Title
Behavior-analytic approaches to decision making

Journal
Behavioural Processes, 66(3)

ISSN
0376-6357

Author
Fantino, Edmund

Publication Date
2004-06-01

Peer reviewed

Behavior-Analytic Approaches to Decision Making

Edmund Fantino

University of California, San Diego

Address Correspondence to:

Edmund Fantino

Department of Psychology, 0109

U.C. San Diego

La Jolla, CA 92093-0109

(858)-534-3927

e-mail: efantino@ucsd.edu

Inclusive word count: 7107

Abstract

Behavior analysis has much to offer the study of phenomena in the area of judgement and decision making. We review several research areas that should continue to profit from a behavior-analytic approach, including the relative merit of contingency-based and rule-governed instruction of solving algebra and analogy problems, and the role of conditioned reinforcement and the inter-trial interval in a type of Prisoner's Dilemma game. We focus on two additional areas: (1) the study of base-rate neglect, a notorious reasoning fallacy and (2) the study of the sunk-cost effect, which characterizes ill-conceived investment decisions. In each of these two cases we review studies with humans and pigeons as subjects.

Key Words: Choice; Decision-making; Base-rate neglect; Sunk-cost effect; Prisoner's Dilemma; Conditioned reinforcement

1. Introduction

Behavior analysts have been studying decision making intensively for several decades. Indeed much of the enthusiasm for organizing the Society for the Quantitative Analysis of Behavior (SQAB) came from researchers investigating quantitative models of choice in a variety of settings. Behavior analysts have also contributed to the development of procedures designed to facilitate investigation of the variables controlling the choices we make, including concurrent schedules, concurrent-chains schedules, successive-encounters procedures, and various self-control and matching-to-sample procedures. Thus, behavior analysts are in an excellent position to contribute to a wide spectrum of problems and issues in the large domain of judgement and decision-making (e.g., Fantino, 1998a,b; Stolarz-Fantino and Fantino, 1990, 1995). Yet, especially where human decision-making is concerned, researchers from other specialty areas dominate the field of judgement and decision-making. These include cognitive psychologists, social psychologists, cognitive scientists, behavioral ecologists, and economists. I believe that behavior analysts are in a strong position to make fundamental contributions to the field of judgement and decision making. In this paper I review the beginnings of an effort from our laboratory to apply the theory and methodology of behavior analysis to some of the central problems of decision making.

In this paper I address four areas in which behavioral principles are clearly implicated in decision making. Research in problem solving, the sunk-cost effect and base-rate neglect all suggest that poor decisions sometimes result from the misapplication of rules. Research on the Prisoner's Dilemma, the sunk-cost effect, and base-rate neglect all suggest an important role for discriminative stimuli in fostering more optimal decisions. Research on the sunk-cost effect and on base-rate neglect study pigeons and people in comparable situations in the hope of better identifying the principles at work. While the emphasis of this paper will be on poor decisions relating to "sunk costs" and "base-rate neglect", some initial research on different instructional techniques and on the Prisoner's Dilemma Game will first be discussed.

2. Rule-Governed and Contingency-Shaped Behavior

The role of rules in problem solving and in transfer has been discussed increasingly by behavioral psychologists. This issue interested B. F. Skinner who defined a rule as a *contingency-specifying stimulus* (Skinner, 1969). He argued that, in general, behavior under the control of rules differed from behavior controlled directly by the behavioral contingencies specified by the rules. For example, when one learns to speak Italian by following a set of grammatical rules in a text, one’s Italian will differ from spoken Italian learned directly by the consequences supplied by an Italian-speaking community (see Hineline and Wanchisen, 1989). Importantly, results from the behavior-analytic laboratory have suggested that *rule-governed* (that is, instructed) behavior is often -less sensitive to changes in environmental contingencies than is *contingency-shaped* behavior (e.g., Catania, Shimoff, and Matthews, 1989; Galizio, 1979; Kaufman, Baron, and Kopp, 1966; Hackenberg and Joker, 1994). For example, Kaufman et al. (1966) gave humans responding on a variable-interval (VI) schedule of reinforcement either accurate or inaccurate instructions about the actual schedule in effect. Some misinformed subjects were told that reinforcement would occur on a variable-ratio (VR) schedule; other misinformed subjects were told that a fixed-interval (FI) schedule was in effect. Despite three hours of exposure to the VI schedule, subjects' behavior was under control of the presumed (VR or FI) schedule of reinforcement. In other words, the instructions overrode the effects of the VI schedule of reinforcement actually in effect. In a sense, then, behavior under instructed control appears to be insensitive to the prevailing contingencies. As both Galizio (1979) and Hackenberg and Joker (1994) have demonstrated, however, this insensitivity can itself be understood in terms of the subjects' prior experience with rules and instructions. In general, the results cited are consistent with the view of Skinner, mentioned above and with results from classic experiments on problem solving reported by Luchins (1942) and by Luchins and Luchins (1950).

