



Optimal and Non-optimal Behavior Across Species

Edmund Fantino
University of California, San Diego

We take a behavioral approach to decision-making and, apply it across species. First we review quantitative theories that provide good accounts of both non-human and human choice, as, for example, in operant analogues to foraging (including the optimal diet model and delay-reduction theory). Second we show that for all species studied, organisms will acquire observing responses, whose only function is to produce stimuli correlated with the schedule of reinforcement in effect. Observing responses are maintained only by “good news”: “no news” is preferred to “bad news”. We then review two areas of decision-making in which human participants (but not necessarily non-humans) tend to make robust errors of judgment or to approach decisions non-optimally. The first area is the sunk-cost effect in which participants persist in a losing course of action, ignoring the currently operative marginal utilities. The second area is base-rate neglect in which participants overweight case cues (such as witness testimony or medical diagnostic tests) and underweight information about the base rates or probabilities of the events in question. In both cases we argue that the poor decisions we make are affected by the misapplication of previously learned rules and strategies that have utility in other situations. These conclusions are strengthened both by the behavioral approach taken and by the data revealed in cross-species comparisons.

Keywords: choice; optimal diet model; delay-reduction theory; observing responses; sunk-cost effect; base-rate neglect.

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It is difficult to gauge which of the following the “typical” layperson finds more intriguing: that non-humans often behave according to principles of strict optimality or that humans often behave dramatically non-optimally. In this review we shall explore data that help to explain why differences in optimality may be seen across species, concluding that such differences do not reflect fundamental differences in decision-making across species.

Operant Analogues of Foraging. We begin by reviewing some vintage research that sparked interdisciplinary excitement in the 1980’s and 90’s between behavioral ecologists and behavioral psychologists. George Collier and his colleagues (e.g., Collier & Rovee-Collier, 1981) developed a laboratory analogue of a foraging situation, one that would permit assessment of the principles thought to control foraging decisions in the field. Specifically, they allowed precise

Address correspondence to: Edmund Fantino
Department of Psychology and the Neurosciences Group
University of California, San Diego,
9500 Gilman Drive,
La Jolla, CA, 92093-0109 e-mail: efantino@ucsd.edu

tests of the optimal diet model of optimal foraging theory.

Optimal foraging theory (OFT) develops hypotheses about how a species would feed if it acted in the most economical manner with respect to time and energy expenditure (MacArthur & Pianka, 1966). Hanson (1987) summarized the assumptions underlying OFT with respect to prey choice as follows:

1. Searching for and handling prey are mutually exclusive activities.
2. Individual prey items are encountered randomly and sequentially.
3. Prey types are clearly discriminable and instantly recognizable.
4. Prey types are categorized according to energy gain (E) and handling cost (h).
5. The value of a prey type to the forager is determined by energy gain per unit of handling cost, i.e., E/h.
6. The forager has accurate knowledge of environmental parameters, i.e., E, h, search costs, encounter rates, etc. (pp 335-336).

Tests of hypotheses generated by OFT were carried out in

several laboratories and were prominently featured in journals and in texts based on interdisciplinary conferences (e.g., Commons, Herrnstein, & Rachlin, 1982; Kamil, Krebs, & Pulliam, 1987). Operant analogues of foraging provided assessments of the generality and external validity of behavior-analytic principles of choice while also assessing predictions derived from optimal foraging theory

