatively innocuous impulse to forestall a graver one is described in the section entitled "Alliances between Rewards." Autonomous impulse control, or willpower, is reviewed in some detail in the section called "Private Side Bets." Under "Rationing Reward," the choice of rate of consumption of reward is presented as an example of conflict between small–early and larger–later rewards. Finally, the possibility that aversive stimuli are compounds of brief reward and longer inhibition of reward is discussed under "Punishment."

Selective Review of the Literature

Economics

Economists were the first social scientists to note the existence of people who sharply discount the future. The early writers generally described the problem as Jevons (1871/1911) did:

> To secure a maximum of benefit in life, all future events, all future pleasures or pains, should act upon us with the same force as if they were present, allowance being made for their uncertainty. The factor expressing the effect of remoteness should, in short, always be unity, so that time should have no influence. But no human mind is constituted in this perfect way: a future feeling is always less influential than a present one. (pp. 72–73)

There has not been much speculation about the nature of this imperfection. It has often been dismissed as "improvidence" due to "intellectual as well as moral causes" (Mill, 1848/1909, pp. 165–7) or a "defect of will" (Bohm-Bawerk, 1891, pp. 253–9). One author guessed that it arises from an inability to clearly imagine distant goals (Bohm-Bawerk, 1891, pp. 253–9; see also Rae, 1834/1905, pp. 52–65), which could imply either incomplete learning of the contingencies of reward or an innate limitation in the amount of this kind of learning that can occur. Samuelson (1937) spoke of it as a "perspective phenomenon," implying that it is an innate property of the way we perceive time. Strotz (1956), the only modern author to analyze the problem in detail, noted that people often change their preferences as time passes, even though they have found out nothing new about their situation. To account for this he hypothesized that a goal's "utility," or rewarding effect, decreases with delay according to an inborn function. The curve he drew to portray this has a pronounced upward concavity, suggesting that utility falls off rapidly for relatively short delays and declines more gradually as delays get longer.

Sociology and Social Psychology

Sociologists have treated the "deferred gratification pattern" (Schneider & Lysgaard, 1953), "impulse renunciation" (Davis & Havighurst, 1946), or "instrumental orientation" (Parsons, 1951, p. 49) as a set of behaviors learned in childhood. Failure to learn them has been said to occur more often in the lower socioeconomic class (Davis & Dollard, 1940; Hollingshead, 1949; Whyte, 1943, pp. 106–7, 141). Unlike the economists, some sociologists have attempted to confirm this hypothesis empirically, but their findings have been inconclusive. Schneider and Lysgaard's (1953) study of high school students' attitudes toward delay showed small but significant class differences in the predicted direction. Straus (1962) found that high school students' gratification-delaying habits, as reported on a questionnaire, had low positive correlations with their school marks and job aspirations but none with their parents' social class. Phypers (1970) found low but significant correlations of grade school students' reports of their delaying behavior in hypothetical situations with both school success and perceived ability to influence their futures. Like Straus, he failed to find a relationship with social class.

Those of the above authors who speculated about why their subjects did not defer consumption of reward mentioned social pressure from peers or disbelief that deferring a reward would make it bigger. This implies that a preference for immediate consumption comes from ignorance of the contingencies of reward or from additional, extraneous reward. A problem with these studies of attitudes has been that they have confounded immediate consumption that reduces total available reward and immediate consumption that may be the best long-range strategy in a particular social situation. A boy in the corner gang described by Whyte (1943, p. 106), for instance, might suffer more if he were stingy and saved his money than if he "invested" it in popularity by sharing with his comrades. Another problem with this research method is validity. When Buss (1964) offered his subjects their choice of actual rewards, as well as posing them hypothetical choices, he found no correlation between the two measures.

Some authors have found that adolescents with histories of impulsive behavior give answers on questionnaires that suggest a defective conception of future time, presumably because of faulty learning. For instance, Stein, Sarbin, and Kulik (1968) found that delinquent high school students expected major events in their lives to happen sooner than did nondelinquent controls matched for age, race, and social status (see also Lavik, 1969; Leshan, 1952; Levine & Spivak, 1959; Siegman, 1961; Teahan, 1958). Differences between the abnormal subjects and normal controls have been small and do not seem to exist for many of the items on the tests. Barndt and Johnson (1955) and Davids, Kidder, and Reich (1962) have found that delinquent adolescents tell stories involving shorter time spans than do normals. Davids (1969) found that grade school children with "acting-out" disorders estimated time more poorly and said they would spend a dime or a dollar sooner than did normal controls.

Recently there have been a number of experiments involving actual reward-delaying behavior. A tendency for grade school children to choose a larger coin or candy bar at a long delay (from 1 to 30 days) over a smaller–immediate reward has been found to be positively correlated with age, intelligence, "social responsibility," and presence of a father in the home and negatively correlated with an acquiescent personality (yea-saying), a disadvantaged family, and the length of the delay interval (Melikian, 1959; Mischel, 1966; Walls & Smith, 1970). Adults' preference for a small–immediate monetary reward over a larger one delayed a period of days has been observed to be related to degree of psychiatric disturbance (Shybut, 1968). Mischel and his co-workers attributed the discounting of delayed rewards to a smaller expectancy of getting them, possibly related to an inability to conceive future events realistically (Mischel & Staub, 1965). However, they also suggested that waiting might be aversive in itself (Mischel & Metzner, 1962).

Bialer (1961) observed that children who thought their actions did not influence their future delayed gratification less than others. Strickland (1972) confirmed this in some subjects but not others. Apparently the relationship is not a simple one (Mischel, Zeiss, & Zeiss, 1974). Walls and Smith (1970) found that disadvantaged children did not initially choose a larger–delayed reward as much as other children but came to do so when they had been given a series of experiences in which a promised delayed reward was actually delivered. These findings provide some support for the theory that the people who do not invest for the future are those who do not expect investment to bring returns. However, the children's behavior was undoubtedly influenced by the social setting (Bandura & Mischel, 1965; Mischel & Metzner, 1962; Strickland, 1972), and what was believed to be behavior toward the ostensible reward may have been, in the minds of the subjects, compliance or negativism toward the experimenters.

Research in social psychology has also defined the entity of "need for achievement," which has been found to be high in people who delay their gratifications and low in those who do not (Atkinson & Feather, 1966, chap. 20; Mischel & Gilligan, 1964). A recent revision of achievement theory makes the tendency to achieve success a function of need for achievement multiplied by all immediate and distant goals added together, but it does not postulate any discount on the distant goals (Raynor, 1969). Lack of diligence is thus not thought to be caused by the low effectiveness of delayed reward, but by a low valuation of certain kinds of reward or disbelief that can be obtained.

Analytical Psychology and Psychiatry

Freud (1911/1956) said that impulses were a product of the operation of the "pleasure principle" and were controlled insofar as a person learned the "reality principle." Of the competition between the two principles, he said:

> The superiority of the reality-ego over the pleasure-ego has been aptly expressed by Bernard Shaw in these words: "To be able to choose the line of greatest advantage instead of yielding in the direction of least resistance." (Man and Superman).

And in the same paragraph:

> Actually the substitution of the reality principle for the pleasure principle implies no deposing of the pleasure principle, but only a safe-guarding of it. A momentary pleasure, uncertain in its results, is given up, but only in order to gain along the new path an assured pleasure at a later time (1911/1956, p. 223)

He was clearly talking about the same issue as the economists and sociologists just discussed, although he broadened it to include purely intrapsychic behaviors such as autistic thinking. He seems to have had a mechanism in mind, but he formulated it vaguely. When he said the "momentary pleasure" is "uncertain in its results" he must have meant that there is a risk of later–larger punishment or loss of reward, since the pleasure itself is at hand and presumably the least uncertain of any of the factors. In a later paper he implied a simultaneous competition between "id-pleasure" and an "ego-pleasure" which has been somehow differentiated from it through learning (1920/1956). He seems to have wondered why behaviors based on id-pleasure persisted in competition with much greater ego-pleasure. In this regard, he postulated a "repetition compulsion" by which behaviors could become immune to extinction (1914/1956) and later a "death instinct" which might make punishment itself rewarding (1920/1956). He never defined how these principles interacted with the pleasure principle.

Reviewing analytic theory in 1950, Rapaport remarked that little was known about the origin of impulse controls, but he did say:

> The core of this change from the primary to the secondary process appears to be change in the character of delay. The delay to begin with was due to external circumstances (i.e., the unavailability of immediate reward) and is turned into an ability to delay, into an internal control. (p. 164)

Hartmann (1956) listed "postponement of gratification and a temporary toleration of unpleasure" as a function of the reality principle, possibly developing because "the pleasure principle is a less reliable guide to self-preservation" (pp. 35–36). He implied that processes which obtain long-term benefit gradually supplant those which obtain only short-term benefit, but he suggested no specific mechanism. Singer (1955) suggested that people learn to control impulses by converting motor impulses to thoughts. Perhaps this is the process of conceptualizing distant goals, which has been studied by the social psychologists (see above). Klein (1954) spoke of "delay mechanisms" exerting a "force" to regulate a person's response to needs. He said that these may act by developing "cognitive attitudes" which can "detour the approaches to need-satisfying objects . . . alter the consummatory process . . . modify the intensity of the need itself, or . . . draft the energy of the need to some other adaptive intention prominent in the situation" (p. 227). None of these authors specified rules relating the force of impulses to the influence of higher processes.

Without referring to any psychodynamic model, Blachly (1970) listed four characteristics common to a number of maladaptive human behaviors:

1. Active participation by the victim in his own victimization.
2. Negativism (knowing the usual adverse consequences of one's actions, but doing it anyway).
3. Short-term gain.
4. Long-term punishment. (p. 4)

He hypothesized that such "seductive behaviors" included drug and alcohol abuse. smoking, overeating, sexual deviation, and various kinds of delinquency (p. 3). Although he ruled out both uncertainty and ignorance of the consequences as reasons for the behavior (Characteristic 2), it is not clear what mechanism he had in mind. His hypothetical curves of the amount of reward produced by these behaviors as a function of time clearly implied that later events are discounted (chap. 8, Figures 6 and 7), but nearby he seemed to suggest that impulsive acts persist by becoming immune to extinction (chap. 8, Figure 8).

Behavioral Psychology

A problem facing all the authors who have studied behavior toward delayed reward in humans has been the possibility that cultural values or other "higher" processes have mediated the patterns they observe. The use of animal subjects presumably reduces this problem, although it introduces the possibility that the results obtained with any one kind of subject have been influenced by innate behavioral patterns that are specific to that particular species. Animal experimentation also permits stronger manipulations than can be attempted on humans. It has produced a much more extensive literature on delayed reward than any of the disciplines just discussed. Starting with Mowrer and Ullman (1945), a growing number of authors have applied principles derived from animal experiments to the human problem of impulse control.

Animal Data

Most authors who have run experiments with animals agree that time elapsing between the occurrence of a behavior and its reward decreases the reinforcing effect of the reward on that behavior. Rate of learning, strength of responding, and preference have been observed to decline as some negatively accelerated function of the time reward is delayed (Hull, 1943, pp. 135–164; many studies reviewed in Kimble, 1961, pp. 140–156, and in Renner, 1964; Logan, 1952). Exceptions are few and have been confined to the case in which the subject's option is to respond and get a delayed reward or not to respond and get no reward at all. In this situation some early experimenters found that animals showed undiminished speed of learning and response strength with reward delays up to 5 min, as long as some kind of cue predicting reward occurred immediately (e.g., Warden & Haas, 1927). This finding was generally not confirmed by later research (e.g., Perkins, 1947; Wolfe, 1934), although Ferster (1953) found that pigeons which have already learned a response for immediate reward continue to emit it at an undiminished rate if delay of reward is gradually increased to 1 min.

There are many different estimates of how rapidly the effect of reward declines. This is partly because in many studies the reward itself is the only information the subject receives as to whether a response will be rewarded. Where the reward is delayed in this kind of experiment, the subject must wait not only for the reward but to find out whether there will be a reward (Perin, 1943a, 1943b). When both information and reward are delayed, even so intelligent an animal as a chimpanzee has been reported not to learn a discrimination after 600 trials with delays of only 4 sec (Reisen, 1940). Other investigators have found learning with longer delays but generally not more than 45 sec (Mowrer, 1960, pp. 345–87). Even when a response is immediately followed by a cue signaling that reward will eventually occur, delay of reward causes a steep decline in animals' performance. For instance, Wolfe (1934) found that maximum possible habit strength declined 60% when rats' rewards were delayed 30 sec. However, he found that rats showed some evidence of learning with delays of up to 20 min. Chimpanzees will work for tokens if they can be exchanged later for food but will stop working when the time before they can be exchanged is increased to 1 hr (Kelleher, 1957). Examining the single response data that were available to him, Hull (1943, pp. 134–164) estimated that maximum habit strength ($_sH_r$) was an exponential function of delay:

$$m' = M'(e^{-jt}), \qquad (1)$$

where m' is maximum habit strength at delay of reward t, M' is maximum habit strength possible with immediate reward, j is an empirical constant, and e is the base of natural logarithms.