We are trying to assess the applicability of the rule-governed versus contingency-governed distinction to transfer from learning on one set of problems to another (e.g., Fantino, Jaworski, Case, and Stolarz-Fantino, 2003) and to do so in more applied and naturalistic settings. Thus, we are exploring the extent to which rule use allows flexibility of problem solving (and transfer to new problem types) in school children of different ages. To date we have used simple math problems, including word or "story" problems, and verbal analogies. In one study (Glaz, Stolarz-Fantino, and Fantino, 2001) participants were 104 6th grade students at a middle school (about 11 years of age). Students were randomly assigned to one of three groups: an instructed rule group whose students received detailed instructions by their regular teacher for solving a set of practice problems, all of which involved making round-trips of some distance a certain number of times per hour, day, week, etc. The teacher presented an example. All problems could be solved by the same rule (X = 2 x Distance x Number of trips). Students in the induced rule group received the same set of practice problems but were not instructed on how to solve them. Finally, students in the changing rules group received no instruction nor could their set of problems be solved by a single rule--each problem was different from the others. Students received feedback after each problem. After reaching a criterion of correctly solving three consecutive practice problems, students moved on to the transfer phase of the study. Since the problems in both rule conditions could be solved only by the rule above, meeting criterion necessarily meant having learned the rule.

The transfer phase of the study consisted of two sets of three test problems, presented in counterbalanced order. These problems could all be solved by the same rule, though a different rule from the practice problems. All involved finding out how much time was spent per unit of work and could be solved by the following rule: X = 60 T/N where T is time and N is the number of work units. In this phase of the study students received no feedback. Glaz *et al.* (2001) found that students who learned the rule on their own during the practice phase (the induced-rule group) did best on the novel test problems during the transfer phase; the number of problems solved by students in the instructed rule group and in the changing rules group were about equal. In addition, students in both the instructed rule and induced rule groups improved from their first to second test problem sets while students in the changing rules group did not improve. Thus, these results also suggest that rule-based problem solving (whether instructed or induced) need not be inflexible. They further suggest that induced learning may be particularly effective in promoting flexible problem solving in a transfer test, at least for children.

Sasada (2003) has obtained similar results in a study using verbal analogy problems with 80 4^{th} grade elementary school students (about 9 years of age). Students in the instructed and induced rule groups solved practice analogies of the form “action to object" (*e.g.,* hear: sound :: see: picture); those in the third group received a set of analogies of mixed types. In the transfer phase, all students solved a set of analogies of the form "part to whole," (*e.g.*, carrot: plant :: cow: animal). The results were consistent with those reported by Glaz *et al.*: Sasada found that the students in the induced-rule group scored significantly higher on the transfer analogies than the instructed-rule and changing rules groups, which did not differ from one another.

These results are also consistent with much of the literature on rule-governed and contingency-shaped behavior discussed above. Students in the induced-rule groups of the present studies are comparable to "self-instructed" students discussed by Rosenfarb, Newland, Brannon, and Howey (1992) and by Hackenberg and Joker (1994). It can be argued that the self-generated rules of the "self-instructed" students are more directly shaped by the contingencies than the rules explicitly given by the teacher or experimenter. At least for the settings of the present experiments, and for children, self-instructed behavior appears more sensitive to changing contingencies than does instructed behavior.

Rule-governed behavior may lead to more or less sensitivity to changing consequences, depending on the nature of the rule and on the type of contact with the consequences that the rule engenders (e.g., Joyce and Chase, 1990). The interaction of the rule with the novel contingencies and both the historical and contemporary context in which the interaction occurs, largely determines whether the rule is applied fruitfully or misapplied. For example, Fantino et al. (2003) found, in a study with college students and a simple algebra problem, that rule use was not counterproductive in a transfer design and that instructed rules were as effective as self-instructed rules.

3. The Prisoner's Dilemma Game

Another research area of current interest that also has potentially important ramifications for human performance is the use of the Prisoner's Dilemma Game to study impulsive behavior and self-control. This work has been pioneered by Howard Rachlin and his students (e.g., Rachlin, 2000) in a series of elegant studies which has raised intriguing possibilities for the further study of choice in a manner that has direct relevance for students of decision making from a cognitive and social persuasion. In the basic procedure, as Steve Meyer and I have adapted it for his Master's thesis research (Meyer, 2003), the subject begins with a choice between opening either of two boxes located at the top of the computer screen. The two outcomes associated with these two boxes are $6 and $5. If the student chooses the larger reward ($6) this choice also brings him a green key for the next trial. The green key will open only the lower two boxes associated with a choice of $2 or $1. Thus, after choosing the larger reward, the student must choose between smaller payoffs on the next trial. On the other hand, whenever the student chooses the lesser of the two rewards a red key is earned. The red key opens the two upper boxes, meaning that the student chooses between the larger payoffs ($6 and $5) on the subsequent trial. In our research completed thus far the student has no opponent. In a sense (and this is the sense Rachlin and his students explicitly adopt), the student is playing against himself. And in this sense, this version of the Prisoner's Dilemma game provides a study of self-control. For the values we have selected, it is optimal, in terms of maximizing total reward, for the student to always opt for the smaller reward (a type of self-control). Choice of the larger reward may be viewed as an impulsive choice (somewhat more reward now, considerably less reward later).

