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Contingencies of Reinforcement and Behavioral Momentum: Research and Applications

Contingencias de reforzamiento y momento conductual: Investigación y aplicaciones

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Abstract

A discriminative operant is defined by the combination of an antecedent stimulus, a response, and a reinforcer. The response-reinforcer contingency determines the rate of the response, and the stimulus-reinforcer contingency determined the resistance to change of that response rate. The product of response rate and its resistance to change is characterized metaphorically as behavioral momentum. This article describes some basic research on the determiners of momentum and discusses some applications of momentum analyses in clinical and educational settings. Some more speculative applications to business and industry, international war, and problems of sustainable development are also considered.

Key words: contingency, behavioral momentum, rate of reinforcement, stimulus control.

Resumen

Una operante discriminada se define por la combinación de un estímulo antecedente, una respuesta y un reforzador. La contingencia respuesta-reforzador determina la tasa de respuesta y la contingencia estímulo-reforzador determina la resistencia al cambio de esta tasa de respuesta. El producto de la tasa de respuesta y su resistencia al cambio está caracterizado metafóricamente como el momento conductual. Este artículo describe alguna investigación básica sobre los deter-

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minantes del momento y discute algunas aplicaciones del análisis del momento en ambientes clínicos y educativos. También se consideran algunas aplicaciones más especulativas en los negocios, la industria, la guerra internacional y problemas de desarrollo sostenible.

Palabras clave: contingencia, momento conductual, tasa de reforzamiento, control del estímulo.

Ten-year-old Carlos arrives home from school and drops his book bag on the hall floor. From the kitchen, his father hears the books hitting the floor, and calls, "Hey Carlos! That you? Come on in and tell me about school. But put away those books, will you?" Carlos stows his books and joins his father in the kitchen, where they drink some juice and talk for a while about school. "Why do you always drop your stuff on the floor when you come home?" asks his father, and Carlos says "Oh I don't know, it's just, you know, like a habit."

The reader may recognize scenes like this from his or her own life. Some mildly irritating response is repeated over and over, "like a habit," even though it has no obvious function. For Carlos, we can guess that in the past, dropping his books led to attention from his parents in the form of requests and reprimands; but now, he enjoys a shared drink and a talk with his father whether he drops the books or not. Why does the response persist?

This article will argue that once some bit of behavior has been selected by reinforcement and has come under stimulus control, it will tend to persist in the face of challenges that generally decrease responding, such as reduced deprivation, extinction, or reinforcement for competing behavior. Moreover, its persistence will be greatest if it was established in an environment that included frequent reinforcers, whether positive or negative. Sometimes this sort of persistence may be desirable, even essential, as when a novice emergency medical technician who has been trained in CPR carries out the procedure successfully under the stressful conditions of a serious accident. Sometimes it may be no worse than a nuisance, as for Carlos and his father. And sometimes it may be destructive, as when a gambler who has been hooked by occasional wins continues to gamble despite heavy losses and mounting personal debt. To achieve a complete account of behavior, it is essential to understand the variables that determine its persistence when conditions are altered as well as its acquisition and maintenance.

The acquisition and maintenance of operant behavior involve the selective effects of reinforcement. For example, whether an untrained rat comes to press a lever rather than grooming or exploring depends on whether lever-pressing is selected by making food contingent on the lever press. Likewise, a high rate of lever-pressing may selected and maintained indefinitely by contingencies that provide more frequent food for rapid responding (cf. Baum, this issue). Moreover, this rate of responding may be controlled by a stimulus: If the contingencies favoring high response rates operate only while a tone is on, the rat will come to respond rapidly only when the tone is on. The result is a stable behavioral unit, sometimes called an ABC unit, where A stands for the antecedent stimulus (tone), B stands for the behavior (lever-pressing), and C stands for the consequences (food). More formally, the ABC unit is known as a *discriminated operant*, which is defined jointly by the stimulus, response, and contingencies of reinforcement.