We had been particularly interested in applications of delay-reduction theory (Fantino, 1969; Fantino & Davison, 1983; Fantino, Preston, & Dunn, 1993; Killeen & Fantino, 1990; Squires & Fantino, 1971), developed in our lab to provide a quantitative account of choice. According to delay-reduction theory (DRT), the effectiveness of a stimulus as a reinforcer may be predicted most accurately by calculating the decrease in time to food acquisition correlated with the onset of the stimulus, relative to the length of time to food acquisition measured from the onset of the preceding stimulus. Critically, it is the *improvement* in time to reward signified by the stimulus, not the absolute time to reward that determines choice. Thus, if two stimuli are both ten seconds from food, but one follows a sixty second waiting period and the other a twenty second waiting period, the stimulus following the sixty second waiting period will represent an 86% improvement (60 of 70 seconds will have elapsed), while the stimulus following the twenty second waiting period will represent only a 67% improvement (20 of 30 seconds will have elapsed). Thus, the stimulus following the sixty-second waiting period will be the stronger conditioned reinforcer (and will be preferred in a direct choice test). It was evident that DRT could be readily applied to the foraging analogues developed by Collier and refined by Stephen Lea and his colleagues. In fact, with few exceptions, it was shown that the optimal diet model (ODM) of optimal foraging theory was mathematically equivalent to DRT (e.g., Fantino & Abarca, 1985). The research we will cite was generally carried out using the successive-encounters procedure developed by Collier and by Lea (1979). Our version of this procedure, from Abarca and Fantino (1982) is shown in Figure 1. In contrast to the simultaneous presentation of options used in studying DRT, the successive-encounters procedure presents the organism with one option at a time; the organism can accept the option or can reject it and return to the start. Thus, the successive-encounters procedure models the foraging situation in which an organism encounters a food source and chooses either to exploit it or to forego it in favor of searching anew with the possibility that a richer source will be available. As shown in Figure 1, each trial begins with a “search” phase during which responding at a white key light (key-pecks in the case of the pigeon) is reinforced on a fixed-interval (FI) schedule of reinforcement—here FI X seconds since search duration is a much-studied independent variable. The first peck following X seconds produces

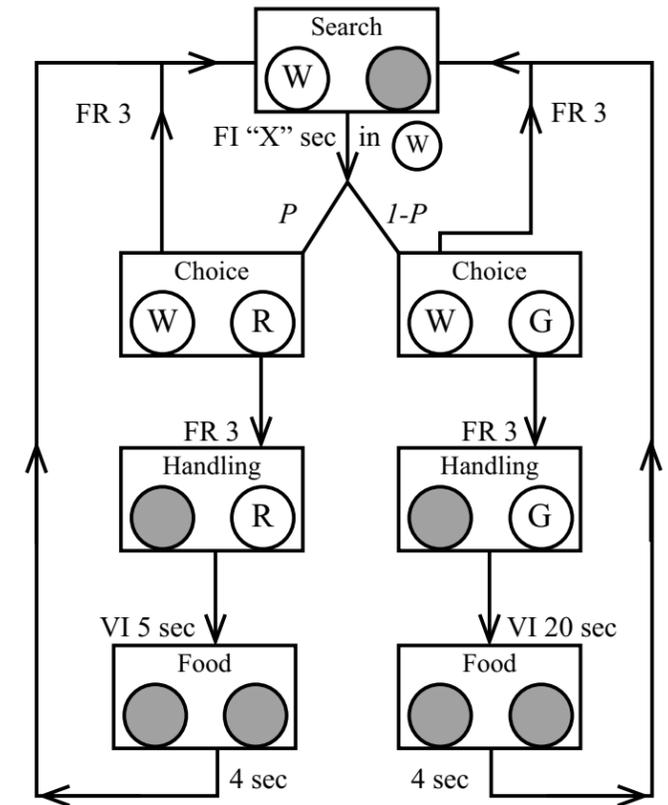


Figure 1. Typical flowchart of the procedure used in operant analogues of foraging behavior. Adapted from “Choice and Foraging” by N. Abarca and E. Fantino, 1982, *Journal of the Experimental Analysis of Behavior*, 38, p. 120. Copyright 1982 by the Society for the Experimental Analysis of Behavior, Inc. Adapted with permission.

entry into the “choice” phase. With a probability of p the choice is between responding three times (fixed-ratio 3 or FR 3) on the white-lit key which would return the pigeon to the search phase and a new trial, and responding three times (FR 3) on the red-lit key which would “advance” the pigeon to the “handling phase”, here a Variable-Interval (VI) 5-seconds schedule for 4 seconds of food presentation. With a probability of 1-p, the choice is between responding on the white key light (FR 3), returning to the search phase and a new trial, and responding three times (FR 3) on the green-lit key and advancing to the handling phase, here a VI 20-seconds schedule for 4 seconds of food presentation. After food presentation on either the VI 5 or VI 20, a new trial commences with the search phase. Unless probabilities are being explicitly manipulated, p is typically .5 (and therefore 1-p is also .5).