Thus far we have examined three variables. The first is the probability that the computer will follow a "tit- for-tat" strategy: if the subject chooses the smaller reward so does the computer; if the student chooses the larger reward, so does the computer. In the condition we described above, selection of the smaller of the two rewards on a given trial always leads to choice of the larger rewards on the next trial and choice of the larger reward always leads to a choice of the smaller rewards on the next trial. But we have also studied conditions in which the probabilities are less than 1.0, including the case in which the subject's choice does not affect the overall rate of reward (the "indifference point"). When the subject is playing against an opponent deviation from a cooperative "tit-for-tat" strategy is viewed as a "defection" and this probability has been termed "probability of reciprocation" (PR). Second we have studied the effect of the inter-trial interval on the degree of impulsivity shown. Third we have studied the effect of allowing the subject to see the key associated with the next trial (i.e., the red or green key indicating the choices on the next trial) during the inter-trial interval.

Before summarizing what we have discovered so far, we should acknowledge that our research is in an early stage. First of all we have used only hypothetical rewards thus far (the points earned are not exchangeable for money). Second, we view the condition in which the subject is playing against himself as a baseline condition against which to assess the effects of social variables. For example, the opposing player could be a silent computer, a computer that is offensive when it defects ("Gothca!"), another student, a student who is offensive when he defects, an adolescent, etc.

Our results on varying the probability were orderly and in the expected direction: the more likely that choice of the smaller reward led to a choice between larger payoffs on the next trial, the more frequently the smaller reward was chosen. There was a strong bias towards impulsive choices, however. When the probability was at the indifference point (choice of the larger and smaller rewards had the same effect on the ultimate amount of reward earned) there was a marked tendency to choose the larger reward (close to 85%, averaging over all subjects in all conditions).

The results varying the inter-trial interval were novel and, perhaps, unexpected. As the inter-trial interval increased the negative consequence of choosing the larger reward was increasingly delayed. Specifically, if choosing the larger reward is punished by the fact that the next trial offers only the two smaller payoffs, then delaying that punishment might be expected to increase selection of the larger reward (more impulsive and fewer self-control choices). There is a second reason for predicting that increasing the inter-trial interval might lower the degree of self-control (that is, lower the proportion of smaller rewards selected). According to Rachlin (e.g., Rachlin 2000), trials closely bunched together enhance the opportunity for response patterning. That is, it is more likely that subjects will treat a series of trials as a functional unit if they are bunched closely in time. Rachlin has noted that response patterning, in turn, facilitates self-control. Again the prediction, based on this view, would be for less self-control with longer inter-trial intervals. Instead we found precisely the opposite. Whatever the effectiveness of delayed punishment and of response patterning, the effects of these variables were overridden by other consequences of the inter-trial interval. We found significantly <u>more</u> self-control the longer the inter-trial interval (in the PR conditions for which self-control responses were optimal. i.e., with PR = 1 and .81). One reason may be that the longer inter-trial interval gave subjects more time to discriminate the contingencies, a possibility that we intend to explore by including an interfering task during the inter-trial interval. A second reason may relate to the third variable we studied: the presence or absence of the key during the inter-trial interval. The data suggested that the effect of the inter-trial interval may be more pronounced when the key signaling the choices on the next trial is present. Our results on the inter-trial interval are consistent with those of Silberberg, Murray, Christensen, and Asano (1988). They found that human subjects were more risk-averse in a gambling situation the longer the inter-trial interval. If gambling is considered impulsive, then these results are similar to ours (less gambling or impulsive choice the longer the inter-trial interval).