Although many researchers, including Skinner (1938), have identified response rate with the notion of "strength," it is now widely recognized that response rate depends on the selective contingencies of reinforcement. If high-rate responding and low-rate responding are equally determined by selective contingencies on response rate, why should we call the former "strong" and the latter "weak?" Suppose, instead, that we identify the notion of strength with the extent to which that response rate resists change. For example, one might measure the decrease in lever-pressing rate in the presence of the tone by providing extra food immediately before an experimental session. If there is little or no decrease, we might call the response "habitual" or simply "strong," whereas if there is a large abrupt decrease we might call it "weak." The extent to which discriminated operant behavior resists change —its strength— can then be studied in relation to its history of reinforcement.

The metaphor of behavioral momentum

The general idea of behavioral momentum is that once a discriminated operant has been reinforced, it will tend to be repeated whenever its antecedent stimulus occurs, in somewhat the same way as an object tends to keep moving once it has been set in motion. Consider what happens when a ball is kicked: It moves forward abruptly, and then gradually slows and stops under the influence of friction. This is like what happens when a single instance of a response is reinforced: Its rate increases immediately, and then gradually decreases to zero during the course of extinction (see

Skinner, 1938, pp. 87-88). If the ball is chased and kicked repeatedly, it will keep moving at a more-or-less constant speed. This is like what happens when a response is reinforced repeatedly on a schedule of reinforcement: Its average rate of occurrence becomes roughly constant. Finally, suppose there are two balls, one light and the other heavy, and that both have been kicked repeatedly until they are rolling along at equal speeds. If both are suddenly diverted into tall grass, the heavier ball will be slowed less than the lighter ball. The same is true of behavior: Even though response rates may be the same for two discriminated operants, responding will be more resistant to disruption in the presence of the stimulus that was better correlated with reinforcement.

In classical physics, momentum is the product of two terms: velocity and mass. Newton's laws of motion state that a moving body tends to remain in motion at a constant velocity until acted upon by an external force, and when a force is applied, the change in velocity is proportional to the force and inversely proportional to the mass. Likewise, behavioral momentum is composed of two terms: the rate of responding under constant conditions, which is analogous to velocity, and the change in response rate when behavior is disrupted by an external variable analogous to an external force. The greater the disruption, the greater the change in response rate; but for a given disruption, a relatively small change in response rate implies relatively large behavioral mass.

Just as velocity and mass refer to different and independent aspects of a moving body, response rate and its resistance to change refer to different and independent aspects of behavior. Experimental research on discriminated operant behavior has shown that response rate and resistance to change are determined by different sorts of reinforcement contingencies.

Empirical analyses of behavioral momentum

Most of the research on behavioral momentum has used nonhuman subjects. For example, Nevin, Tota, Torquato, and Shull (1990, Experiment 1) trained food-deprived pigeons to peck at a key for food in a multiple schedule of reinforcement. The schedule components were defined by lighting the key alternately green and red for three minutes, separated by a one-minute timeout. In the green component, pecking was reinforced according to a variable-interval (VI) 1-minute schedule: that is, the first peck to occur after an unpredictable period averaging 1 minute was followed immediately by 3 seconds' access to food. In the red component, an identical schedule of

reinforcement was in effect for pecking, and in addition, food was given independently of pecking at unpredictable intervals averaging 30 seconds (known as a variable-time (VT) 30 second schedule). These baseline conditions established two discriminated operants defined by the green and red key lights and the different reinforcement contingencies for key-pecking correlated with each color.

The procedure was designed to pit the response-reinforcer contingency against the stimulus-reinforcer contingency. Food was better correlated with pecking in the green component than in the red component (the response-reinforcer contingency) because no other behavior was ever followed by food when the key was green, whereas both pecking and other behavior were followed by food when the key was red. However, food was better correlated with the red key light than with the green key light (the stimulus-reinforcer contingency) because of the added food when the key was red.