A canonical prediction of ODM is that, when food is plentiful, only the preferred of two nutritional food items will be accepted; as food becomes more scarce, a point is reached where the less preferred item will also be accepted. That point is predicted by both ODM and DRT and is gener-

ally the same for both (Fantino & Abarca, 1985). In operant analogues of foraging, schedule preference is used as a surrogate for food preference—i.e., instead of manipulating the quality of different foods, the ease of acquiring food is varied. A good food source might be one that provides food every 10 seconds, while a poor food source might be one that provides food every 100 seconds. In terms of the situation presented in Figure 1, the VI 5-seconds outcome should always be accepted. The question of interest is whether or not the less preferred VI 20-seconds outcome is accepted and whether its rate of acceptance varies with the search duration (X seconds in Figure 1). In fact, acceptance of the VI 20-seconds outcome tends to occur only when it is correlated with a reduction in time to reward (DRT) and when it is correlated with energy gain (ODM)—the first finding listed below.

Studies in our laboratory confirmed the following predictions of ODM and DRT (for the mathematical underpinnings of these predictions, see Fantino & Abarca, 1985):

- As search time increases, pigeons shift from rejecting the less profitable of two outcomes to accepting it and this shift occurs precisely at the search duration required by the models (e.g., Abarca & Fantino, 1982).
- When handling times are increased (the VI schedules or outcomes), pigeons shift from accepting to rejecting the less profitable of two outcomes (Ito & Fantino, 1986).
- In a choice between a rich schedule leading to food on only a percentage of trials and a lean schedule always leading to food, pigeons preferred whichever outcome provided the higher overall mean rate of reward (Abarca, Fantino, & Ito, 1985).
- Preference for the preferred outcome decreases as travel time between alternatives increases (that is, pigeons became less selective). The way travel time was manipulated is described in Fantino and Abarca (1985).
- Although Figure 1 shows a single search phase (FI X seconds), the X leading to the preferred and less preferred outcomes (FI 5-seconds and FI 20-seconds, respectively) can be separately manipulated. In other words, we can change the accessibility of either outcome across conditions by separately manipulating X. As predicted, changing accessibility of the more profitable outcome had a greater effect on choice than changing the accessibility of the less profitable outcome (Fantino & Abarca, 1985).
- In what is to many a counterintuitive prediction and finding, increased accessibility of the less profitable outcome led to *decreased* acceptability of that outcome when accessibility was varied by manipulating the search time leading to the less profitable outcome: time leading to the more profitable outcome was held constant, while time leading to the less profitable out-

come was varied (Fantino & Preston, 1988).

One issue of abiding interest involves the possible identification of a mechanism by which pigeons, rats (studied by Collier's group—see reference above) and humans (studied by Fantino & Preston, 1989 and by Stockhorst, 1994) are sensitive to the more optimal outcome, for example, to the higher energy food item. Before discussing this issue, we clarify the distinction between the optimal-foraging and delay-reduction approaches. Central to classical optimal foraging theory (MacArthur & Pianka, 1966) is the notion of maximization of energy intake per unit time (modulated by various constraints—for example the forager must be on the lookout for predators). Although as we have pointed out, ODM and DRT are functionally equivalent in most important respects, the question of whether foraging organisms rely primarily on rate maximization or on environmental cues correlated with greater reductions in waiting time to food remained unexplored. Wendy Williams' procedure involved one outcome that provided two 3-second rewards each arranged by a VI 60-second schedule and a second outcome that provided a single 3-second reward, arranged on a VI 30-second schedule. The search phase consisted of two equal schedules one leading to the more immediate single reinforcer, the other to the less immediate but dual reinforcers. The duration of the search phase was varied over a wide range including an intermediate area (61 seconds to 132 seconds) where rate maximization required preference for the dual reinforcers but DRT required preference for the more immediate smaller reinforcer (for details, see Williams & Fantino, 1994). For this critical area, results were consistent with DRT's ordinal predictions in 11 of 11 replications. Indeed, the predictions of rate maximization were upheld only when they dovetailed with those of DRT.