The best way to study the quantitative effect of delay has been to give subjects a variety of two-way choices between rewards of different sizes at different delays. Davenport (1962) and Logan (1960, 1965) performed this experiment with rats, using a two-panel choice of box and a T-maze, respectively. For each of several combinations of amount and delay of reward, they obtained a series of different amounts at different delays which were equivalent, that is, which the rat chose over the given combination on 50% of the trials. Logan (1965) used these data to estimate the function by which the "incentive value" of an alternative ("a number that characterizes its ability to compete with other alternatives" (p. 9)) declines with increasing delay:

$$\text{Incentive value} = k - .13D^{.5}, \qquad (2)$$

where k is a function of amount, D is delay in seconds, and .13 and .5 are empirical constants.

Rather than finding which combinations of amount and delay of reward yielded equal preference, Chung (1965) offered pigeons rewards of equal size for pecking each of two keys and observed how delaying one reward on one key affected the proportion of responses on that key. However, he did not reward every response but made the alternatives occur on a variable interval 1-min schedule. This meant that the birds rarely received an immediate reward for pecking either key. Thirty seconds elapsed between an average peck and its consequences, which were reward or delay followed by reward. Nevertheless he found that the proportion of pecks on the delay key declined in a curve similar to the one for habit strength described by Hull (Formula 1). He reported that his data best fit the exponential function:

$$\text{Proportion of responses on delay key} = 55.3e^{-11t} + .94, \qquad (3)$$

where e is the base of natural logarithms, t is the delay in seconds, and 55.3, .11, and .94 are empirical constants. However, when Chung and Herrnstein (1967) performed similar experiments varying delay on both keys, they obtained data that adequately fit both an exponential equation like Formula 3 and the simple inverse ratio:

Proportion of responses seeking alternative

$$E = \frac{d_s}{d_e + d_s}, \qquad (4)$$

where d_e is the delay of reward E and d_s is the delay of its alternative, S. The authors pointed out that the fit by Formula 4 was the more remarkable of the two since it did not involve the adjustment of an empirical constant. By a similar experiment Shimp (1969, Experiment 2) also found that preference for a reward seemed to be inversely proportional to its delay. By varying the details of this experiment, Herbert (1970) found that only some data fit the inverse ratio of delays, while those obtained under slightly different conditions clearly fit an exponential curve. Killeen (1968, 1970) gave his pigeons a choice between two keys programmed on identical variable interval schedules, but a successful peck was rewarded not by food or delay-then-food but by a second task, which was in turn rewarded by food on a variable- or fixed-interval schedule. He (1968) found that when the second tasks were rewarded on variable-interval schedules, the birds preferred them in proportion to their mean immediacies of reward (inverses of delay, calculated from the time of the effective peck in the first task to the time the reward became available). However, when the second tasks were rewarded on fixed intervals, the birds preferred earlier rewards even more than the ratio of their mean immediacies predicted (1970). Their choices seemed to be in proportion to immediacy raised to the 2.5 power.

The foregoing methods of estimating reward effectiveness (habit strength, incentive value, or proportional preference) are not precisely comparable because of the different conventions of measurement they use. However, it is clear that they predict different shapes of a curve that plots reward effectiveness on the y-axis against delay of reward on the x-axis. All these shapes would be negatively accelerated or, in other words, upwardly concave. The curve would decline rapidly near the reward but flatten out into a long tail at longer delays. The least sharply concave would be the exponential curves (Formulas 1 and 3); next would come Logan's square root curve (Formula 2); and then a simple proportion (Formula 4), which is a hyperbola. Proportionality to a power of delay, as found by Killeen (1970), would produce the most sharply concave curve of all. The importance of concavity is discussed presently.

Behavior Therapy

Mowrer and Ullman (1945) created an explicit model of human impulsiveness by shocking rats if they ate food within 3 sec after it became available. They found that if the shock occurred at the end of the 3 sec, the rats learned not to eat the food too soon; if the shock was delayed up to 12 sec, the rats generally ate too soon and were shocked. But the growing number of behavior therapists who deal with impulsiveness rarely mention this model or specifically attribute impulsiveness to the discounting of delayed reward. Goldiamond (1965) and Homme (1966) spoke generically of the stimuli that "control" impulsive behavior, without specifying the relationship of these stimuli to the contingencies of reward. Similarly, Stuart (1971) said that unwanted eating could be maintained by the environmental stimuli usually present during eating. It is not clear whether he meant that the unwanted eating is still governed by the law of effect or whether he meant to suggest some other basis, like classical conditioning. Kanfer and Phillips (1970) made statements suggestive of three possible models. They asserted that

> it is only when the controlled behavior has immediate positive reinforcing value and long-range aversive consequences [or conversely] that any question at all arises whether the person is executing self-control. (p. 416)

This suggests that impulsiveness arises because of the discounting of delayed events. However, they spoke nearby of a "tempting response" losing its "associated rewarding consequences" (p. 414) by a process of extinction, implying that impulsiveness exists before behavior reaches equilibrium with the contingencies of reward. They also spoke of behavior being governed by "stimulus conditions" in addition to "contingent reinforcement" (p. 413), thus seeming to introduce a factor beyond differential reward, perhaps classical conditioning. The great majority of behavior therapists writing about impulsiveness have appealed to common knowledge of what it is and have not discussed even tangentially their assumptions about it.

Conclusions from the Literature

The various behavioral sciences have generated three explanations for their subjects' apparent preference for smaller rewards over larger ones: (a) Their subjects do not learn the contingencies of reward as well as they could; (b) their subjects are not responding to the contingencies of reward, because of such factors as classical conditioning or repetition compulsion; and (c) delayed rewards are innately less effective, either because subjects cannot conceptualize them or for some other reason. It would be hard to rule out the first two explanations in the situations in which they have been proposed. However, in the parametric choice experiments on animals they were probably not important: The animals' behavior came to equilibrium over a large number of trials making incomplete learning unlikely; and the same kind of behavior was required for both alternative rewards, making it unlikely that behavior which obtained the earlier reward was learned according to a different principle. In these studies the effectiveness of reward apparently declined as a function of delay itself.

Unless one postulates that the operation of reward is radically different in humans than in animals, this effect should be taken into account in addition to whatever other factors seem to be present in human choice situations. In the case of frequency (rather than simple immediacy) of reward, Schroeder and Holland (1969) found that human preference for points on a counter was described by the same simple proportion that describes pigeons' preference for food. Schmitt (1974) did not find this to be true when he used money as a reward, but the money might not have controlled his subjects' behavior adequately. No parametric study has been done in humans using known primary rewards.

Hypothesis About Change of Choice as a Function of Delay

As we have seen, the exact shape of the curve in which reward effectiveness declines as a function of delay has varied with small changes in the technique used to measure it. The importance of this shape becomes clear if we ask again why people are sometimes impulsive and sometimes not. The mere fact of a decline in the effectiveness of delayed reward is only half of an explanation. It accounts for the tendency to choose a small–immediate reward at the expense of a larger–long-term loss, but it suggests no countervailing tendency. It predicts impulsiveness but not impulse control. Some of the specific delay functions listed above (Formulas 1 and 4) imply this second prediction, while the others do not.

If the effectiveness of reward declines in an exponential curve (Formulas 1 or 3), then rewards occurring at fixed times will always have the same relationship to one another, assuming that the time constant of decay (j in Formula 1) does not vary for different rewards. This is evident from the fact that for every unit of time an exponential curve will lose the same constant proportion of its remaining height. If at a time t a small reward due at $t + 1$ sec is twice as effective as a large reward due at $t + 30$ sec, then it will also be twice as effective when anticipated from $t - 30$ sec or $t - 2$ hr. The choice maker will never be motivated to "control" its disproportionate effectiveness.

Could this be the case? Perhaps the time constant of decay varies widely among individuals, either through heredity or differences in an acquired ability to modify it, and *impulsiveness* and *thriftiness* are just what we name the ends of the spectrum. Persons in whom the effectiveness of reward declined more slowly would have a greater tendency to prefer larger–later rewards to smaller–earlier ones. An observer comparing them to persons with steeper reward-effect curves would say that they were less impulsive, that they deferred gratification more. But this would not account for the claims by individuals with "impulse disorders" that they initially want to avoid the impulse to drink, or lose their tempers, or go on a spending spree, but that they regularly change their preference and do these things (e.g., Shapiro, 1965, pp. 134–176). Nor would it predict the common experience of wanting to avoid temptation, which implies that one's current choice can be expected to change in some predictable and, hence, avoidable way. Indeed, unless the preference for the smaller of two rewards is temporary, there can be no motive for avoiding it in the future or regretting it in the past. To fully account for impulsiveness, there has to be more than just a decline in effectiveness as reward is delayed. There has to be a reversal of choice. Graphically, this is to say that the curves describing the motivating effect of the consequences of behavior as a function of time must cross one another.

This may happen either because curves from different kinds of consequence have dif-

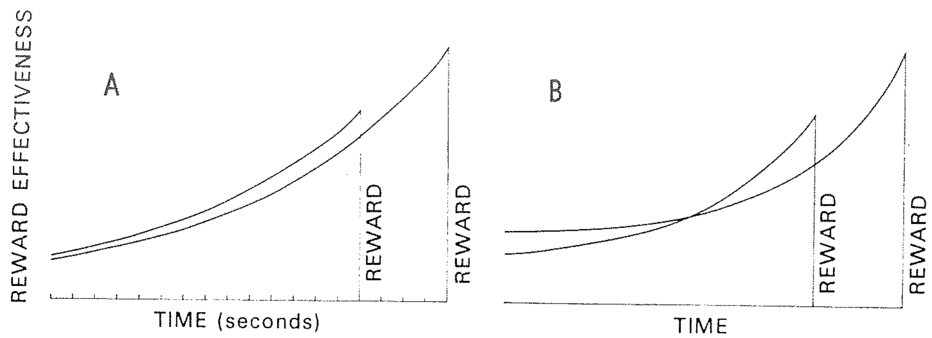

FIGURE 1. The predicted effectiveness of two alternative rewards in the period before they are available: A, if effectiveness declines in an exponential curve $\{Y = Y_0 \times \exp\,[-.1\ (T_{Y_0} - T)]$ in which Y_0 is the reward$\}$; and B, if effectiveness declines in a curve more concave than an exponential one (drawn freehand).

ferent shapes or because curves from all consequences are highly concave. Two illustrations of the former hypothesis come to mind. (a) If preference for a consequence did not depend on its differential rewarding effect because, for instance, of a "compulsion" to seek it, a curve describing its tendency to be preferred as a function of time could obviously take a number of shapes that would allow it to cross curves from rewards. Some mechanisms of choice that have been postulated to be beyond the reach of the law of effect have been reviewed in the preceding section. (b) There is evidence that different rewards lose their effectiveness at different rates when delayed. Logan and Spanier (1970) found that delay of water was less detrimental to learning than delay of food. This might make possible situations in which one of two alternative rewards was regularly preferred until a certain time before this reward became available and was unpreferred after this time. The curves of rewarding effect as a function of delay could cross; and depending on one's assumptions about the relative "objective" sizes of the rewards, one choice or the other could be called impulsive.

Differently shaped curves from different kinds of events might be responsible for important conflicts between impulsiveness and impulse control in humans. Not much more can be said about them in the absence of further data. However, in many human situations, the apparent consequence of impulsive behavior is an eventual deprivation of the same reward that the behavior sought—money, popularity, power, and the like, or whatever primary rewards give these entities their motivating effect. When a choice is based on different amounts of the same reward at different delays, a temporary preference for one alternative could occur only if the delay function of the reward was more concave than an exponential curve. This highly concave function was the shape postulated by Strotz (1956, p. 177).

The distinction is illustrated in Figure 1. The effectiveness of pairs of alternative rewards is graphed as a function of time, that is, as delay decreases. "Effectiveness" is a number like Logan's "incentive value" which depicts the reward's tendency to be chosen over alternatives. At a given moment, the reward with the greater tendency to be chosen has the higher curve. Exponential functions produce curves depicted in Figure 1A. The ratio of the curves' heights stays the same throughout their course, and the same alternative is preferred at all times. The curves of Figure 1B are more concave and show a change of choice as the rewards draw nearer. At first the larger–later reward is preferred, but later the smaller–earlier one is preferred. The impulse to choose the earlier reward would be present from the time the curves cross to the time the earlier reward would be due if chosen.