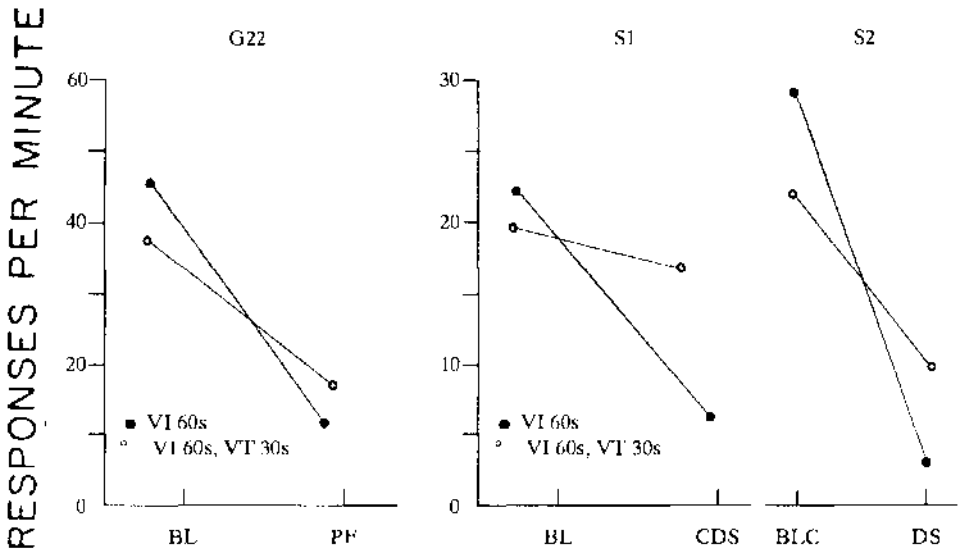
Under these baseline conditions, which were in effect for 32 daily sessions, all pigeons pecked at a higher rate in the green component than in the red component. This difference in response rates is consistent with the difference in response-reinforcer contingencies. However, when resistance to change was tested by providing food before the experimental session (prefeeding), or by withholding food altogether (extinction), the rate of responding decreased less when the key was red than when it was green. This difference in resistance to change is consistent with the difference in stimulus-reinforcer contingencies. The left-hand panel of Figure 1 portrays the prefeeding results for the median pigeon.

Similar results have been obtained with two retarded adults sorting red or green plastic dinnerware with coffee or popcorn reinforcers, where resistance to change was tested by turning on a television set (Mace, Lalli, Shea, Lalli, West, Roberts, & Nevin, 1990). The right panels of Figure 1 show that the results for both humans are remarkably similar to those for the median pigeon. Most recently, these results have been repeated with college students engaged in a computer-controlled typing task with points as reinforcers, where resistance to change was tested by giving them a "Where's Waldo" puzzle book (Cohen, 1994). The findings of some related experiments with pigeons (e.g., Nevin, 1984; Nevin, Smith, & Roberts, 1987; Nevin, 1992) join the results described above to suggest the following conclusions:

a) The selective effects of the response-reinforcer contingency determine response rate maintained in baseline conditions. In terms of the ABC unit, this is a B-C relation.

b) The strengthening effects of the stimulus-reinforcer contingency determine resistance to change when baseline conditions are altered. In terms of the ABC unit, this is an A-C relation.

Figure 1



The left panel shows the rates of key-pecking for the median pigeon in a multiple schedule with a VI 60s schedule of food reinforcement in one component, and an identical VI 60s schedule with additional response-independent food delivered according to a VT 30s schedule in the other component (adapted from Nevin et al., 1990). The data points over BL (baseline) represent maintained response rates during training, and the data points over PF (prefeeding) represent response rates when performance was disrupted by giving food immediately before a test session. The right panels show the rates of dinnerware sorting for two human subjects exposed to the same schedules. The data points over BL (baseline) represent maintained response rates during training, and the data points over CDS (concurrent distracting stimulus) represent response rates when performance was disrupted by turning on a television set (adapted from Mace et al., 1990).