In a sense this result is not at all surprising. An extensive literature on self-control underscores the central role of immediacy in decision-making. But given this fact it is also not surprising that organisms may not be so directly sensitive to a variable such as rate of energy intake. It is our contention that sensitivity to reductions in delay to food (“delay-reduction”) may be a “rule-of-thumb” guiding successful foraging. Far more often than not, stimuli correlated with delay reduction also lead to a maximization of energy intake or rate maximization. By focusing on these delay-reduction cues the forager does well. Fantino (1988) first proposed this notion in a commentary on Houston and McNamara (1988). It has been elaborated on by Williams & Fantino (1994) and most elegantly by Houston, McNamara, and Steer (2007) whose title is aptly: “Do we expect natural selection to produce rational behavior?” We say “aptly” because we will soon turn to situations wherein humans (and sometimes pigeons) behave in a dramatically irrational manner. To sum-

marize, the general notion is that there are relatively proximal surrogates for vital currencies such as energy intake and that delay-reduction may be one of them. Stimuli correlated with delay reduction are considered conditioned reinforcers, whose potency derives from their relation to more fundamental (“primary”) reinforcers. The role of conditioned reinforcers in behavior has been the focus of extensive research in animal learning and behavior (e.g., Fantino, 2008; Fantino & Romanowich, 2007) and need not be addressed further here.

While the bulk of research on operant analogues to foraging has been carried out with pigeons, rats, and other non-humans, there has been some work with humans (e.g., Fantino & Preston, 1989). We will briefly note an interesting example that assessed the counterintuitive prediction discussed in the sixth and final point bulleted earlier. Specifically, Ursula Stockhorst conducted her dissertation research at Heinrich-Heine University in Duesseldorf on this very problem. Students were trained under a successive-choice schedule to make responses in order to interrupt a tone presented through headphones. The response requirement to access the more profitable alternative (which turned off the tone on a VI 3s schedule) was held constant (FI 7.5s), while the requirement to access the less profitable alternative (which turned off the tone on a VI 18s schedule) was varied. Results were compatible with previous work exploring the same variables with pigeons: increased accessibility of the less profitable outcome led to decreased acceptability of that outcome (Stockhorst, 1994)

In the laboratory and in the field, there is an indication that optimal diet theories are better at predicting foraging behavior in some species than others. After reviewing a wide range of studies covering a large number of species, Sih and Christensen (2001) concluded that such theories are best at predicting the foraging behavior of organisms that feed on immobile prey.

While pursuing the mechanism for optimal behaviors is satisfying, unearthing mechanisms for our non-optimal behaviors may be just as interesting. We will consider three areas, each providing a different “take-home” message. The three areas address the following phenomena: (1) information *per se* does not appear to be reinforcing unless it may be utilized productively; (2) we persist in non-optimal pursuits once we have invested in them (“sunk-cost effect”); (3) we ignore base rates at our decision-making peril (“base-rate neglect”). We will review the first two somewhat briefly and then concentrate on base-rate neglect since it provides a particularly instructive story

Observing. We think of ourselves as information seekers and rightly so. Certainly in this age of information technol-

ogy the point is obvious. Nonetheless, scores of studies over several decades have addressed the question of whether or not humans and various species of non-humans will maintain behavior when the only putative reinforcer is the production of stimuli correlated with information that has no utility. If information *per se* serves as a reinforcer, then it should maintain its acquisition, whether or not it is useful. Moreover, information that has no utility today may be useful tomorrow (observing the location of a dry cleaners). The battleground over which researchers have argued this question involves a procedure known as the observing-response procedure, developed by Wyckoff (1952). In this paradigm, observing responses are those which produce stimuli correlated with schedules of reinforcement, but that have no effect on the occurrence of reinforcement. For example, two equally probable schedules of reinforcement differing only in frequency of reinforcement—say, variable time (VT) and extinction (EXT)—may alternate unpredictably. Effective observing responses would produce stimuli identifying the schedule in effect. In the case of a pigeon, an observing response might be pecking a lighted key or pressing a pedal—a response that does not produce food—in order to produce a stimulus that is uniquely correlated with the schedule in effect at that moment. Thus, it has a strictly informative value.