The studies conducted by Rachlin and his students using the Prisoner's Dilemma did not vary the inter-trial interval. Thus, events during the inter-trial interval could not be manipulated. For half of our subjects the key reliably correlated with the next trial was on the screen during the interval. The key was an accurate cue for the choice that would be offered on the next trial even in the conditions for which the probability of reciprocation was less than one. We reasoned that the red key might function as a conditioned reinforcer for choosing the smaller reward (especially in the conditions in which the probability of reciprocation was 1.0). By the same token, the green key might provide conditioned punishment for choice of the larger reward (since it gave evidence throughout the inter-trial interval that the next trial would involve choice between the two smallest payoffs). If these conjectures were correct we should have obtained more self-control choices (that is, more choice of the smaller reward) in the conditions in which the key was present than in those when the key was absent during the inter-trial interval. Indeed, the smaller reward was selected significantly more often when the key was present during the inter-trial interval. Thus, decision-making in this analog of the Prisoner's Dilemma game was more optimal when the game's contingencies were more salient. We next turn to a common error in human decision-making, the "sunk-cost effect" in which a similar message about discriminative stimuli and saliency will be shown to be relevant.

4. The Sunk-Cost Effect

The sunk-cost effect literature has focused on two distinct variations of the phenomenon: resource-allocation and continuing-to-invest. A good example of the resource-allocation version is that of Arkes and Blumer (1985):

> Assume that you have spent $100 on a ticket for a weekend ski trip to Michigan. Several weeks later you buy a $50 ticket for a weekend ski trip to Wisconsin. You think you will enjoy the Wisconsin ski trip more than the Michigan ski trip. As you are putting your just purchased Wisconsin ski trip ticket in your wallet you notice that the Michigan ski trip and the Wisconsin ski trip are for the same weekend! It's too late to sell either ticket, and you cannot return either one. Which ski trip will you go on?

Most subjects (this hapless author included) select the Michigan trip even though they expect to enjoy it less, since they have invested more in it.

The "continuing-to-invest" version is well illustrated by the ingenious research of Dr. Sonia Goltz, which utilizes the knowledge and techniques of behavior analysis to understand the phenomenon). For example, Goltz (1992, Experiment 1) tested persistence in a simulated investment task in which she manipulated subjects' past experience of the success or failure of their investments. Subjects received returns on their investments (i.e., success) in one of two investment alternatives on one of the following schedules: (1) on every trial; (2) on every other trial; or (3) unpredictably, but, on the average, on one of every two trials. In behavioral terms, these are equivalent to continuous, fixed-ratio 2, and variable-ratio schedules of reinforcement. When conditions were later altered such that the investment alternative continuously failed to pay off (that is, extinction) those subjects who were exposed to the least predictable schedule (i.e., the variable-ratio schedule) persisted in investing significantly longer than those in the two other conditions. Most interesting was the finding, in a second experiment from Goltz (1992), that "control" subjects that had not been given investment experience in the experiment, behaved more like those subjects given the variable history of investment success. This finding suggests that subjects' pre-experimental histories are variable with respect to investment success and that they are therefore susceptible to maladaptive persistence. Goltz (1999) also found increases in persistence as subjects' past histories included higher rates and greater magnitudes of reinforcement. All of these results are consistent with a behavioral view of the importance of reinforcement history for understanding persistence of commitment.

Anton Navarro and I have developed an analog of the sunk-cost situation that we are using in the laboratory both with college students and pigeons as subjects. In our basic procedure with college students, the students are instructed to earn money by pressing keys on a computer keyboard. They are instructed, truthfully, that for 30 minutes they will face unlimited trials in which they must press a "reward" key an undetermined number of times until the screen flashes a dollar reward. They are also instructed that at any time they can press an "escape" key once to cancel the current trial and initiate a new one. Thus, a new trial begins either after a reinforcer or after one press to the escape key. Designed to model an investment that goes bad, the reward key has an operant schedule that creates a diminishing chance of reinforcement as responses increment. In our basic condition, for example, every trial has one of four fixed-ratios, with each ratio having a different probability of occurrence: FR 10 (50% probability), FR 40 (25% probability), FR 80 (12.5% probability), and FR 160 (12.5% probability). With these values, the expected ratio for each trial rises from 45 at the beginning of the trial, to 70 after the 10th reward key response (if no reinforcement occurs), to 80 after the 40th and 80th reward key responses (if no reinforcement occurs). As students respond without incurring reinforcement, the amount of work remaining for reinforcement becomes increasingly large. The student's optimal strategy, therefore, is to press the escape key after 10 responses to the reward key, which reduces the expected ratio from 70 to 45. After ten non-reinforced responses the students face a sunk-cost decision: they have made an investment, and must choose whether to continue with that investment and keep responding on the reward key or to abandon the investment and press the escape key. We are also studying the comparable problem in an analogous set of conditions with pigeons as subjects. Comparison of results with students and pigeons should permit us to compare the susceptibility of students and pigeons to the sunk-cost effect and to assess the conditions under which each is most susceptible. Our procedure also relates to experiments on choice in a situation of diminishing returns. For example, results from studies such as those of Hackenberg and Hineline (1992) and Hackenberg and Axtell (1993) have raised the possibility that humans may be more likely to attend to molar consequences while pigeons may be more likely to attend to molecular consequences.