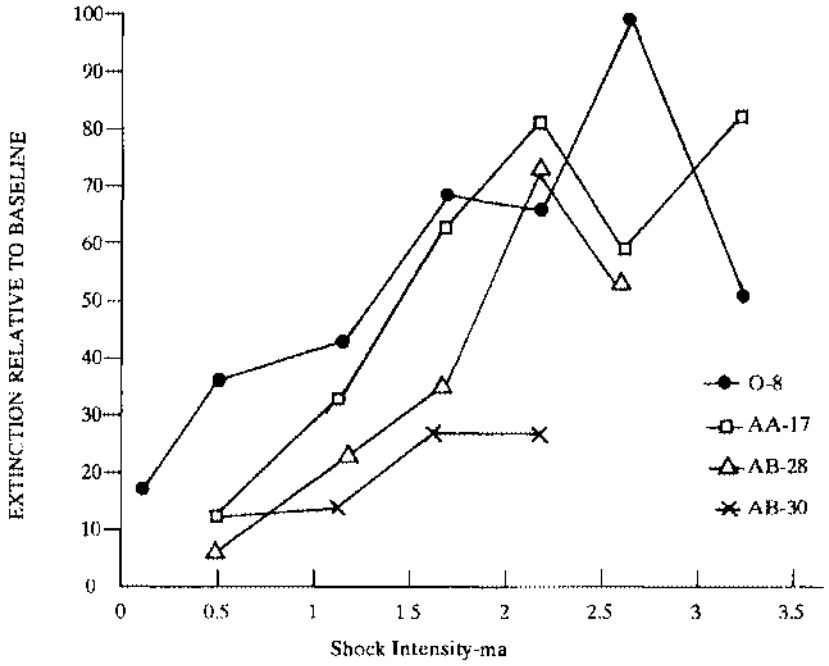
The hypothetical case of Carlos, who "habitually" drops his books whenever he returns from school, can be understood in these terms: Book-dropping may have been selected by the attention it received, and now it may persist for a long time because his return home is correlated with a variety of reinforcers.

Nearly all of the research on behavioral momentum has employed positive reinforcers. However, there is some evidence that the mass-like aspect

of behavior may depend similarly on the frequency, intensity, or contingencies of negative reinforcement. For example, Boren, Sidman, and Herrnstein (1959) found that the rate of lever-pressing during extinction after shock avoidance training, expressed relative to stable lever-pressing rates in baseline, increased with the intensity of shock used during training, as shown in Figure 2. This result is similar to the finding that resistance to extinction is positively related to the amount of food reinforcement in a component of a multiple schedule (Shettleworth & Nevin, 1965).

Figure 2

From Boren et al. (1959)



Total responses during a three-hour period of extinction after avoidance training for four rats, expressed relative to baseline response rates and plotted as functions of shock intensity during baseline avoidance training (adapted from Boren et al., 1959).

With respect to the stimulus-reinforcer contingency, Sidman, Herrnstein, and Conrad (1957) showed that responding during extinction after avoidance

training is enhanced by stimuli correlated with unavoidable electric shock. This effect of the stimulus-shock relation is similar to the effects of the stimulus-food relation described above. Tentatively, it appears that the principles of behavioral momentum apply equally to positive and negative reinforcement.

Clinical applications

Understanding the determiners of resistance to change is especially important when efforts are made to eliminate some undesirable behavior such as self-injury. The people who take care of a child who hits or bites herself almost inevitably attend to her and comfort her whenever she injures herself, and self-injurious behavior of this sort may be maintained by the reinforcing effects of attention. Therefore, common methods for reducing self-injurious behavior involve attending to the child only when the self-injury has not occurred for some time (a contingency known as differential reinforcement of other behavior, DRO) or when some desirable behavior is occurring (a contingency known as differential reinforcement of alternative behavior, DRA). However, DRO is not always effective unless coupled with other procedures (e.g., Mazaleski, Iwata, Vollmer, Zarcone, & Smith, 1993). The reason may be that self-injurious behavior may be maintained in part by its sensory effects, and adding social or attentional reinforcers, even if for other behavior, strengthens the overall situation-reinforcer contingency and thereby makes the undesired behavior more persistent.