Data Predicting Change of Choice as a Function of Delay

There is evidence to suggest that the situation depicted in Figure 1B can occur. If the curve that Logan (1965) derived from his data (Formula 2) is plotted for some pairs of

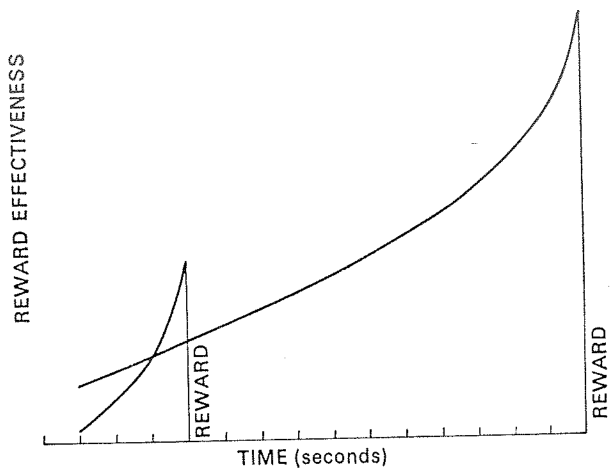

FIGURE 2. The effectiveness of one food pellet versus three food pellets 11 sec later, as predicted for rats by Logan's (1965) formula $[Y = Y_0 - .13 (T_{Y_0} - T)^{.5}$, where Y_0 is the reward].

alternative rewards separated by certain intervals, the curve from one reward crosses that from the other (Figure 2). For instance, a rat should prefer one pellet ($k = .241$) immediately to three pellets ($k = .563$) delayed 11 sec, but not one pellet delayed 3 sec to three pellets delayed 14 sec, although this is the same choice seen at 3 sec greater distance.

Similarly, one can draw curves according to Chung and Herrnstein's (1967) function (Formula 4). These would be hyperbolic, so that preference for a truly immediate reward would be infinite if the function held for all delays. The theoretical questions raised by this limiting case are deferred here by considering the curves only up to 1 unit of time before the rewards are due. Even in this range, the curves can cross (Figure 3). For instance, a pigeon should prefer a reward delayed 1 sec to one three times as great delayed 4 sec, but not a reward delayed 3 sec to one three times as great delayed 6 sec.

An important property of the curves in Figure 3 is that their tails come to be almost proportional to the amounts of their rewards. The curve is higher than that of a reward three times as large 1 sec before the earlier reward. The curve is two thirds as high 3 sec before the earlier reward, and it would be just about one third as high 100 sec before. This would predict that even rewards that are due at different times will be chosen in proportion to their actual amounts, as long as the choice is made far enough in advance.

Direct Evidence for Change of Choice as a Function of Delay

As Chung and Herrnstein (1967) pointed out, there is too much ambiguity in the current data from delay of reward experiments to discriminate between exponential curves and nonexponential curves of a roughly similar shape. However, the possibility of highly concave curves has suggested a mechanism of impulse control that is testable by direct experiment. If one reward is preferred at one time and its alternative at a later time, any means to obtain the larger–later reward must include a device to forestall the change of choice. Subjects not having such a device in their repertoire might learn one offered by the experimenter. If, on the other hand, their preference usually did not change over time, there would be no reason to expect them to learn such a device. Subjects in two recent experiments have learned devices to limit their own future freedom of choice.

It is well known that pigeons will peck a key that has been associated with food, even when not pecking leads to much greater reward (Fantino, 1966; Schwartz & Williams, 1971). Ainslie (1974) found that pigeons would regularly peck a red key for 2-sec access to food where not pecking led to 4-sec access to food beginning 3 sec later. If the key lit up green 12 sec before it was due to light up red, some of the subjects came to

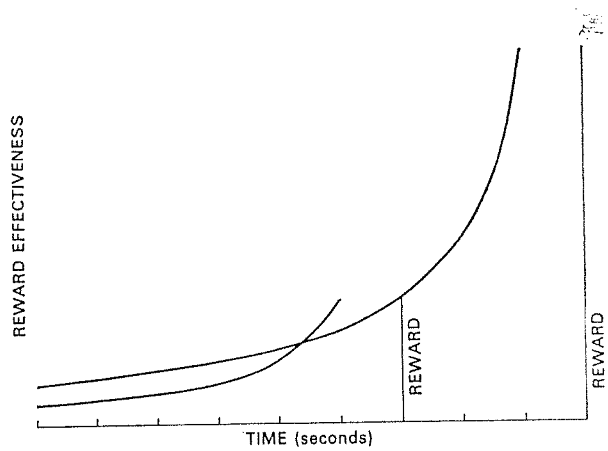

FIGURE 3. The effectiveness of a duration of access to food versus a duration three times as long beginning 3 sec later, as predicted for pigeons by Chung and Herrnstein's (1967) matching formula $[Y = Y_0/(T_{Y_0} - T)$, where Y_0 is the reward]. (Just before the rewards are due their curves become infinitely high; this portion is not depicted.)

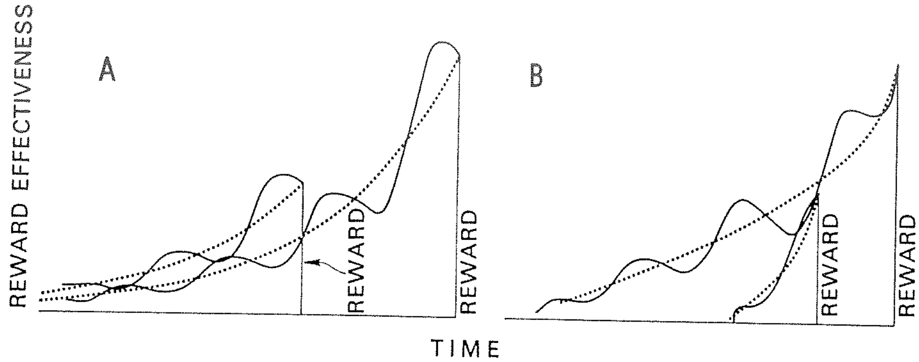

FIGURE 4. Oscillating curves of reward effectiveness which cross even though their central functions do not: A, oscillations within ±30% of curves drawn according to an exponential formula [$Y = Y_0 \times \exp$ [$-.1\ (T_{Y_0} - T)$, where Y_0 is the reward]; and B, oscillation within ±30% of curves drawn according to Logan's (1965) formula [$Y = Y_0 - .13\ (T_{Y_0} - T)^{.5}$, where Y_0 is the reward].

peck it on a majority of trials when its only effect was to prevent the key from lighting up red later in the trial. They pecked the green key much less in a control condition in which pecking the red key had no effect and thus did not need to be avoided. They also pecked the green key very little when this was made *necessary* in order for the key to light up red later, thus ruling out the possibility that preference was changing haphazardly between two curves which lay close to each other (Figure 4A; see Hull, 1943, p. 304–321). The situation depicted in Figure 4B—divergent, oscillating curves which cross haphazardly near the early reward—was not ruled out, but it is not much different conceptually from Figure 1B. Subjects apparently learned to peck the key when it was green only if this forestalled the temporary attractiveness of the red key.

However, this impulse-controlling phenomenon developed in only 3 out of 10 birds. Even in the 3, the single-key design of the experiment made it impossible to tell whether the impulsive behavior was based entirely on the earlier food reward or on a combination of this food and the pecking activity that produced it. In a refinement of this study, Rachlin and Green (1972) gave their subjects a choice between two keys. If the 25th peck fell on one key, there occurred a delay of T seconds followed by a choice: (a) an immediate, 2-sec access to food or (b) a 4-sec access to food 4 sec later. If the 25th peck fell on the other key, the same delay, T, was followed by presentation of a single key, a peck on which led to a 4-sec access to food 4 sec later. Subjects that pecked the key which led to the choice subsequently made it in favor of the immediate, 2-sec feed on more than 95% of the trials. As the interval T before the later key(s) was presented was increased in steps from .5 to 16 sec, three of the five subjects greatly decreased their preference for the key that led to the choice. When the interval T was shortened again, pecking on this key rose again. This is further evidence not only that choice between two alternatives may change simply as a function of the time the choice is made, but also that a subject may seek to avoid changing its choice. The failure of some subjects in these two studies to avoid the later choice might mean that for them the effectiveness of reward declined in a different kind of curve than for the other subjects, but it also might have been due merely to the difficulty of learning a task at that distance from the rewards.

DEVICES FOR CONTROLLING IMPULSES

Although more exploration is needed, there is now some reason to believe that the relative effectiveness of alternative rewards can shift simply as a function of elapsing time. This could fully account for our well-described ambivalence toward our impulses and could remove the apparent circularity from the concept of controlling one's own self. If a smaller reward is available long before a larger alternative, any device to get the larger–later reward must include some means of dealing with the temporary attractiveness of the smaller–earlier one. The skill of impulse control would then be the ability to devise ways of committing oneself to get past these smaller rewards. Henceforth I refer to a reward that becomes temporarily preferable to a later–larger reward as "specious" with respect to the larger reward. This states a relationship of the smaller to the larger reward and implies nothing about the smaller reward taken by itself.

As Strotz (1956) pointed out, the first analysis of precommitment appeared in the *Odyssey,* in which Odysseus had to sail past the Sirens. Because the sound of their voices was more alluring than any other motivation, his problem was to keep himself and his crew from rowing toward it and onto the rocks. He found two devices: Because he wanted to be able to hear the Sirens, he had his crew tie him to the mast and ordered them not to untie him until they had reached their goal. His crew, however, had to be left free to row, so he stopped their ears with wax. These two tricks, plus a third that was not open to him—finding enough reward to compete with the specious reward—seem to exhaust the possible strategies for controlling impulses. One can set up the future situation so that (a) he will not change his choice, (b) he will not be able to act on his new choice, or (c) he will not receive or will not integrate the cues needed to change his choice. With rare exceptions (e.g., James, 1890, vol. 1, p. 123), Homer's suggestion has been revived in the behavioral sciences only within the last two decades.

Skinner (1953, pp. 230–241) listed nine ways that an individual can control his impulses. The first, "physical restraint and physical aid," seems to be strategy b. "Changing the stimulus" coincides with strategy c. "Depriving and satiation," "manipulating emotional conditions," "using aversive stimulation," "drugs," "operant conditioning," and "punishment" all seem to act by changing the contingencies of reward for the impulsive behavior and hence depend on strategy a. His last device, "doing something else," may use any of the three strategies. Skinner did not portray the problems of impulse control as a private conflict, but rather a clash between the individual's wishes and those of society. He said that the incentive to adopt self-controlling devices comes from social pressure. He did not mention the change of preference implied by the need to constrain future behavior. Kanfer and Phillips (1970) came closer to recognizing this change of preference when they pointed out that Skinner's devices act by " 'interruption of an [impulsive] behavioral sequence at an *early* stage' " (p. 414).

Strotz (1956) was the first to specifically postulate a predictable change of preference:

> An individual is imagined to choose a plan of consumption for a future period of time so as to maximize the utility of the plan as evaluated at the present moment. . . . If he is free to reconsider his plan at later dates, will he abide by it or disobey it—*even though his original expectations of future desires and means of consumption are verified?* Our present answer is that the optimal plan of the present moment is generally one which will *not* be obeyed, or that the individual's future behavior will be inconsistent with his optimal plan. If this inconsistency is not recognized, our subject will typically be a "spendthrift". . . . If the inconsistency is recognized, the rational individual will do one of two things. He may "precommit" his future behavior by precluding future options so that it will conform to his present desire as to what it should be. Or, alternatively, he may modify his chosen plan to take account of future disobedience, realizing that the possibility of disobedience imposes a further constraint . . . on the set of plans which are attainable. (p. 166)

Actually, these do not seem to be alternatives. Strotz's rational individual should (a) make no plans that are unlikely to be realized *and* (b) enlarge the category of realizable plans by precommitment. Precommitting devices include irrevocable contracts, compulsory savings plans, telling friends to "Kick me if I don't . . .," and so on.

A sociologist, Becker (1960), seems to have come independently to a similar device. He spoke of commitment as a making of "side bets," irreversibly arranging to forfeit something valuable, especially social standing, if the given decision were not maintained.