Specifically, humans may be sensitive to average rate of reinforcement over a fairly large time frame whereas pigeons may be sensitive to at most the next several rewards from a single choice point. Thus far, however, we have not uncovered differences in the results from our human and avian subjects for the initial conditions studied.

Our initial results point to one major conclusion: When the contingencies are clearly discriminable both students and pigeons appear to behave close to optimally for the values we have tested thus far. For example, using the values in the example of the preceding paragraph, pigeons reliably escape when a different light illuminates the reward key for each of the four fixed-ratio schedules. That is, pigeons reliably escape when escaping is optimal (in this case when the FR 40 is signaled)[1]. When thesame stimulus is present on the reward key, however, pigeons and students are likely to persist, often continuing through the last and longest fixed ratio (fixed-ratio 160). But when the values and probabilities of the four fixed-ratio schedules are manipulated to make escaping after the first (non-reinforced) ratio more obviously optimal, both humans and pigeons escape reliably. Thus, these results on discriminability are consistent with those, discussed earlier, involving the key manipulation in the Prisoner's Dilemma game.

Dr. Arturo Bouzas suggested that we include a condition in which persistence is optimal. We have done so with pigeons. When persistence is optimal our pigeons have no problem in persisting. Indeed our interpretation of sunk-cost phenomena (when they occur) is that lessons (or "rules") learned about persistence are eagerly applied (and misapplied!). Thus, we are told "If at first you don't succeed, try and try again" and "Waste not, want not", both lessons that may often put us in good stead but which may also be misapplied to our detriment. Laboratory pigeons are less likely to have been taught these lessons. It is perhaps unsurprising, therefore, that non-humans have yet to produce convincing evidence of a sunk-cost effect (Arkes & Ayton, 1999). Whether or not we may manipulate our pigeons' histories to the point that our pigeons will demonstrate a sunk-cost effect is yet to be determined. The importance of experimental history is central to our research on base-rate neglect to which I now turn.

5. Base-Rate Neglect

When assessing the probability of an event people often ignore background information in favor of case-specific cues. For example, consider the classic example of base-rate neglect modified from that presented in the pioneering research of Tversky and Kahneman (1982):

> A cab was involved in a hit and run accident at night. Two cab companies, the Green and the Blue, operate in the city. You are given the following data: (a) 67% of the cabs in the city are Blue and 33% are Green. (b) a witness identified the cab as Green. The court tested the reliability of the witness under the same circumstances that existed on the night of the accident and concluded that the witness correctly identified each one of the two colors 50% of the time and failed 50% of the time. What is the probability that the cab involved in the accident was Green rather than Blue?

The example provides two sources of information: the base rates of the two types of cabs in the city (the "background information") and the reliability of the witness who identified the cab as Green (the "case-specific information"). Thus, base-rate neglect problems may be thought of as problems involving multiple stimulus control. In the taxicab example the information provided by the witness is worthless (the witness's ability to identify cab type

---

[1] We have yet to study humans with different stimuli correlated with the four fixed-ratio schedules.

is measured at chance level). Thus, the witness statement should exert no control and subjects should rely exclusively on the second source of information, the base rates. For the example given the appropriate answer is simply that the probability the cab involved in the accident was Green is 33% (the base rate of Green cabs in the city). In fact, however, subjects ignore the base-rate information and judge the likelihood that the cab is green around 50%, or equal to the accuracy of the witness.

Adam Goodie and I wondered about the robustness of base-rate neglect. The many studies reporting base-rate neglect typically did so with a single "paper-and-pencil" question. Generally the studies were carried out in large classrooms with no special care taken to foster motivated and attentive students. Based on our own experiences collecting data in large classroom settings we had strong reasons for doubting the attention and motivation of many of our subjects. We wondered, therefore, if base-rate neglect would still occur in a behavioral task where we could better insure subjects' attention and motivation and where we could conduct repeated trials, thus assessing the durability of base-rate neglect. In an earlier paper (Stolarz-Fantino and Fantino, 1990) we had proposed the use of a matching-to-sample (MTS) procedure to assess base-rate neglect in a behavioral setting. In an MTS procedure a sample stimulus is presented followed by two comparison stimuli, one of which typically is the same as ("matches") the sample. The MTS procedure also involves multiple stimulus control: control by the sample cue and control by the base rates. The MTS procedure permits manipulation of these two sources of control separately with repeated trials in a behavioral setting. The sample corresponds to the witness in the taxicab problem (or, more generally, to the case-specific information in base-rate problems); the probabilities of reinforcement for selecting the comparison stimuli, independent of the sample cues, correspond to the incidence of taxicab types (or, more generally, the base rates or background probabilities of the relevant events).