Some specific evidence on the effects of DRA has been reported by Mace (1991), who explored ways to eliminate food-stealing by a retarded child. Mace evaluated the persistence of attempts to steal food when each attempt was blocked so that it went unreinforced. The child's persistence in attempts to steal food despite blocking depended on how food-stealing had been treated during a series of sessions preceding blocking. In the no-treatment baseline, food-stealing occurred nearly 100 times per hour, but blocking reduced theft attempts to near zero in four sessions. In a separate phase of the study, explicit reinforcement for appropriate behavior at table (DRA) reduced food-stealing to about 10 times per hour, but then over 30 sessions of blocking were needed to reduce theft attempts to zero. Thus, alternative reinforcement for appropriate behavior both reduced the rate of the undesired behavior by changing the response-reinforcer contingency, and increased its persistence as a result of changing the situation-reinforcer contingency, exactly as found in basic research on behavioral momentum.

To avoid strengthening undesired behavior by adding alternative reinforcement, it may be best to eliminate all reinforcers —that is, to arrange extinction (e.g., Mazaleski et al., 1993). However, it is not easy to eliminate reinforcers that occur naturally, as a part of the behavior itself. For example, feeling high is a natural reinforcing consequence of drinking alcohol, and it cannot be eliminated without aversive chemical intervention.

If extinction cannot easily be arranged, it may be helpful to arrange reinforcement for alternative behavior in a totally different setting. A total change of setting is like imposing a powerful external force on a moving object: There should be a large decrease in the undesired behavior. Equally important, the added reinforcers will not be correlated with the environment in which the undesired behavior had occurred. For example, the abuse of alcohol can be eliminated quite effectively in an in-patient treatment center, which is very different from the drinker's natural home environment, by any of a number of procedures including positive reinforcement for refraining from drinking.

A general problem for behavior modification is to make the changes established in a special controlled environment, such as an inpatient clinic, persist when the client returns to his or her natural home environment. For example, when former drinkers return to their home environments where they had abused alcohol before inpatient treatment, relapse is very likely, especially under conditions of stress or loss. How might we design a program to make abstinence generalize to the home environment, and then be maintained in the face of cues and temptations provided by that environment —that is, to endow abstinent behavior with high mass? One way to facilitate generalization is to continue providing the reinforcers that were available in the treatment center within the home environment, thus making the two situations more alike (cf. Koegel & Rincover, 1977). If these reinforcers are supplemented with a variety of other reinforcers through continuing outpatient treatment, the environment-reinforcer correlation should make abstinence more persistent even if those reinforcers are unrelated to abstinence. The effectiveness of Azrin's (1976) community-based reinforcement program for recovering alcoholics may be understood in these terms.[2]

2 I thank Tom Critchfield for this observation.

Applications in education

Ordinarily, classroom instruction is designed to establish correct performance on a variety of problems within the classroom itself. For example, instruction and practice in arithmetic is expected to establish competence in basic operations such as addition and subtraction as evaluated by performance on tests in class. However, it is at least equally important that a child be able to perform well on numerical problems in other classes or in everyday life. This is an issue of behavioral momentum: Students should be able to respond rapidly and accurately in class (high velocity) and use their classroom skills effectively in other settings, regardless of disrupting events, for the rest of their lives (high mass). Rapid, accurate responding is known as fluency, and classroom skills are more persistent through time, more resistant to distraction, and better remembered after overtraining to fluency than after bare mastery (e.g., Binder, Haughton, & Van Eyk, 1990; Lindsley, 1992).

Fluency can be established for a broad range of students and course material by a method known as precision teaching, under which students graph the results of timed tests —for example, the number of subtraction problems completed per minute— in a way that directly exhibits their rates of improvement over time. The added persistence that follows from fluency training may well result from the additional reinforcement that derives from seeing the graphed data points move upward, and from the social reinforcement that students seem to derive from the entire fluency-learning process.