> Decisions not supported by such side bets will lack staying power, crumpling in the face of opposition or fading away to be replaced by other essentially meaningless decisions until a commitment based on side bets stabilizes behavior. (p. 38)

Strotz's and Becker's devices involve either changing the reward contingencies so that the earlier–smaller reward is never the more effective one or binding one's own future behavior so that when the earlier reward is more effective one will not be able to obtain it. Devices to keep attention away from the specious reward have also been described. Mischel and Ebbeson (1970) have studied the tendency to wait for a preferred reward in pre-school-age children. Each subject was told he could have a food he preferred if he waited for 15 min or an unpreferred food immediately whenever he wanted to stop waiting. They observed that when either or both foods were present in the room in which the subject was waiting, he would generally devise a "self-distraction technique" that involved taking his eyes off the food in some way. Even then, only a sixth of the subjects managed to wait the full 15 min, as compared with three quarters of those who did not have the food in the room. Mischel, Ebbeson, and Zeiss (1972) found that whether or not food was present in the room, children delayed less than 4 min if they thought about the food, but delayed at least 12 min if they thought about "fun things" or had toys to play with. Many of the "mediating behaviors" described in animals that are differentially rewarded for responding slowly may also represent attempts to avoid impulsiveness by distracting attention (Bower, 1961; Kramer & Rilling, 1970; Schwartz & Williams, 1971).

Although Skinner, Strotz, and Becker spoke of people consciously setting out to constrain their future behaviors, and Mischel and coworkers' children also seem to have been behaving deliberately, there is no need to assume that consciousness is necessary for gratification-delaying behavior. If an appropriate delaying device arises by trial and error at a time when the curve from the larger–later reward is higher, one would expect it to be learned on that basis alone. Indeed Bruner and Revusky (1961), who rewarded human subjects for waiting a certain period and then pressing a key, found that the subjects could do this efficiently if they were provided with other keys which had no effects whatsoever. The subjects reported no awareness that delay was required but believed that pressing the dummy keys somehow set up the effective one. Precommitting devices might be learned in the same way.

This is an important point, for if the precommitting of future behavior plays an important part in the way humans control their impulses, it seems to be largely unrecognized. In ordinary speech, one is said to *make* a decision, as if the choice had inertia and would remain the same until acted upon further. That this inertia has to be created by self-committing devices is recognized only in pathological cases. For instance, it might be said of an alcoholic that he fails to transmit his current resolutions about alcohol consumption to his future self and so should take steps to predict and constrain that self as if it were another person. One would not expect to hear it said that a nonalcoholic was in the same predicament but was already successfully making precommitments.

It is reasonable to view the kind of skills often called ego functions as a set of devices for preventing speciously rewarded behavior. The conflict between ego and id would then be the competition between successive preferences, in which each side has its weapon. Because later–larger rewards are preferred at first, they may cause the learning of devices to make their earlier, specious competitors unavailable or undesirable, or direct attention away from the cues that signal their availability. But any such device must be learnable on the relatively tiny reinforcing effect present at that distance from the reward. Because the smaller–earlier rewards are preferred last, they will inevitably be chosen if no such device has been learned.

The tendency of animals and people to learn precommitting devices is probably limited not only by whether they can discover them, but also by the unpredictability of the rewards involved. Since these devices make future behavior less flexible, they may reduce rather than increase reward in a changing environment. For instance, if the smaller–earlier reward in Ainslie's (1974) or Rachlin and Green's (1972) experiments were suddenly replaced by a reward larger than either of the two original rewards, a bird performing with maximal efficiency on the original task would never discover the difference because it would always press the key that constrained it to wait for the later reward. Unpredictability of reward reduces the differential reward for rigid behavior and would be expected to reduce preference for precommitting devices.

Application to an Experimental Problem

The tendency of hungry pigeons to actively avoid certain opportunities to get food (Appel, 1963; Azrin, 1961; Zimmerman & Ferster, 1964) seems inconsistent with the orthodox concept of reward. If the fixed number of pecks on a key required for a single food reward is high but not so high that pecking ceases (between 50 and 2,000), pigeons will peck a second key whose only effect is to make the original key unavailable for a period of time (a time-out). Azrin speculated that a poorly rewarded task could become aversive, but since his subjects received no penalty for not performing it, they could simply refrain from pecking if this were the case. There seems to be no reason to predict that they would work to avoid the opportunity to peck. Indeed Zimmerman and Ferster observed that their birds did not avoid the most poorly rewarded tasks; they simply did not perform them. The avoided tasks were those which were barely rewarding enough to be performed or which had been well rewarded but were starting to extinguish. That is, the subjects that sought time-outs from the opportunity to get food were those that presumably faced close choices between resting and working for poor reward. In such a situation their choice could be expected to vacillate between the alternatives. If we suppose that ambivalent behavior is less rewarding than that of sticking to either alternative, the subjects might seek a device that bound their future behavior to one or the other, or at least reduced the frequency of change. (A human illustration might be going for a walk and discovering that every so often there was a penny embedded in a crack in the sidewalk. A person with an urge to stop and work each one out might find that it spoiled his walk, but he might be able to prevent this by walking with his gaze away from the sidewalk.) The value of time-outs from positive reinforcement might be to forestall the subjects' own susceptibility to vacillation.

If this were true, one would expect that anything which increased or decreased the rate of reward so that it was no longer close to the cost of responding would make the time-out key undesirable or unnecessary, respectively. Also, the subject should seek time-outs only near the beginning of the pecking task since pecking the key would reduce the number of pecks still needed, thus making the reward nearer and more effective. Extinction of a well-rewarded task would lower the secondary reward for pecking so that it might temporarily equal that for doing nothing, making the time-out key useful; however, as extinction proceeded, the tendency to peck should fall until it was well below the tendency to do nothing, at which time there would again be no reason for pecking the time-out key. All of these phenomena were reported by Zimmerman and Ferster (1964).

The hypothesis presented here does not predict what amount of vacillation is optimally rewarding. Zimmerman and Ferster found that pigeons which could also end the time-out sought time-outs more than those which were confined to the time-out for a minimum period of time, suggesting that the birds did not prefer total rigidity.

The birds' responsiveness to differences in reward schedule suggests that they were not simply following an innate tendency to peck keys in situations in which food is sometimes present (Herrnstein & Loveland, 1972; Williams & Williams, 1969), although this tendency might have been interacting with whatever other factors were present. Furthermore, Redd, Sidman, and Fletcher (1974) recently found that monkeys will press a key early in a food-rewarded task to obtain a time-out from that task. The tendency to seek time-outs increases as the rate of food reward for the task decreases. The authors interpreted this behavior as precommitment by the monkeys to forestall their own tendency to work on the task.

Application to Human Behavior

Change of choice as a function of time leads to some further predictions about im-

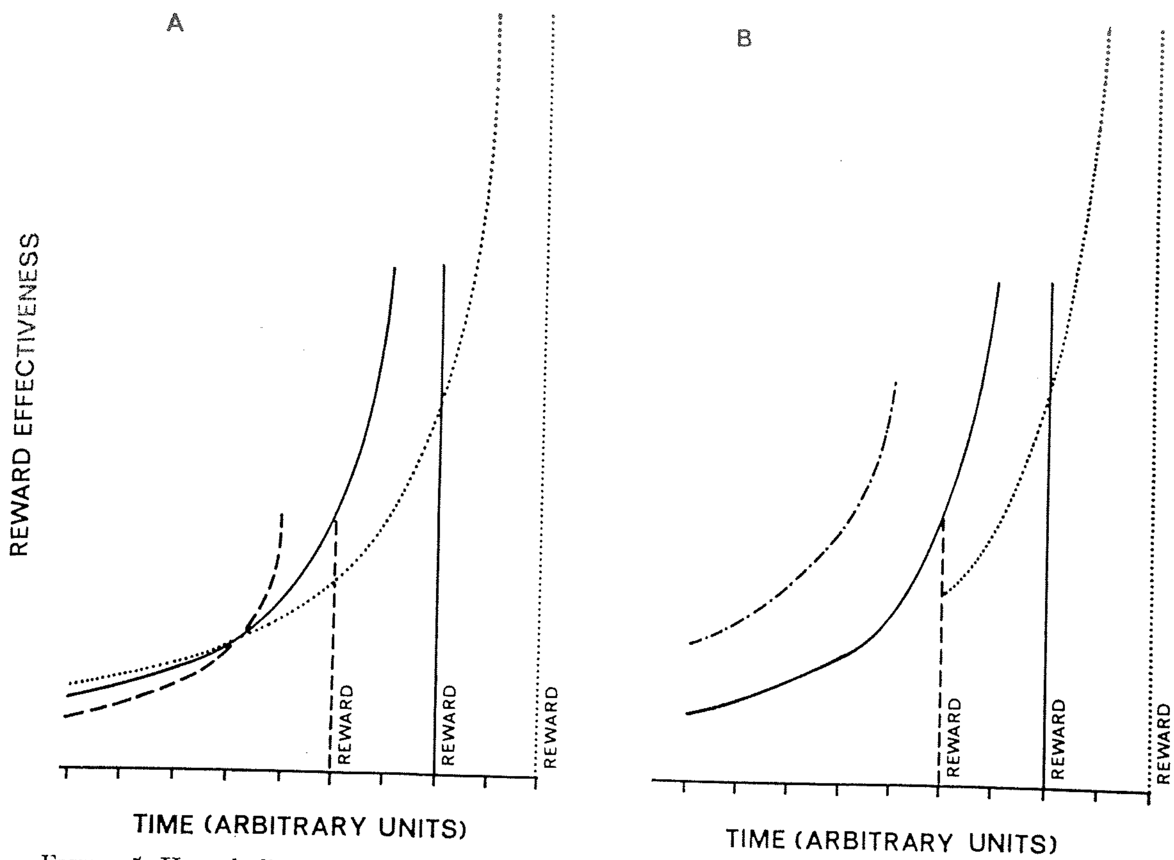

FIGURE 5. Hyperbolic curves [$Y = Y_0/(T_{Y_0} - T)$] of the effectiveness of three rewards: A, if each reward is an exclusive alternative to each other reward; and B, if the earliest reward precludes the middle one and the middle one precludes the last one, but the earliest one does not preclude the last one. (The summed effect of the earliest and last rewards is depicted by the dash-and-dot curve.)

portant human behaviors. These predictions are discussed with reference to hyperbolic curves describing effectiveness as a simple inversion of delay, but they can also be made if the curves have any of a number of other shapes, as long as the curves are more concave than exponential ones. The curves are drawn only for delays greater than one arbitrary unit of time, and the heights of the rewards themselves are depicted as equal to their effectiveness at this delay. In this discussion heights of the rewards and their curves represent the process of rewarding that goes on within the subject and determine his preference; these may or may not be proportional to the physical parameters of reward.[1]

[1] Logan (1965) estimated that his amount factor, k, was related to actual number of food pellets (A) by the formula, $k = 1 - 10^{-.12A}$. Neuringer (1967), whose experimental approach was similar to that of Chung and Herrnstein (1967), found that choice was directly proportional to duration of access to food (and, hence, roughly proportional to amount of food).

In cases in which this internal rewarding process occurs repeatedly or continues over a period of time, the simplest assumption is made: Multiple rewards are additive and a reward that continues over time is the sum (or integral) of the rewards in each period during that time.

Alliances Between Rewards

There may exist combinations of alternatives such that a delayed reward which has specious alternatives is itself specious with respect to a still later, larger reward (Figure 5). If the reward available earliest is not specious to the reward available last (i.e., does not prevent it from occurring; Figure 5B), it may serve as one of the devices a person learns in order to make himself wait for the largest–last reward. The last reward may ally itself, as it were, with the early reward in order to make the middle reward impossible before it would be preferred. For example, if the rewards have relative amounts of 1, 2, and 3, respectively, and they are due 2 units of time apart, then hyperbolic curves describing effectiveness as an inverse proportion of delay predict that the combined effectiveness of the earliest and latest rewards will always be greater than that of the middle reward in the period before the earliest reward is due. No device can be learned to avoid the earliest reward and obtain the middle one, thereby losing the last one. However, if the earliest reward is not available, the middle and last ones would become equally effective 6 units before the last one is due ($4/20 = 2/10$), and the middle one will be preferred thereafter. If no other precommitting device has been learned on the basis of the last reward, the middle reward will inevitably be chosen.

This pattern might explain some human behaviors which are otherwise paradoxical from the point of view of learning theory. For instance, a person might learn that the temptation to get angry, although temporarily compelling, usually leads to unrewarding experiences and might therefore learn devices to avoid this temptation. But if a situation arose in which his greatest long-term benefit required him to do something hurtful to another person (firing an employee for instance), he might find he always lost his resolve at the last minute unless he had first gotten angry at the person. Thus, he might opt for the temptation to get angry in order to get by the temptation to avoid the whole issue. Of course he might obtain still greater reward if he could find a way to keep his resolve without resorting to anger, but if he could not, the anger might be an adequate precommitting device.