In one condition of Goodie and Fantino (1995) the sample in the MTS task was either a green or blue light. After the sample was terminated, green and blue lights appeared as the comparison stimuli. UCSD students were instructed to choose either. Students were presented with repeated trials rapidly (from 150 to 400 trials per 1-hr session, depending on the experiment). Consider the condition corresponding to the taxicab problem above. Following a green sample, selection of the green comparison stimulus was reinforced on 33% of the trials and selection of the blue comparison was reinforced on 67% of the trials. Following a blue sample, the same contingencies were in effect: selection of the green comparison stimulus was reinforced on 33% of the trials; selection of the blue comparison stimulus was reinforced on 67% of the trials. In other words, in this condition, as in the taxicab example above, the sample had no discriminative (or predictive) function. Only the base rates were relevant: selection of blue was reinforced twice as often as selection of green, no matter what sample preceded the choice. Thus, if our subjects selected optimally they should have come to choose the blue comparison stimulus on every trial, thereby obtaining reward (either points or points backed by money depending on the experiment) on 67% of the trials. They should never choose green. However, a rich literature on probability matching (e.g., Fantino and Esfandieri, 2002; Humphreys, 1939) shows that when humans are presented with repeated and identical binary choices, they match their choices to the arranged probabilities instead of maximizing their payoff by always selecting the stimulus with the higher probability of reinforcement. If our students displayed probability matching they should have chosen green on 33% of the trials instead of the optimal 0%. But if our students displayed base-rate neglect they should respond even less optimally: They should be primarily sensitive to sample accuracy and match the sample 50% of the time, corresponding to the responses of students in the paper-and-pencil taxicab problem. In fact, subjects chose the green comparison stimulus 56% of the time following a green sample. These data and others from Goodie and Fantino (1995) reveal strong base-rate neglect, demonstrating that such neglect occurs in a behavioral task and that it persists over several hundred trials.

What if were to conduct the same experiment with pigeons as subjects? Pigeons have often been studied in MTS tasks. Indeed Hartl and Fantino (1996) conducted a similar experiment with pigeons. Interestingly, in the comparable MTS task pigeons displayed neither base-rate neglect nor even probability matching. They behaved optimally attending to the base rates and ignoring the sample in a condition comparable to the one presented above, and showing control by the sample, while ignoring base rates, in a condition where the sample and not the base rates was more predictive of reinforcement. Perhaps this stark difference in the behavior of pigeons and college students can instruct us on the cause of base-rate neglect. We speculated that humans have acquired strategies for dealing with matching problems that are misapplied in our MTS analog (e.g., Stolarz-Fantino and Fantino, 1995). For example, from early childhood humans learn to match like colors and shapes at home, at play, and at school (e.g., in playing with blocks and puzzles and in reading picture books with their parents). Pigeons, on the other hand, have not experienced a rich history of matching. Thus, they should not have developed a tendency to match. The argument for human subjects has applicability to the results from the paper-and-pencil demonstrations of base-rate neglect as well. These examples usually involve a witness (as in the taxicab problem) or other case-specific cues such as an expert’s diagnosis or the results of a medical test. In each case we have learned to expect that this case-specific information is generally accurate.

Adam Goodie and I explored this possibility that base-rate neglect is a learned phenomenon. If it is, we should be able to eliminate base-rate neglect by having the sample stimulus be physically unrelated to the comparison stimuli. Hence, in our next series of experiments (Goodie and Fantino. 1996), we employed an MTS procedure in which the sample and comparison stimuli were unrelated: the sample stimuli were line orientations while the comparison stimuli were again the colors green and blue. This change in procedure eliminated base-rate neglect, thus supporting the learning hypothesis. Instead, our UCSD students’ responses were well described by probability matching. We next introduced a condition in which the sample and comparison stimuli were physically different but were related by an extensive history: The samples were the words “blue” and “green”; the comparison stimuli were again the colors blue and green. A robust base-rate neglect was again obtained. These and additional experiments led us to conclude with confidence that base-rate neglect results from preexisting associations between stimuli. These results support our conjecture that humans have acquired strategies for dealing with matching problems that are misapplied in our MTS analog. Pigeons, on the other hand, are unfettered by acquired strategies that might be misapplied in the MTS task. But what if we created a "sophisticated pigeon"?

Ongoing research in our laboratory suggests that when pigeons are given a sufficient history of matching and are then tested in our MTS base-rate analog that they too succumb to base-rate neglect.