When a student learns arithmetic, consequences such as corrective feedback, approval, points, test grades, and advancement to more complex material are surely necessary to establish and maintain rapid, accurate performance. But a variety of additional reinforcers in the classroom, such as access to magazines, computer games, and cooperative building projects, may help to make that performance more persistent. This is only a guess, based on the laboratory research and clinical examples described above, but at the least, additional noncontingent reinforcement of this sort should serve to make school more enjoyable, and students are likelier to persist in attending school (rather than dropping out), thereby encountering new information and learning to solve new problems, if school is an attractive place to be. Much remains to be learned about how to make education more effective for more people, and ideas from the study of behavioral momentum may prove useful in this endeavor.

Applications in business and industry

As we move farther from the tightly controlled conditions of the experimental laboratory, and the relatively controlled conditions of the clinic and classroom, it becomes harder to identify antecedent stimuli or reinforcers and to interpret events unambiguously in relation to behavioral momentum. Also, as we shift our emphasis from individual to group behavior, we must assume that groups behave in ways that are functionally similar to individuals. Nevertheless, interpretations based on laboratory findings can be helpful. For example, effective management techniques for groups in business and industry seem closely related to those determining velocity and mass for individuals in experimental, clinical, and educational settings. In particular, the approach known as "total quality management" involves employees in teams that identify problems, propose solutions, monitor their effectiveness on the basis of data, and thereby enhance the individual performances of team members and corporate achievement by the team. In its emphasis on data and accomplishment, the approach may be analogous to the establishment of fluency through precision teaching, and its effectiveness might be enhanced by explicit reinforcement contingencies (e.g., Mawhinney, 1992).

Contingencies may be even more important when economic conditions turn for the worse. For example, when times get tough and layoffs are threatened, the persistence of extra effort on the job may be increased by a history of frequent recognition of accomplishments and other social reinforcers -- and just might keep a company in business. Ideas derived from the study of behavioral momentum could prove useful in organizational behavior management, which is largely concerned with specifying desirable behavior and reinforcement contingencies in the workplace.

Some aspects of behavioral momentum may also help us to understand the tendency for institutions to become committed to a course of action that was once promising (if not outright successful) and to invest ever-greater resources in efforts to avoid failure. This pattern is known as "escalation" in the literature of business administration (e.g., Staw & Ross, 1989), who cite the collapse of Pan American Airlines as an example.[3] Pan Am was the first airline to make scheduled transoceanic flights, and it rapidly built a reputation for reliability as its service expanded to cover most of the globe. As it grew, it diversified into real estate and hotels.

3 I thank Don Hantula for introducing me to the literature on escalation.

However, it was hit hard by the deregulation of the airlines industry, and sold off the Pan Am Building and then its Intercontinental Hotel chain in order to meet its debts and keep its aircraft flying. Finally, it was forced to sell some of its airline routes, and eventually succumbed to bankruptcy. From the standpoint of corporate survival, it would probably have made more sense to sell off the airline routes as soon as their losses became obvious, and keep the profitable real estate and hotels. However, Pan Am persisted in efforts to maintain its international airline operation, which had a long history of positive reinforcement. Moreover, efforts to salvage the airline by liquidating other assets avoided failure temporarily, thus adding a history of negative reinforcement. As its fiscal crisis worsened, Pan Am's persistence in a failing business strategy seems consistent with the principles of behavioral momentum.

Momentum and War

The United States' involvement in the Vietnam War was a classic case of escalation, in the sense of investing ever-greater resources in a failing course of action. And its escalatory character was predicted early in the war by George Ball, then Undersecretary of State, in a memorandum to President Johnson:

> "Once large numbers of U.S. troops are committed to direct combat, they will begin to take heavy casualties in a war they are ill-equipped to fight in an uncooperative if not downright hostile countryside. Once we suffer large casualties, we will have started a well-nigh irreversible process. Our involvement will be so great that we cannot — without national humiliation — stop short of achieving our complete objectives. Of the two possibilities I think humiliation will be more likely than the achievement of our objectives -- even after we have paid terrible costs" (1 July 1965; quoted from *The New York Times* by Staw & Ross [1989]).