Another example might be a person with antisocial impulses who has found that acts of delinquency put him into unrewarding situations and thus tries to avoid the temptation to perform them. However, if he is afraid that he may get out of control and get himself into bigger trouble, he may stop avoiding the temptation to act up in smaller ways, so that the authorities (police, ward attendants, etc.) will exert more effort to guard him. The long-range desire to avoid a major rampage causes him to look for devices that will constrain his future behavior; because such a device must be chosen early, when the effectiveness of the reward it leads to is low, one that also produces an immediate thrill may be choosable, while one that stands on its own may not be.

Similar arguments can be made for other instances of impulsive behavior, such as drinking to get one's courage up. The trouble with all examples from human society is the impossibility of knowing for sure how much effect the long-range rewards really have. Do people ever perform impulsive acts largely to obtain the committing effects of these acts, or are the committing effects always just byproducts? The situation suggested by Figure 5B can be, but has not been, looked for experimentally.

Private Side Bets

The precommitting devices so far described hardly seem adequate to account for the feats of self-control commonly seen in human society. The method of diverting attention from cues that would give rise to impulses seems to have little power (Mischel & Ebbeson, 1970); and the plan of setting up an environmental situation that forces future behavior in the desired direction depends on whether certain ingredients happen to be available in the environment. For instance, a person trying to stick to a diet could padlock his cupboard and mail himself the key, if he could get all his food in the cupboard and the cupboard would take a padlock and he did not live close to a restaurant or grocery store. Or he could bet something valuable with a friend that he would not eat the forbidden food, if he had a friend handy who was willing to hold the bet and who was willing and able to check on his eating habits and who would not let him out of the bet if he said he had changed his mind. Certainly dieters use some devices like this—not leaving tempting foods around, taking appetite suppressants, joining weight-watching clubs, and so on. But there are also people who diet through sheer willpower and, conversely, many people for whom all the above devices are not enough, who lack some additional quality needed to make a diet work.

Many people seem to delay gratification largely on their own, an observation that led

Strotz (1956) to wonder if one can learn to change the function by which reward effectiveness declines with delay. If a person could learn to bend his delay function into a less concave shape, he would certainly solve his self-control problem, but it is hard to believe that anyone simply removes the allure of his temptations and becomes impulseless. And the properties of very concave delay functions predict a mechanism for private impulse control, without having to postulate variability in the shape of the decay curve.

Figure 6A illustrates a choice between a smaller–earlier reward and a reward twice as great due 3 units of time later. If their effectiveness decayed in a hyperbolic curve, they would be equally effective 3 units of time before the smaller one was due ($1/3 = 2/6$), and the smaller one would tend to be chosen after that. If this choice occurred twice in succession, a diagram of the effectiveness of the rewards would just be two successive copies of Figure 6A, unless it were possible to make both choices at the same time (Figure 6B). In the latter case, the effectiveness of the two larger rewards would be the sum of their curves, and similarly for the two smaller ones. (The possibility of choosing one smaller and one larger reward is not discussed.) These summed curves would cross about 2.4 units before the earliest reward was due. The summed curves for six pairs of rewards would cross 1.6 units before the first reward was due (Figure 6C), and so on. If a long series of large rewards were opposed in a single choice to a long series of preceding, specious rewards, the large rewards would be preferred longer than if a single large reward were opposed to a single specious one.

The shift of the moment of crossing closer to the time the first specious reward is due might enable an organism to avoid specious rewards it would otherwise choose. For instance, if a pigeon can peck a key for a specious food reward and it takes 1 sec to peck the key and then get to the food in a hopper, a bird whose preference changes 2 sec before it can get to the food will peck the key. A bird whose preference changes .5 sec before it can get to the food will not peck, since just standing in the chamber it is always at least 1 sec away from the food reward. Similarly, an alcoholic, whose preference for not drinking usually ends some minutes before a drink is available, will probably not be able to keep liquor in his house or go to a party or to a bar if he is to keep himself from drinking. If his preference shifts only seconds before a drink is available or does not shift at all before he actually begins drinking, he will probably be able to do these things and still stay dry. He will not need to go so far out of his way to avoid his impulse.

If a person could group his impulses and their alternatives together in a series, he would clearly increase his ability to avoid the impulses. But this could be done by a side bet similar to the kind discussed by Becker (1960): the whole series of larger rewards to be forfeited if, at any choice point, the specious reward were not avoided. It would not be necessary for anyone to hold the bet, since *the mere knowledge that this bet was necessary to avoid the specious rewards would make it binding*. If the person chose the first specious reward when it became available, he could not expect to avoid any of the later ones, and by this loss of expectancy he would pay the bet, however much he might want to welsh on it. This situation can be described in purely behavioral terms: If an organism's future reward depends on its behavior, then cues which predict this behavior can acquire secondary rewarding properties. If the organism detects the similarity of a series of choice points, its behavior at one point can become a cue predicting its behavior at later points. If it waits for the later–larger reward at one point, it will also obtain secondary reward from the fact that this behavior predicts similar rewards in the future. Insofar as a choice provides cues about future choices, it will be affected by the rewards that depend on these future choices. It will be made on the basis of summed curves such as those depicted in Figure 6C rather than just the curves from the first two rewards.

This hypothesis suggests two routes by which an individual can acquire a private skill for controlling impulses, without relying on other people or the mechanical properties of the environment. He can learn to attend to

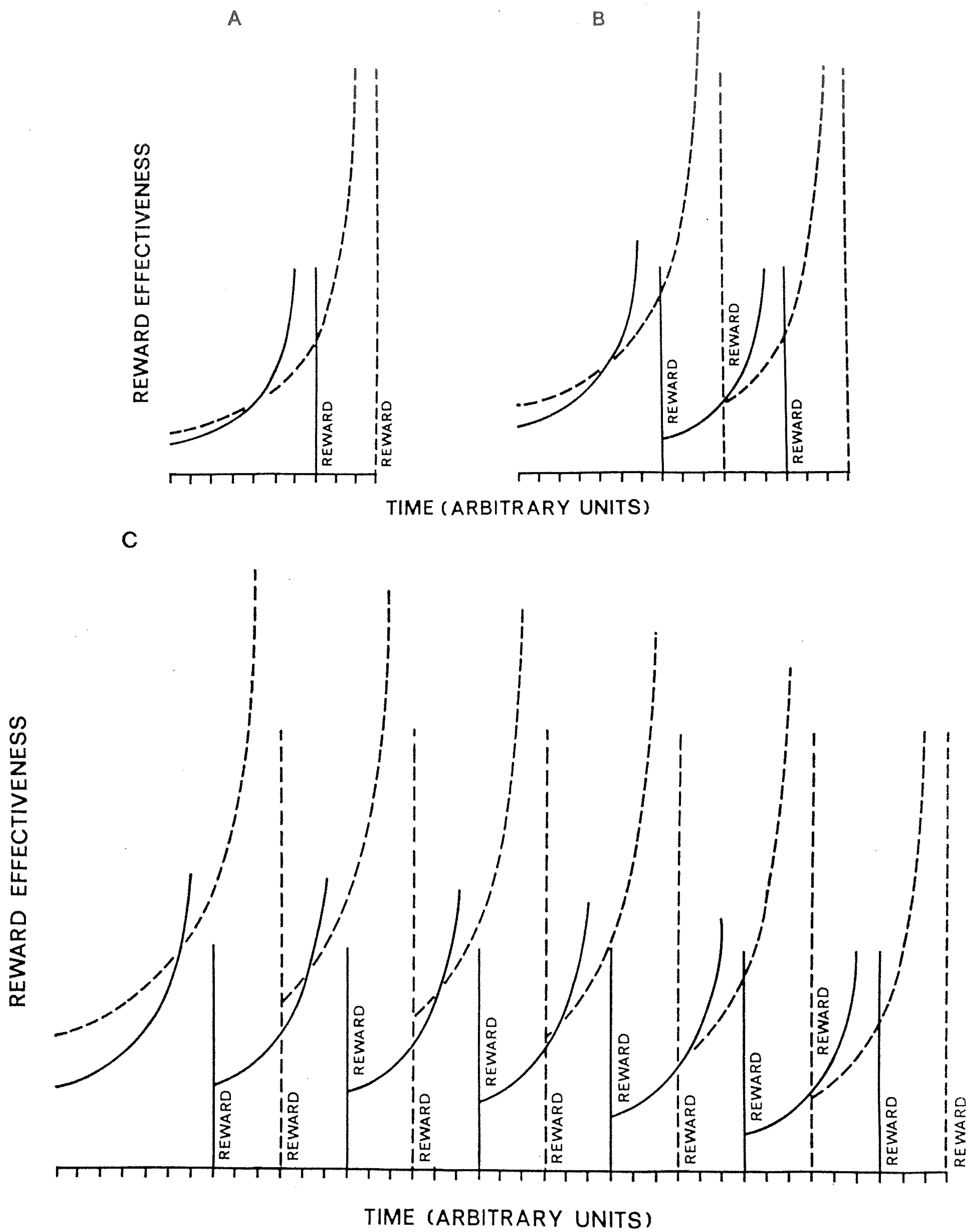

FIGURE 6. Summed hyperbolic curves of the effectiveness of two alternative sets of rewards, small rewards (solid lines) and rewards twice as great (dashed lines): A, sets of one reward each; B, sets of two rewards each; and C, sets of six rewards each.

cues in his behavior that predict future behavior, thus finding secondary reward to bet against impulses. But in cases in which this does not provide enough reward, he can also create categories of gratification-delaying behavior whose members will stand or fall together. That is, he can arbitrarily propose a bet which, if it has the necessary properties, can motivate his future behavior just as well as the bets set up by chance.

Properties of Private Side Bets

To succeed, a private side bet would have to meet three requirements. Take as an example a person who wants to lose weight and thus bets with himself that he will stick to a diet.

1. The cumulative effect of all the benefits he can expect from dieting must be enough to motivate abstention on every occasion that the bet requires it. Unless the differential reward is unusually high, he will be ill-advised to bet that he will get by on 500 calories/day, for at some moments he will get so hungry that he will be apt to prefer to lose the bet.

2. He must perceive the series of choices as endless, or at least very long. As he nears the end of a finite series, he will have decreasing amounts of future reward to bet against his impulses to eat, until at some point he will prefer to lose the bet. If he knows that he will not avoid the last temptation, he will not be able to avoid the one before it; and if he recognizes this, he will not be able to avoid the next earlier one, and so on. Depending on his perceptions, this process may or may not proceed like a row of falling dominoes to make the whole bet worthless. At least his dieting performance can be expected to fall off near the end of any finite period during which the bet is to be in force.

A sophisticated bettor may get around this limitation by grouping his private side bets in turn into still larger categories. The largest possible group will be the set of all his private side bets, which will constitute a lifelong series but will make each of his private side bets vulnerable to the loss of any one of them. If our dieter does not want to stake his whole capacity for impulse control on his dieting behavior, he may define a category such as all of his private side bets governing the consumption of food, which may be lifelong but still discriminated from other and possibly more important private side bets.

3. The bet cannot be ambiguous. If, for instance, it stipulates that he will eat only when very hungry or will make an exception only on festive occasions, it will leave the way open for evasive devices based on individual specious rewards. His threshold for feeling hunger or perceiving festive occasions may drop markedly, and the bet will be made worthless without ever having been lost.

Flexibility of Private Side Bets

In addition to these three necessary properties, private side bets that are to be used in an unpredictable environment often need some provision for flexibility so that the bettor can take advantage of unforeseen sources of reward or so that he is not forced to lose the bet through confrontation with a hopelessly large alternative reward. The ability to formulate categories of behavior that permit avoidance of the most specious reward at the expense of the least rigidity is the skill involved in making private side bets. One must permit exceptions to the terms of the bet in cases in which the required behavior would cost a large amount of reward, without permitting exceptions to obtain small rewards that are effective because they are imminent. Since redefining a bet can be just another device to obtain specious reward, the process of redefinition must in turn be limited by rules enforced by private side bets if the whole betting process is to retain any force.

For instance, if a person wanted to commit himself to keeping his shoes shined, he might make a rule that he would shine them every morning before breakfast. He would be betting whatever the expectation of having shiny shoes was worth to him against his tendency to skip shining them on any particular morning, since if he skipped one morning he would be just as apt to skip the next. He might make this part of a larger bet, say, that he would shine his shoes and brush his teeth before breakfast, but this would not change the nature of the process. If he found he had overslept on a given morning, he might be faced with the choice of losing his bet or making himself late to work, which might also be costly for him. This is where he would need skill at redefining bets. He could get to work on time and still have a bet that would keep him shining his shoes by saying he was to shine them before breakfast every morning that he was not late, but only if he knew that he would not begin to sleep later every morning just to evade the chore. This form of the bet would give him the choice when he first awoke of sleeping a few minutes more or of getting up and shining his shoes. Unless he knew of other factors that would generally keep him from sleeping later, he would probably ruin the side bet by redefining it in this way. He might solve his dilemma by keeping the original terms of the bet (i.e., to shine his shoes *before breakfast*), not shine his shoes, and not eat breakfast. Not eating breakfast might be a smaller cost than either losing the bet or getting to work late, but enough to keep him from oversleeping often. In this case, his skill at private side bets might be further called upon to decide whether he could have a glass of orange juice and not call it breakfast, or perhaps have a very early lunch. He might even rule that he could skip shining his shoes 1 day a week for any cause whatsoever, but his rules about redefining bets would have to be such that he could expect not to change this to 2 days if he overslept the next morning as well. Lastly, if he ever decided that shiny shoes were not worth all this effort, he would best protect the credibility of any similar private side bets by not calling this bet off just before he was due to shine them again, lest he perceive the bet as having been lost.