The tendency for humans to focus on case-specific cues and not base rates is extremely robust in the behavioral experiments we have conducted. For example, Goodie and Fantino (1999b) demonstrated the power of sample accuracy in base-rate decisions in a study that pitted potential control by sample accuracy and base rates against one another. In a series of manipulations using repeated trials with MTS we showed rather remarkable control by the sample at the expense of control by base rates. One way to diminish control of the sample is to conduct more than a thousand trials. Goodie and Fantino (1999a) eliminated base-rate neglect entirely in a study that conducted 1600 trials. But surely this is an unnatural situation: Life rarely offers 1600 trials! Can we diminish control by the sample (the heart of base-rate neglect) other than by giving many hundreds of trials? Yes. By giving subjects experience with the base rates of reinforcement while omitting the sample (in repeated binary choices) we found, in both within-subject and between-subject manipulations, that their behavior became more sensitive to base rates in subsequent MTS tests (Case, Fantino, and Goodie, 1999). Specifically, base-rate neglect was minimal in these students when they were then studied in the MTS procedure. Thus, all of these results suggest that base-rate neglect is a learned phenomenon and that more optimal decision making may be facilitated with appropriate training and by appropriate presentation of the problem.

6. Conclusions and Implications

The technology and methodology of the behavior-analytic laboratory has much to offer in the study of decision making. Moreover by illuminating principles of decision making behavior analysts can have greater impact on other areas of psychology as well as on related, and increasingly influential, areas such as behavioral economics and behavioral ecology. Some of the research discussed in this paper suggests that poor decision making is often the result of the misapplication of rules and principles that have led to effective decisions in the past. I present an anecdotal example. Most of us have learned that we save by buying larger sizes of the same product (the "economy size"). Similarly, when a music festival offers a subscription of five concerts we may assume that the cost of the subscription will be the same or less than the cost of purchasing single tickets for each of the five events. Thus, we often act on these assumptions when in fact the opposite is sometimes true. For example, a recent solicitation for a subscription to a chamber music series in La Jolla, California (August 2003) touted a "Flexible Series: Pick 5 concerts" option which cost $250. Buying tickets in the same seating section singly for the same 5 concerts cost only $210. The principles that we have acquired from a lifetime of experience enable us to make rapid and efficient decisions. But when the principles don't apply we may be led astray. Obviously we need appropriate discriminative stimuli to help us decide which principles apply. The research on both the Prisoner's Dilemma Game and the sunk-cost effect, outlined in this paper, emphasize the role discriminative stimuli can play as aids to optimal decision making. This research, as well as the other research discussed in this paper, all suggests that it is probably futile to characterize decision making as "rational" or "irrational", "normative" or "non-normative". Decisions will be based, in large measure, on historical and contemporary contingencies of reinforcement. Our decisions are determined by our past experience in similar situations and by the effectiveness of the discriminative stimuli and other contextual cues present in the decision environment. As simplistic as these points may seem to behavior analysts they have been too often ignored in the study of human decisions. Behavior analysts have a uniquely useful role to play in the increasingly influential psychology of decision making.

REFERENCES

Arkes, H.R., & Ayton, P. (1999). The sunk cost and Concorde effects: Are humans less rational than lower animals? *Psychological Bulletin, 125,* 591-600.

Arkes, H.R. & Blumer, C. (1985). The psychology of sunk cost. *Organizationa Behavior & Human Decision Processes*, *35*, 124-140.

Case, D.A., Fantino, E. & Goodie, A.S. (1999). Base-rate training without case cues reduces base-rate neglect. *Psychonomic Bulletin & Review*, *6*, 319-327.

Catania, A. C., Shimoff, E., & Matthews, B. A. (1989). An experimental analysis of rule-governed behavior. In S. C. Hayes (Ed.), *Rule-governed behavior: Cognitions, contingencies, and instructional control* (pp. 119-150). New York: Plenum.

Fantino, E. (1998a). Behavior analysis and decision making. *Journal of the Experimental Analysis of Behavior, 69,* 355-364.

Fantino, E. (1998b). Judgment and decision making: Behavioral approaches. *The Behavior Analyst*, *21*, 203-218.

Fantino, E., & Esfandiari, A. (2002). Probability matching: Encouraging optimal responding in humans. *Canadian Journal of Experimental Psychology, 56*, 58-63.

Fantino, E., Jaworski, B.A., Case, D.A., & Stolarz-Fantino. S. (2003). Rules and problem solving: Another look. *American Journal of Psychology*, *116*, 613-632.

Galizio, M. (1979). Contingency-shaped and rule-governed behavior: instructional control of human loss avoidance. Journal of the Experimental Analysis of Behavior, 31, 53-70.

Glaz, I., Stolarz-Fantino, S., & Fantino, E. (2001). Solving math problems: Does rule use allow flexibility? Poster presented at the Biennial Meeting of the Society for Research in Child Development, Minneapolis, MN, April, 2001.

Goltz, S.M. (1992). A sequential learning analysis of continued investments of organizational resources in nonperforming courses of action. *Journal of Applied Behavior Analysis*, *25*, 561-574.