Ball correctly anticipated the course of events in Vietnam, and, in hindsight, those events can be interpreted in relation to the principles of reinforcement and momentum operating at the national level. Before Vietnam, the US had won its international wars: The Spanish-American War, World War I, World War II, and the Korean War, the latter of which ended in a political stalemate but was a military victory for the US in the sense that it lost far less of its combat forces and equipment than North Korea and China, and prevented North Korea from achieving its goals. Also, the US had also achieved its political and economic goals in Latin America

through repeated military intervention throughout the 20th century. In effect, the US had a substantial history of reinforcement for military intervention and warfighting —a history that can be seen as selecting military intervention over economic and political alternatives in dealing with Vietnam, and making the pursuit of armed victory highly resistant to change despite growing losses and evidence of failure.

This pattern is not unique to the US, but holds also for all the established nations of the world for the past five hundred years. Nations that have won their previous wars are more likely to start their next wars than nations that have lost —and the difference increases with the number of preceding victories increased, which is consistent with the selective effect of reinforcement (Nevin, 1995). Winners were also quicker to start their next wars than losers. Thus, warmaking by victorious nations seems to acquire a sort of momentum and persist despite the death and destruction and social disruption that inevitably accompany war, for winners as well as losers. In that respect, warmaking is similar to the resistance to disruption of frequently reinforced key-pecking by pigeons. Of course, each individual conflict between nations is set in a unique context that combines with their military histories of reinforcement to determine whether the conflict will escalate to war, but an understanding of the general principles of behavioral momentum may help humankind to eliminate this particular form of self-injurious behavior from its repertoire.

Population, Resources, and Sustainable Development

The advent of nuclear weapons has made warfare potentially suicidal as well as self-injurious for *homo sapiens*, but the threat of general nuclear devastation seems fairly remote as I write. A different sort of threat to the survival of our species arises from the explosive growth of the world's population and the need for resources to achieve a decent standard of living for all. The industrially developed and economically advanced nations have established a remarkable level of health, education, and well-being for most of their citizens, but only at the cost of overconsumption, pollution, and environmental degradation. Similar advances are desperately needed by the developing nations, but can they be accomplished without total collapse of the global environment that sustains all of us?

Consider the problem of food production, which is central to our lives. With the growth of population and agricultural technology, food production has become a big business, with a host of adverse side effects that fol-

low from heavy use of fertilizers and pesticides, most notably soil depletion and water pollution. But agribusiness depends on these methods for its profits, and people all over the world depend on its products for their nutrition. As population increases, the intensity of land use for large-scale food production is likely to increase, and the side effects may become devastating. Traditional alternatives such as crop rotation and diversification are being practiced on a small scale in many parts of the world, without the adverse effects of large-scale single-crop production methods, but can they be adopted widely without severe economic disruption and risk of famine?

This is not the place to explore the complex of interlocking cultural, economic, environmental, political and technical problems that humankind must overcome to achieve a stable population and long-term sustainable development, but considerations of behavioral momentum suggest that huge difficulties lie ahead. Most of the people living in the advanced nations have enjoyed a high level of material well-being for a number of years, and their high-consumption lifestyles are going to be extraordinarily resistant to change. The same is likely to be true for the exploitative and polluting practices of large-scale free-market capitalism, which have been richly reinforced by corporate profits. When the resources that support material well-being become truly scarce, and the unfettered growth of global capitalism becomes even more obviously destructive for the planet, the principles of behavioral momentum suggest that humankind's acquisitive behavior will persist and lead to calamity unless some revolutionary changes bring it to a halt. If the science of behavior can help people to understand their own actions and accomplish the necessary changes, it will have made a magnificent contribution to the future.

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