The study of observing has been seen as central to an understanding of the basis for conditioned reinforcement. Does a stimulus function as a conditioned reinforcer (and therefore maintain observing responses) because it is correlated with the occurrence of primary reinforcement (the “conditioned-reinforcement hypothesis”)? For example, according to DRT, a stimulus will be a conditioned reinforcer when its onset is correlated with a reduction in time to primary reinforcement. This prediction is also consistent with other major theories of conditioned reinforcement, e.g., the hyperbolic, value-added model of Mazur (2001). Alternatively, does a stimulus function as a conditioned reinforcer (and therefore maintain observing responses) because it informs about the availability of reinforcement (the “information” or “uncertainty-reduction hypothesis”)? Bloomfield (1972) argued that the critical test for distinguishing between these views is whether or not “bad news” is reinforcing. For example, is the stimulus correlated with EXT a reinforcer, in the sense that it will maintain observing? Such a stimulus certainly reduces uncertainty and so should maintain observing according to the information hypothesis. But since bad news should not be a conditioned reinforcer (for example, according to DRT) it should not maintain observing according to the conditioned-reinforcement hypothesis of observing. The overwhelming preponderance of evidence shows that only the more positive of two stimuli—that is, only the good news—maintains observing (e.g., see Dinsmoor, 1983; Fantino & Case, 1983), a result consistent with the

conditioned-reinforcement hypothesis. Interestingly, a wide variety of species make observing responses (including the goldfish, Purdy and Peel, 1988). But although all unequivocal tests have shown that bad news does not maintain observing, this conclusion did not please some who found it counter-intuitive. And indeed, some credible evidence that human observing may be reinforced by stimuli correlated with EXT was provided by Perone and Kaminski (1992) and by Lieberman, Cathro, Nichol, and Watson (1997). However, more recently, Escobar and Bruner (2009) have shown that Perone and Kaminsky's findings are more parsimoniously explained in terms of conditioned reinforcement. Similarly, Fantino and Silberberg (2010) conducted a series of five experiments further exploring the Lieberman et al. studies. They determined that in the Lieberman et al. studies, responses that did not produce "bad news" were actually indicative of "good news," and thus their results were consistent with a conditioned-reinforcement view. And based on their own results, Fantino and Silberberg concluded that information is reinforcing if and only if it is positive or useful. As required by the conditioned-reinforcement hypothesis, stimuli correlated with bad news or useless news does not maintain observing.

These data from the observing literature could argue that we do not seek all the information that would enable us to be optimal decision makers or that we are judicious and efficient in our information seeking. In any event, that we are less than ideal decision makers is evident from a wide range of other studies. For example, a series of studies showing suboptimal choice (mainly with pigeons), begun by Kendall (1974), and continued by Fantino, Dunn, and Meck (1979), Dunn and Spetch (1990), and Stagner and Zentall (2010), among others, has shown that, under certain arrangements of the contingencies, it is possible to get significant deviations from optimal responding.

The research surveyed thus far shows a great degree of similarity across species. When we approach areas in which humans behave non-optimally or illogically it is less obvious that this should be the case. For example while the "sunk-cost effect" has been reported widely with humans, until recently there was no solid evidence that it occurred with non-humans (e.g., Arkes & Ayton, 1999). However, recent research from two laboratories has found sunk-cost behavior in pigeons (e.g., Navarro & Fantino 2005; Pattison, Zentall, & Watanabe, in press). We discuss one such example briefly, as it is instructive in illustrating how the sunk-cost effect may be mimicked in an operant chamber with pigeons.

Sunk-cost effect. People become more likely to persist in questionable courses of action once they have made an investment.

The sunk-cost effect has interested researchers because it involves the inclusion of past costs into decision-making, which counters the maxim that choices should be based on an assessment of costs and benefits from the current point onwards. Although Arkes and Ayton (1999) reported that there were no clear examples of sunk-cost behavior among non-humans, certain lines of research with humans suggest the possibility that non-human animals could display this effect. For example, reinforcement history has been shown to affect sub-optimal persistence in an investment (Goltz, 1992, 1999). In order to explore conditions of uncertainty and reinforcement history under which human and pigeon participants might persist in a losing course of action, Navarro and Fantino (2005) designed a procedure that mimics the sunk-cost decision scenario. They defined such a scenario as one in which an investment has been made towards a goal, negative feedback concerning the investment has been received, and the participant can persist in the investment or abandon it in favor of a new one. In their procedure, pigeons began a trial by pecking on a key for food. The schedule on the food key arranged a course of action with initially good prospects that turned unfavorable. On a given trial, one of four fixed-ratio (FR) schedules was in effect: short (10), medium (40), long (80), or longest (160). On half the trials, the short ratio was in effect; on a quarter of the trials, the medium ratio was in effect; and on a quarter of the trials either of the two long ratios was in effect. With these parameters, after the pigeons emitted the response number required by the short ratio, if no reinforcement had occurred (because one of the longer ratios happened to be in effect), then the initially easy endeavor had become more arduous—the expected number of responses to food was now greater than it had been at the onset of the trial (with the values shown above, 70 responses would now be the expected number, rather than 45 at the onset of the trial).