Goltz, S.M. (1999). Can't stop on a dime: The roles of matching and momentum in persistence of commitment. *Journal of Organizational Behavior Management, 19,* 37-63.

Goodie, A.S., & Fantino, E. (1995). An experientially derived base-rate error in humans. *Psychological Science*, *6*, 101-106.

Goodie, A.S., & Fantino, E. (1996). Learning to commit or avoid the base-rate error. *Nature, 380*, 247-249.

Goodie, A.S., & Fantino, E. (1999a). What does and does not alleviate base-rate neglect under direct experience. *Journal of Behavioral Decision Making*, *12*, 307-335.

Goodie, A.S., & Fantino, E. (1999b). Base rates versus sample accuracy: Competition for control in human matching to sample. *Journal of the Experimental Analysis of Behavior, 71*, 155-169.

Hackenberg, T.D. & Axtell, A.M. (1993). Humans' choices in situations of time-based diminishing returns. *Journal of the Experimental Analysis of Behavior*, *59*, 445-470.

Hackenberg, T.D. & Hineline, P.N. (1992). Choice in situations of time-based diminishing returns: Immediate versus delayed consequences of action. *Journal of the Experimental Analysis of Behavior, 57*, 67-80.

Hackenberg, T. D. and Joker, V. R. (1994). Instructional versus schedule control of humans' choices in situations of diminishing returns. Journal of the Experimental Analysis of Behavior, 62, 367-383.

Hartl, J.A., & Fantino, E. (1996). Choice as a function of reinforcement rates in delayed matching to sample. *Journal of the Experimental Analysis of Behavior, 66,* 11-27.

Hineline, P.N.,& Wanchisen, B.A. (1989). Correlated hypothesizing and the distinction between contingency-shaped and rule-governed behavior. In S.C. Hayes (Ed.), *Rule-governed behavior: Cognition, contingencies ,and instructional control* (pp. 221-268). New York: Plenum.

Humphreys, L.G. (1939). Acquisition and extinction of verbal expectations in a situation analogous to conditioning. *Journal of Experimental Psychology*, *25*, 294-301.

Joyce, J. H. and Chase, P. N. (1990). Effects of response variability on the sensitivity of rule-governed behavior. Journal of the Experimental Analysis of Behavior, 54, 251-262

Kaufman, A., Baron, A., and Kopp, R. E. (1966). Some effects of instructions on human operant behavior. Psychonomic Monograph Supplements, 1, 243-250.

Luchins,A.S. (1942). Mechanization in problem-solving: the effect of einstellung. *Psychological Monographs, 54,* (6, Whole Number 248).

Luchins, A.S. & Luchins, E.J. (1950). New experimental attempts at preventing mechanization in problem solving. *Journal of General Psychology, 42*, 279-297.

Meyer, S. (2003). *Effects of ITI manipulation on self-control in a probabilistic iterated Prisoner's Dilemma game.* Unpublished master's thesis, University of California, San Diego, La Jolla, California, U.S.A.

Rachlin, H. (2000). *The science of self-control.* Cambridge, MA: Harvard University Press.

Rosenfarb,, I. S., Newland, M. C., Brannon, S. E., and Howey, D. S. (1992). Effects of self-generated rules on the development of schedule-controlled behavior. Journal of the Experimental Analysis of Behavior, 58, 107-121.

Sasada, K. (2003). *The effects of different instructions on learning and transfer with verbal analogy problems*. Unpublished master's thesis, University of California, San Diego, La Jolla, California, U.S.A.

Silberberg, A., Murray,P., Christiansen, J., & Asano, T. (1988). Choice in a repeated-gambles experiment. *Journal of the Experimental Analysis of Behavior*, *50*,187-195.

Skinner, B.F. (1969). *Contingencies of reinforcement: A theoretical analysis.* New York: Appleton-Century-Crofts.

Stolarz-Fantino, S. & Fantino, E. (1990). Cognition and behavior analysis: A review of Rachlin's *Judgment, decision and choice*. *Journal of the Experimental Analysis of Behavior*, *54*, 317-322.

Stolarz-Fantino, S. and Fantino, E. (1995). The experimental analysis of reasoning: A review of Gilovich's *How We Know What Isn't So. Journal of the Experimental Analysis of Behavior, 64*, 111-116.

Tversky, A. & Kahneman, D. (1982). Judgments of and by representativeness. In D. Kahneman, P. Slovic, & A. Tversky (Eds.) *Judgment under uncertainty: Heuristics and biases*. Cambridge, U.K.: Cambridge University Press

FOOTNOTE

NIMH Grant MH57127 funded the research discussed herein. I thank Stephanie Stolarz-Fantino for help in developing some of the ideas presented herein. Reprints may be obtained from Edmund Fantino, Department of Psychology, University of California, San Diego, La Jolla, California, 92093-0109.