These considerations of how to safely redefine private side bets can be summarized in a fundamental rule. Loopholes must be limited to: (a) events outside the person's control which do not happen too often and which are clearly distinguished from any similar events which do happen too often (e.g., on New Year's morning he can arbitrarily rule that he does not have to shine his shoes on "major holidays," if in his perception the major ones stand out clearly from the minor ones and if holidays stand out from other potential pretexts, such as rainy days, weekends, etc.); and (b) events within his control but which entail so much effort or other penalty that he would not bring them about just for the sake of evading his bet (days that he skips breakfast in the example about shoe shining, or days he is leaving on a trip or has company in the house, etc.). The considerations involved in a person's bargaining with himself in this way are much the same as those described by Schelling (1960, pp. 21–80) for interpersonal bargaining. Instead of a person's showing evidence to other people that his behavior in a given situation will be limited by unique boundaries which he is not likely to change, he must show this evidence to himself.

Private Side Bets Based on Human Leadership

There are ways of formulating private side bets which reduce the likelihood that they will need redefinition. If a person knows of a cue in the environment that will be present when a given behavior is preferable in the long run and absent when it is not preferable, he can bet that he will perform the behavior whenever the cue is present. He may bet that he will diet in a certain way whenever his weight is over a given amount or that he will study instead of playing ball after school whenever he has a test less than a week away.

An important source of this kind of cue is the behavior of other people. For instance, a person may bet that he will eat dessert only when someone else invites him to or will do his homework whenever his older brother does his. This differs from the public side bet described by Becker (1960) in that the people whose leadership is being used are not given any power over the bettor—they do not hold the bet. They do not even have to know a bet exists. In a public side bet the bettor may boast to his friends that he will behave in a certain way, or he may join the army to "straighten himself out." If he loses the bet, the penalty will be something the other people will do to him (e.g., laugh at him or put him in the brig). If he loses a private side bet, the penalty will be the loss of the power of the bet.

However, a side bet may have both a private and a public aspect. It may be hard for an observer to tell whether a soldier is obeying his officers mainly because he thinks they will punish him if he does not, or because he has bound himself by private side bets to follow their commands. A child's use of private side bets that hinge on the behavior of leaders may be an important mechanism in the processes that psychoanalytic theory calls identification, introjection, and the formation of the superego.

Private side bets that hinge on someone else's leadership are flexible not only because human behavior may meet the bettor's needs more than cues from nonhuman sources, but also because the bettor may be able to influence the leader he has chosen. But this can also defeat the purpose of the bet. For instance, a person who has bet that he will allow himself to get angry only when someone else has gotten angry at him first may try to provoke other people to anger whenever he would like to get angry himself. The ability to choose leaders who have optimum flexibility is part of the skill involved in this kind of betting.

A betting system based on leadership may deteriorate through the choice of leaders whose behavior the bettor can influence too much. It can also degenerate through the bettor's lowering his threshold for perceiving the specified behaviors in the leader. The person waiting for the other to get angry first may begin to perceive unremarkable behaviors as signs of anger. This change may be the basis of the "defense mechanism" of projection.

Private Side Bets in Normal Self-Control

The private side bet seems to be a sufficient mechanism to account for private impulse control. However, since it has not been described in these terms before, the question of how much people actually use it remains. It is not hard to believe that aspects of a person's behavior can acquire secondary rewarding properties without his being able to report this. However, if a great part of his impulse control depends on this process, he is likely to have some way of speaking of it. Perhaps this was the role of three terms current in different historical eras: oaths, effort of will, and self-reward.

Oaths. Impulse control has often been discussed in theological terms, which a modern author translates into behavioral concepts at his peril. However, it may be possible to account for a simple behavior which, until modern times, was widely used to secure contracts and private vows. To increase the likelihood that they would perform some difficult act in the future, people would take an oath that invoked the help of some sacred entity (Lewis, 1838, pp. 4–9; Paley, 1788, chap. 16, pp. 133–138). If they did not do what they had sworn to do, they expected to lose the goodwill of that entity, who would then withhold his help in the future. The behaviors secured by oaths to a particular sacred entity formed a set, the performance of all of which was threatened by the nonperformance of any one behavior. But this is the same situation we have been discussing. It may be that the machinery of oaths and sacred entities was a construct that enabled people to conceptualize an otherwise subtle process—the private side bet.

Effort of will. The organ of self-control has commonly been called the *will,* although this term has also been used to name the process by which any incentive is translated into behavior. Early psychologists, like Bain (1886, p. 320) and James (1890, vol. 2, pp. 535–537, 548–549), distinguished impulse control from the ordinary willing of behavior by the presence of *effort.* They never said precisely how effort operated but did leave some clues as to how they imagined it. For instance, James distinguished the use of effort from other, less stable means of making choices:

> the mind at the moment of deciding on the triumphant alternative dropped the other one wholly or nearly out of sight, whereas here [in the case of effort] both alternatives are steadily held in view, and in the very act of murdering the vanquished possibility the chooser realizes how much in that instant he is making himself lose. (p. 534)

Thus, effort does not involve avoiding information about the impulsive alternative but must act by some other mechanism. In discussing how "anti-impulsive conceptions" are threatened by redefinition, James revealed their similarity to private side bets:

> How many excuses does the drunkard find when each new temptation comes! It is a new brand of liquor which the interests of intellectual culture in such matters oblige him to test; moreover it is poured out and it is a sin to waste it; or others are drinking and it would be churlishness to refuse; or it is but to enable him to sleep, or just to get

through this job of work; or it isn't drinking, it is because he feels so cold; or it is Christmas day; or it is a means of stimulating him to make a more powerful resolution in favor of abstinence than any he has hitherto made; or it is just this once, and once doesn't count, etc., etc., *ad libitum*—it is, in fact, anything you like except *being a drunkard. That* is the conception that will not stay before the poor soul's attention. But if he once gets able to pick out that way of conceiving, from all the other possible ways of conceiving the various opportunities which occur, if through thick and thin he holds to it that this is being a drunkard and is nothing else, he is not likely to remain one long. The effort by which he succeeds in keeping the right *name* unwaveringly present to his mind proves to be his saving moral act. (p. 565)

In other words, the anti-impulsive conception of not being a drunkard permits no exceptions but is evaded by distinguishing individual acts of drinking, so that they are not perceived as exceptions. In this passage James (1890) seems to be dealing with the problem of redefining private side bets, discussed above in the section on flexibility.

Sully (1884) made some suggestive observations on effort of will:

The feeling of effort arises as a concomitant of the calling into activity of some new force distinct from the impulses primarily engaged. In making an effort the will seems to throw in its strength on the weaker side . . . to neutralize the momentary preponderance of certain agreeable sensations. (p. 669)

The will was said to gain its strength through the gathering of behaviors into sets:

When the child begins to view each individual action in its bearing on some portion of his lasting welfare, his actions become united and consolidated into what we call conduct. Impulse as isolated prompting for this or that particular enjoyment becomes transformed into comprehensive aim and rational motive. Or to express the change otherwise, action becomes pervaded and regulated by principle. The child consciously or unconsciously begins to refer to a general precept or maxim of action, as "maintain health," "seek knowledge," "be good," and so forth. Particular actions are thus united under a common rule, they are viewed as members of a class of actions subserving one comprehensive end. In this way the will attains a measure of unity. (p. 631)

Sully and other writers thought that strength of will was generated by "habit," but their concept of habit is revealing. Sully said that the increasingly automatic avoidance of impulse with repetition

shows that the process of self-control is becoming habitual in a new sense. Certain motives are acquiring a fixed place in the mind as ruling forces, while other and lower forces are losing ground. Every repetition of this kind of action . . . tends to fix conduct in this particular direction. (p. 663)

To form this kind of habit, a choice had to be correctly made not just on most occasions but every time. Bain (1886) said, "It is necessary, above all things, never to lose a battle. Every gain on the wrong side undoes the effect of many conquests on the right" (p. 440). And James (1890, vol. 1) emphasized, *"Never suffer an exception to occur"* (p. 123). But it is now known that repeatedly making a choice in the same direction does not in itself strengthen the tendency to choose in that direction and may actually weaken it because of the phenomenon of response alteration (Dember & Fowler, 1958). Certainly the modern experimental concept of habit does not require perfect performance. Private side bets, however, both require and generate consistent choice in a single direction. These would seem to be a reasonable mechanism for the *force* of habit upon which the *effort* of will was said to be based. Good habits might be behaviors grouped together by side bets; bad habits might be behaviors based on specious reward, which prevail in an area in which side bets have been lost.

Self-reward. Bandura and Kupers (1964) proposed that people control themselves by differentially consuming and abstaining from rewards that are within their control. Children who are given private access to rewards after performing a game of skill do not take all that are available, but rather reward themselves in proportion to their perceived success (Bandura & Whalen, 1966; Mischel, Coates, & Raskoff, 1968). Behavior therapists have begun to include differential self-reward in their techniques of dealing with impulsive behavior. For instance, subjects who want to study more draw up a list of rewarding and punishing events that are within their control. They then give themselves the rewards when they have studied for a criterion length of time and give themselves punishments when they have chosen alternatives incompatible with studying (Beneke & Harris, 1972). Many similar approaches have been reported, usually in combination with other techniques (reviewed in Mahoney, 1972). Self-reward is an intuitively pleasing strategy until one asks how the self-rewarding behavior is itself controlled (Rachlin, 1974). A subject does not actually recruit additional reward by planning to delay a cigarette until he has finished a difficult task. On the contrary, he sets himself a second task: He must both defer smoking *and* work on his original task on the basis of the same differential reward that has always confronted him. What, then, can be the function of self-reward?

All the self-rewarding behavior described in the literature has been systematic. People trying to control their own behaviors have not rewarded themselves haphazardly but according to some rule. As Bandura and Kupers (1964) said, "People typically make self-reinforcement contingent on their performing certain classes of responses which they have come to value as an index of personal merit" (p. 1). Mischel (1973) put it this way:

> The essence of self-regulatory systems is the subject's adoption of *contingency rules* that guide his behavior in the absence of, and sometimes in spite of, immediate external situational pressures. Such rules specify the kinds of behavior appropriate (expected) under particular conditions, the performance levels (standards, goals) which the behavior must achieve, and the consequences (positive and negative) of attaining or failing to reach those standards. (p. 274)

It may be that the subsequent increase in people's self-control results from their having defined a precise category of behaviors to be performed or avoided and noticing in a regular way whether they are succeeding (see Kanfer, 1970). This is to say that they have grouped together a set of behaviors into a private side bet or defined an existing bet more rigorously to close loopholes. Kanfer and Karoly (1972) came close to this interpretation with their concept of "beta control," in which a person is said to make a contract with himself to reward himself or not on the basis of "self-observation." They listed six factors that determine whether the person will fulfill the contract, two of which are "the explicitness or clarity of the contract" and "past experience as a basis for the expectation of success or failure."

The foregoing explanation is sufficient when the self-reward is mainly symbolic, a token of success, such as a rising line on a behavior graph (e.g., McFall, 1970). But why should people try to delay substantial rewards until they have done what the bet requires? The answer may lie in the variable strength of some kinds of impulses. If the urge to perform an undesirable behavior is sometimes much stronger than at other times, the benefit to be expected from complete abstention may sometimes fail to overcome the impulse it is a bet against, causing the bet to be lost. However, if the person bets the benefit he would get from a reduction in the behavior, that he will not perform the behavior without foregoing a specified self-reward, he may have created a durable bet. Even though the deferment of available reward is added to the cost of avoiding each impulse, it provides a kind of safety valve for unusually strong impulses. Whenever the urge to overeat or shirk is greater than the effectiveness of the self-reward, the person will simply do these things and forfeit the reward, without losing the bet. If he has estimated correctly, he will prefer to forfeit the reward few enough times so that he can expect enough gain from impulse avoidance to maintain his bet.

There are probably other ways that people have described their private side-betting process. Many people doubtless experience it as a process of trial and error that has become second nature and conceptualize the penalty for lapses as uneasiness or guilt. The three examples presented above were selected because the elements of the private side bet clearly seemed to be present.

Private Side Bets in Obsessive–Compulsive Neurosis

Evidence of private side betting may also be found in obsessive–compulsiveness. It may have struck the reader that the side-betting process I have described is too mechanical to fit normal volition but sounds more like this neurosis. People can usually intend a course of action without so much rumination about loopholes. But just as the feedback system that governs muscular coordination becomes obvious only in cases of neurological disease, so the compulsive patient may display in extreme form a process that goes on more gracefully in others.

The cardinal features of obsessive–compulsive neurosis are a preoccupation with horrifying impulses that seem to the patient to be on the verge of getting out of control, a persistent feeling of guilt or foreboding with a tendency to seek self-punishment, a niggling concern for categorical principles that renders the patient indecisive, and an inexplicable urge to repeat ritualistic acts, particularly those that might be thought of as preventing or undoing the feared impulses (Batchelor, 1969, pp. 162–171; Chapman, 1967, pp. 115–118; Shapiro, 1965, pp. 23–53). If a person is afraid that he will not be able to avoid certain impulses, such as an urge to attack his mother, one thing he can do to increase his control is to set up private side bets against the impulse. If the impulse is strong, the category of delayed rewards bet against it will have to be correspondingly large so that the aggregate effect of these rewards will always be great enough to motivate avoidance of the impulse. It will also have a strengthening effect to define the requirements of the bet with the utmost precision, a process that is apt to increase conscious awareness of the bet. However, the increase in impulse control will be accompanied by an increase in the range of behaviors that threaten this control, since failure to wait for any of the rewards in the category will decrease the probability of waiting for them all. It may even seem dangerous to permit redefinitions, so that the bet will take on the quality of a universal moral principle. The cost of increased control will be rigid, excessively consistent behavior.

If the person perceives himself to have succumbed to any of the specious rewards in the category, he may doubt whether he will avoid the impulse that inspired the category. He may try to remove this doubt in several ways. (a) He can look for punishment or an impulse leading to punishment that has some intrinsic connection with this particular lapse, so that he will not expect to do it again. This is essentially to redefine the rule from "I will not do *X*" to "I will not do *X* without punishment *Y*," which he will not have violated. Such a rule is analogous to the strategy of self-reward discussed above. (b) He can further enlarge the category, thus demanding even more rigid behavior of himself. A reduced probability of obtaining a broader category of large rewards may be as desirable as the original, narrower category that was more likely to be obtained. (c) He can perform other feats of impulse avoidance perceived to be in the original category, thus increasing his expectation so that he will avoid the others. If, by whatever line of association, turning out a light or stepping on a crack or some other behavior makes him think of attacking his mother, then it can be included in a broadly defined category of mother-hating activities. Avoiding them despite great inconvenience may increase his belief that he can avoid all such activities, which will be a self-confirming prophecy. In this way mere symbols acquire the power of causality. Concern with them need not be seen as a strange, poetic conceit on the part of the patient. (d) He may avoid information that he has violated the bet. (e) He can look for devices other than private side bets to constrain his future behavior—moving away, getting himself arrested, and so forth.

The first three strategies will lead to self-punitiveness, increased concern with principle, and ritualistic behavior. The picture of compulsiveness will be complete if the person's perception of diminished capacity for self-control is the sensation called *guilt*. Certainly the first two strategies are traditional remedies for guilt, that is, expiation and the resolution to do better. Strategies d and e represent a decay or abandonment of the private side bet. They should lead to traits different from compulsiveness, although the rituals of undoing seen in compulsive patients may be an attempt to avoid information that the bet has been lost.

Excessively rigid private side bets might be formed not only because of unusually strong impulses, but also from lack of skill in betting. For instance, if a child had to rely on private side bets at an unusually early age, he might unwittingly define them so as to forbid large categories of reward which did not have to be avoided. If he were not able to reformulate these bets in later life, he would be burdened by a "punitive superego."

Such concepts as will, conscience, and private rules have been little discussed since the time of William Jones. Perhaps we have had it in mind that motivational complexity resides in the environment and that to optimize their consumption of reward, people have only to identify the events that motivate them (e.g., Skinner, 1971). If we recognize the possibility of making private side bets, we can at least ask systematically about the complexity that develops within a person and determines his individual response to the world.

Rationing Reward

Most human activities are not rewarded by a single, discrete event but by a continuing process. This is particularly true of the activities often called *exploratory,* which by producing "a feeling of efficacy" (White, 1959) or "affective arousal" (Young, 1955) themselves constitute the consummatory behavior (see also Berlyne, 1950; Hebb, 1955; Woodworth, 1958). Besides requiring certain conditions in the environment and certain behaviors on the part of the person, such a process will not begin before there is a capacity ("drive") for it to produce reward and will not continue after this capacity has been used up ("satiated"). For many activities, the total amount of reward that occurs before a given capacity is used up is probably not constant but varies within the person's behavior. This is to say that satiation may not be a function just of the amount of reward that has occurred, but of the intensity of rate at which it has occurred. An obvious example is sexual intercourse, in which satiation in the human male occurs abruptly after a threshold of intensity has been reached, regardless of how much activity has occurred before this point (Masters & Johnson, 1966, pp. 4–6). Similarly, a person can probably get more pleasure from satisfying a given level of hunger if he goes to a slowly paced banquet than if he were to bolt the same food in ten minutes. He may enjoy a joke more if the comedian takes a while to get to the punch line or a mystery story more if he does not skip to the end to see how it comes out.

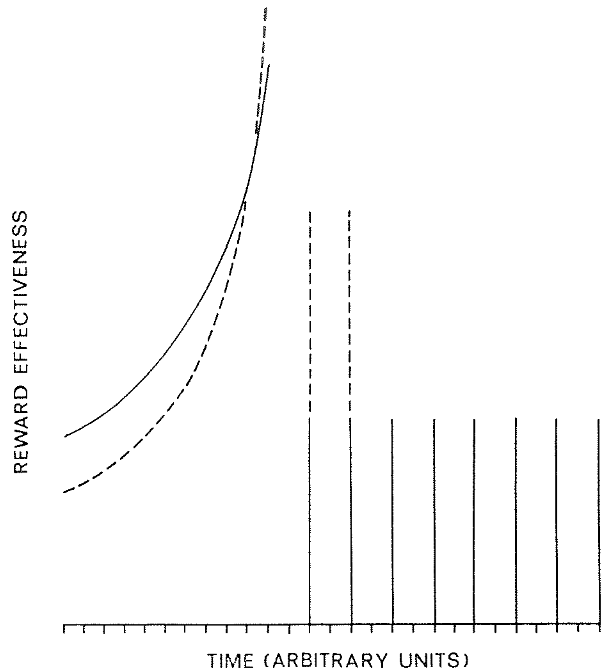

FIGURE 7. Summed hyperbolic curves of the effectiveness of two alternative modes of reward consumption: intensive consumption in two tall spikes or slower consumption in eight shorter spikes beginning at the same time.

The choice between a short period of intense reward and a longer period of less intense reward is diagrammed in Figure 7. So as not to change the diagramming conventions that have been used so far, the continuing reward is represented as spikes separated by 1 unit of time, which recur as long as the reward lasts and whose effectiveness curves are summed. In this example, the briefer–higher reward is more effective than the longer–lower reward just before they are due, despite the fact that the product of the latter's amount times its duration is twice as great. If the diagram represents the reward available for two ways of consuming a given reward, a person will be expected to choose the faster way unless he has previously committed himself not to do this.

In any activity in which a higher rate of consumption brings about greater intensity of reward, a person should soon learn to consume the reward at the highest possible rate. Maximizing his rate of consumption may also maximize his aggregate reward in the long run, if other activities are available which produce relatively large rewards. If such other activities are not available, a maximal rate of consumption may greatly reduce aggregate reward. In either case, increasing experience with the consummatory behavior will tend to form the reward into fewer, taller spikes as the person learns more ways of increasing his rate of consumption. Thus, the reward for an activity may attenuate not only through nonavailability (extinction), but also through the increasing efficiency of the activity. Graphically, aggregate reward can diminish not only by losing height, but by losing duration as well.

If rapidly consumed rewards can be specious with respect to the same rewards consumed slowly, then at some time before rapid consumption is possible, responses that bind future consumption to some kind of rationing device may be learned. Likely examples are not hard to think of. The rationer may be a physical barrier, such as the anaesthetic creams sold to delay orgasm in sexual intercourse, or the shell of a lobster or crab for people who prefer to eat these things whole. It may be a social situation, such as a picnic at which the group as a whole determines the mixture of exercise and relaxation, or the sharing of any kind of reward with someone else in such a way that one's own rate of consumption depends on the other's behavior. It may be a rule enforced by a private side bet, such as saving the dessert for last, never looking ahead for the solution of a story or puzzle, or not permitting a daydream to reach its goal too fast. Private side bets may also produce additional commitment to the mechanical and social devices.

The process of premature satiation may be the mechanism of a familiar but little-studied phenomenon, the decline in the value of an activity as it becomes a habit. It is well known that a task can be too easy to be enjoyable as well as too difficult, and this has been acknowledged by most writers who have gone beyond a tissue-need theory of reward. Many have stressed the reward-enhancing effect of novelty, even though an organism should be less efficient at "consuming" unfamiliar stimuli (Berlyne, 1950; Butler, 1958; Glanzer, 1958; Harlow, 1953). McClelland, Atkinson, Clark, and Lowell (1953, pp. 6–98) specifically postulated that reward is enhanced by difficulty in obtaining it. Atkinson, Bastian, Earl, and Litwin (1960) have found evidence that this is true whether or not the learning of a skill is required. A maze experiment by Mahut (mentioned in Hebb & Thompson, 1968) suggests that this may even hold true for rats obtaining food. Hebb and Thompson (1968) have noted that moderate amounts of fear as well as difficulty enhance reward.

Some of these authors have accounted for the value of challenge by postulating that organisms seek an optimal level of stimulation. This ignores the fact that the activities involved are generally goal directed; the subject who seeks difficulty, novelty, risk, fear, and so on, then turns around and works to get rid of them. He does not seem to be maintaining homeostasis but alternately creating tension and relieving it. By what principles do these seemingly contradictory behaviors cooperate in order to optimize reward?

If there is something rewarding (either intrinsically or secondarily) in such mental processes as recognition, comprehension, and mastery, then in recurring situations preference for the more intense of two rewards should cause these processes to occur with increasing rapidity. Attention races ahead to the solution of a familiar problem, and the capacity of the process of solving it to generate reward is used up almost immediately. The function of challenge may be to slow down the process of resolution, thereby increasing the aggregate amount of reward it generates. Like any rationing device, it must be chosen before rapid satiation becomes immediately available.

It might be objected that satiation is not a limiting factor in the kind of activity we are discussing and that the person can always develop curiosity or suspense about something else and thereby reestablish his capacity to be rewarded by its resolution. But the setting up of a new problem presumably demands a certain amount of attention, which must interfere with other reward-getting activities. If a person prematurely harvests this problem's reward, it may not repay the minimum cost of setting it up. Satiation of the problem-solving kind of drive may be reversed in a short time, but if the subsequent reward is even shorter, the average reward for the whole cycle will be low.

A farsighted strategy for rationing reward must steer between premature satiation and excessive interference with reward getting. The decision as to whether or not to ration a given activity will tend to divide behavior into two types: (a) activities which are highly rewarding in themselves ("ends"), which become maximally rewarding through the learning of rationing devices; and (b) rather unrewarding activities ("means"), which are necessary in order to get to a more rewarding activity. Means permit the most reward when they have become habits and occupy attention for as little time as possible.

Depending on what sources of reward are available, a person may choose to treat a given activity as a means at one time and as an end at another. For instance, he may drive a car in some pattern that optimizes the pleasure of riding or in a pattern that demands as little attention as possible in order to attend to something more rewarding. In a society in which people's physiological needs are readily satisfied, strategies for increasing aggregate reward may depend largely on the effective use of rationing devices.

Punishment

The nature of punishment has been a problem for behavioral theory (see Herrnstein, 1969; Solomon, 1964). In one respect its action is the opposite of reward. Behaviors followed by reward tend to recur; those followed by punishment tend not to recur. These are the defining characteristics of reward and punishment. But punishment resembles reward in that they both tend to attract attention and to impart this tendency to cues predicting them. If punishment had the opposite effect from reward on stimulus learning and attention, it could not have its well-known vividity. Punishment must be different from simple unreward. The most popular way of accounting for both the behavioral and attentional effects of punishment has been Mowrer's (1947) two-factor theory. This states that cues preceding punishment become connected to it by classical conditioning, but behavior becomes, in effect, disconnected from it through operant learning. The *stimuli* leading to punishment are remembered because the classical conditioning process does not require reward; the organism must pay attention to punishment and, ultimately, to the cues predicting punishment because of the preemptive nature of punishing stimuli. However, any *behavior* leading to punishment is eliminated through nonreward. Furthermore, behavior leading to cues that predict punishment is eliminated because these cues themselves take on the capacity to induce a nonrewarding state, through the classical conditioning process.

This last feature of Mowrer's two-factor theory has been found to accord poorly with recent experimental data. Hineline (in press) has reviewed extensive evidence that animals do not avoid a stimulus that predicts punishment and may even seek it, as long as the occurrence of the stimulus does not increase the frequency of punishment. He concluded that the existence of stimuli predicting punishment is a weak factor, compared with even small changes in the frequency of punishment, in motivating animals' preference for one punishment schedule over another. The relative ineffectiveness of secondary or conditioned punishment has led Herrnstein (1969) to doubt it as a mechanism for motivating avoidance behavior. Instead, he has proposed that punishment simply reduces subjects' tendency to perform behavior it has followed, in a manner symmetrically opposite to reward. He attributed the symmetry only to behavior, however. He distinguished behavior from learning, by which he meant the tendency for sequences of stimuli to be remembered (Brown & Herrnstein, 1975, chap. 3). Thus, he retained a two-factor theory: that actions are chosen or not chosen according to their expected reward or unreward; and sequences of stimuli are learned by association, independently of or according to a different principle of reinforcement.

The difficulty with dividing psychological processes into input and output components, each with its own principle of selective retention, is that operant reward clearly has a great effect on the input processes. Moray (1969) reviewed evidence that humans have extensive voluntary control over their sensory input. Even the great distortions of perception reported in hysteria are apparently responsive to operant incentives (Parry-Jones, Santer-Weststrate, & Crawley, 1970). In view of this control of input it would be hard, perhaps impossible in principle, to determine whether all stimuli attended to become associated or whether they must be further selected. But in either case we are left with the question of why an operant like attention would be emitted to obtain punishing stimuli. Why not avoid them by just not attending to them?

Apparently people sometimes do this, at least in the case of that most-studied punishment, physical pain. There are many accounts of neurologically normal people who, in certain situations, did not perceive painful stimuli. People with hysterical anesthesias, patients undergoing surgery under hypnosis, and soldiers wounded in the heat of battle who report that they do not feel their wounds all provide examples of some psychological process that keeps attention from being drawn to pain (Beecher, 1959, pp. 157–190). It may not be justifiable to say that this process is voluntary, but it at least shows that a capacity to ignore pain is part of the human repertoire. Melzack, Weisz, and Sprague (1963) described the way human subjects could deliberately increase their tolerance for some kinds of pain by "diverting their attention" to auditory stimulation when it was available. But if a person has the capacity to withhold his attention from painful stimuli, why does he not generally learn to do this? Or if, as Sternbach (1968, pp. 140–141) suggested, pain is a response that people can be instructed to withhold, why do they not spontaneously learn to withhold it? It would be awkward to invoke the adaptive value of pain, to say that people had learned that by not ignoring pain they could get greater reward in the long run. Not only would this require the attention-attracting capacity of pain to depend on the highly attenuated effectiveness of delayed reward, but it would not account for a person's usual inability to ignore pain that he knows is useless for any adaptive purpose. It would describe the available facts better to say that for attention-directing behavior, pain seems to act as a reward; but for behavior that makes a painful stimulus more or less likely to occur, pain seems to act as the absence of reward.

Another look at highly concave reward-effect curves may make this paradox more manageable. We must start by noticing one possible aftereffect of behavior: the inhibition of other sources of reward.

There are some psychological processes that temporarily inhibit the capacity for other processes to generate reward. For instance, pain and fear cause hungry animals not to eat available food, even though the painful stimulus is not contingent on eating, and even though the same painful stimulus interferes much less with the performance of operants to make food available (Masserman & Pechtel, 1953; Solomon, 1964). This situation argues for Solomon's (p. 242) suggestion that punishment "kills the appetite." Probably any reward-getting activity that requires a particular mental set will be inhibited by stimuli that distract attention to too great an extent. A process which is intensely but briefly rewarded and which interferes with other sources of reward for a time after it has occurred will be temporarily attractive but costly in terms of aggregate reward (Figure 8A). If there exists an intense reward that satiates rapidly but whose rewarding potential regenerates almost as rapidly, it can produce the situation depicted in Figure 8B: a recurring specious reward which is dominant only just before it is due and which the organism is strongly motivated to avoid at other times.

Such a process is visible in the behavior of people who have a sore tooth, an aphthous ulcer, or other kinds of sores. They report an urge to bite or worry these sores to produce a brief, pungent sensation (e.g., James, 1890, vol. 2, p. 554). However, the constant opportunity to do this is a "distraction," a tax on the attention paid to more rewarding activities, and sores are regarded as a nuisance that people go to doctors to be rid of. An analogous argument can be made for itches, which people generally try to avoid or mollify, despite the fact that scratching can be intensely pleasurable for a moment. It would seem to be the cyclic nature of this reward, the drive's periodic intrusion into consciousness to disrupt ongoing thought in return for

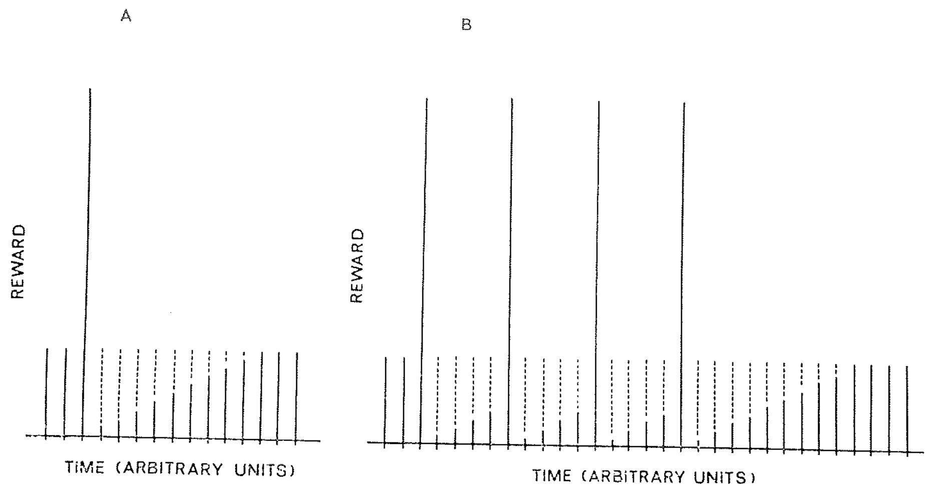

FIGURE 8. Graphic representation of brief, intense rewards which temporarily inhibit a continuing, less intense pattern of reward: A, a single, intense reward; and B, a recurring, intense reward. (The reward lost due to inhibition is represented by dashed lines.)

a brief reward, that makes people avoid incurring itches, put anesthetic lotion on them, or simply make personal rules against scratching. If such a cycle occurred more rapidly, perhaps several times a second, an organism might not perceive the successive phases of increased and decreased reward. As in flicker fusion, they would sum to a single stimulus that had the features of each. Behaviors such as attention, which could respond quickly to rapid changes in incentive, would tend to seek the brief, intense reward whenever it was available. Behaviors with longer latencies, such as muscle movement, would be governed by the incentive that was dominant most of the time. Thus, a recurring opportunity for intense but rapidly satiating reward could produce a motivational pattern identical to punishment.

The above proposal does not imply that punishment is really any less aversive than we have always thought. Although it has recently been shown that a particular experimental history can make animals seem to work for electric shock (Kelleher, Riddle, & Cook, 1963; McKearney, 1969; Pomerleau, 1970), this seems better explained as subjects' confusion about the true response contingencies (Dreyer & Renner, 1971) than as the unmasking of a rewarding effect capable of sustaining muscular behavior.

Whether rapidly satiating reward should produce a pattern of punishment or a more neutral pattern, like premature satiation (Figure 7), probably depends on two factors: (a) the effectiveness of the reward at the time it can be chosen, and (b) the extent to which a choice of the reward interferes with other sources of reward. The former factor includes the intensity and duration of the reward and the lag from the time it is chosen to the time it occurs. The latter factor includes the innate inhibitory effect of each spike of reward on other sources of reward and the frequency with which these spikes can occur. Rewards with high initial effectiveness, which interfere with other sources of reward to a great extent, should act as punishments, since they can command attention at a great cost in total reward. Rewards which have low initial effectiveness or which interfere little with other sources of reward should have only a trivial motivating effect.

An event might spoil some sources of reward but not others and thus be aversive or not depending on which other rewards the organism is seeking at the time. For instance, a moderate degree of pain may add to sexual pleasure but diminish the pleasure available from food.

If this is the nature of pain, there is no intrinsic line between punishing and rewarding events. Events which excite a long period of reward relative to their interferences with other sources of reward will be sought. Those which reward briefly and spoil other sources of reward for a relatively long time afterward will be avoided. One could categorize escape as avoidance occurring between spikes of reward, rather than before the train of spikes had begun. Psychological devices which help people "overcome" unavoidable pain (hypnosis, distraction, Lamaze childbirth) may act by somehow preventing the availability of the specious rewarding effect of the pain from influencing their attention-directing behavior. The perception of aversive stimuli could thus be added to the long list of impulsive behaviors that have been proposed in this article. But at this point we are clearly outrunning the data that have suggested these proposals.

Summary

This article has reviewed representative works on impulsiveness and impulse control in the several behavioral sciences that have studied them. Particular note has been taken of recent experiments which suggest that delaying rewards from the moment of choice causes them to lose effectiveness according to a highly concave function of that delay. Assuming, perhaps precociously, that this function describes delayed reward in general, I have compared its properties with existing reports about several areas of behavior:

1. Highly concave delay curves from some pairs of smaller–earlier and larger–later alternative rewards can cross, predicting an initial preference for the larger reward, which changes in favor of the smaller (*specious*) reward as the smaller reward becomes imminently available. This description accords with an intuitive view of what temptation is like. It implies three kinds of devices to forestall temptation, all of which have been described in the literature: (a) those which rearrange the reward contingencies so that the earlier alternative is never preferred; (b) those that irreversibly constrain future behavior so that an earlier, specious alternative cannot be obtained when it is preferred; and (c) those that direct attention so that cues about the availability or proximity of specious alternatives cannot be obtained. The fact that pigeons will learn a device of type b suggests that neither impulsiveness nor the capacity to learn a device for impulse control depend on social learning or other higher functions.

2. The tendency of animals to seek timeouts from poor schedules or reward, but not from completely unrewarding schedules, may be an example of a precommitting device.

3. If we make the rather conservative assumption that multiple rewards combine in some additive way, then we can expect some rewards to act in concert with one another. The simplest example would be the combination of a small–early reward and a large–late reward to motivate avoidance of a middle-sized alternative which would be available at an intermediate time. This might account for phenomena like delinquent behaviors that "ask" for controls.

4. Whole sets of large–delayed rewards are more resistant than single large–delayed rewards to the temporary attractiveness of small–immediate rewards, even when the small rewards are also grouped into sets. Sets may be created when a person perceives his own current choice behavior as a cue predicting similar preferences in the future. Because a person who perceives himself rejecting one delayed reward in a set thereby gets a cue predicting that he will not obtain any of the delayed rewards in the set, he may come to weigh the whole set of delayed rewards against the set of immediate rewards at each choice point. Signs of this kind of set formation can be seen in obsessive–compulsive neurosis as well as in private rules and in the activities called oath taking, effort of will, and self-reward.

5. It would be expected that patterns of consuming a reward that produce the greatest early rewarding effect would tend to be learned. Where a person's rapid consumption reduces overall effectiveness of the reward, devices to forestall rapid consumption might be learned at some time before the reward is available. Such devices may be visible in behaviors that seek challenge, unfamiliar stimuli, and risk, which at first glance, look like attempts to reduce reward.

6. If a particular capacity for reward can be rapidly satiated when it is attended to and rapidly regenerated again, it may interfere with other sources of reward without itself producing much total reward. Such a brief reward might be able to control short-latency responses like attention, which could obtain

the reward virtually at once, but not responses with longer latencies like muscle movement. This recurring, brief reward would take on the character we are familiar with as pain: unrewardingness combined with irresistible attraction of attention.

The foregoing proposals are not presented as mature theories but as examples of the kind of hypotheses that emerge readily, given highly concave curves of reward effectiveness as a function of delay. Such curves have been demonstrated only by the relatively narrow avenues of experimentation described earlier in this article. The theoretical fertility of these curves argues for expanded experiments on this particular parameter of reward.

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