Navarro and Fantino (2005) gave pigeons the option of escaping the now less-favorable endeavor by allowing them to peck an "escape" key that initiated a new trial. If the short ratio did not happen to be in effect on a given trial, then once the value of the short ratio had been met the optimal choice was to peck the escape key (and then begin anew on the food key). That is, the expected ratio given escape was lower than the expected ratio given persistence. Notice that at this choice point the pigeons encountered a sunk-cost decision scenario. Namely, they had made an initial investment, they had received negative feedback—no reinforcement—and they could either persist in the venture or abandon it in favor of a new and most likely better one. This general procedure allowed examination of the role of uncertainty in the sunk-cost effect in two ways. One way was through the presence or absence of stimulus changes. If a stimulus change occurred at the moment when escape became optimal, then the

economics of the situation should have been more salient than if no stimulus change had occurred. Navarro and Fantino hypothesized that pigeons responding on this procedure with no stimulus change would persist more than pigeons responding on this procedure with a stimulus change present. The results supported their hypothesis—when stimulus changes were absent, the majority of pigeons persisted to the end of every trial ("sunk-cost behavior"). When changes were present, however, all pigeons escaped as soon as it became optimal (this trend appeared once behavior had become stable). A second way to manipulate uncertainty is by varying the difference between the expected value of persisting and the expected value of escaping. The closer these expected values were to each other, the less salient the advantage of escaping and the more likely the pigeons should be to persist. The results again supported the hypothesis: as the advantage of escaping decreased (although escape remained optimal), persistence rose.

Additionally, by modifying this procedure for use with human subjects, previous findings with human subjects could be extended to a novel format. The above experiments with pigeons were replicated with human adults (Navarro & Fantino, 2005; Navarro & Fantino, 2007) in a computer simulation. In the human experiments, the computer keys were the operant, hypothetical money served as reinforcement, and the same contingencies were used. The human data mirrored those of the pigeons. These results suggest that at least two factors that contribute to the sunk-cost effect—economic salience and the presence of discriminative stimuli—may affect both non-human and human participants in a similar manner.

The sunk-cost effect is of more than academic interest. All of us have likely experienced situations in which we have persisted at an endeavor long after it was prudent to continue. Moreover we are all aware of decisions resembling the sunk-cost effect in the news. For example, the sunk-cost effect can help understand projects gone awry such as the Concorde airplane (indeed, we have the phrase "Concorde Fallacy") and the Vietnam War. In many real world cases, it is difficult to discriminate when a cause is lost or the point at which it becomes lost. Moreover, persistence in pursuit of one's goals is highly valued in our society. Rachlin (2000) has argued that persistence is the backbone of self-control (and the avoidance of impulsive decision-making). The great American inventor Thomas Edison is believed to have said: "Many of life's failures are people who did not realize how close they were to success when they gave up". The trick of course is in discriminating when to persist. Our ability to discriminate craftily will depend upon how much relevant information we have in hand. Given sufficient information (or discriminative stimuli) people and pigeons appear to avoid the sunk-cost effect.

Base-rate neglect. This robust phenomenon refers to the fact that people typically underweight the importance of base rates in decision tasks involving two or more sources of information (e.g., Goodie & Fantino, 1996; Tversky & Kahneman, 1982). In base-rate experiments, participants are generally provided with information about base rates, which concern how often each of two outcomes occurs in the general population, and case-specific information, such as witness testimony or the results of a diagnostic medical test. Typically, the participant's task is to select the more likely of the two outcomes or to provide a verbal estimate of the probability of one or both outcomes. An iconic base rate problem, described by Tversky and Kahneman, is the *taxicab problem*:

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 Blue rather than Green?

In this transparent version of the problem, the participant is given the information that the witness is totally unreliable (correctly identifies blue and green taxis under the illumination conditions of the accident at 50%) and that two-thirds of the taxis in the city are blue and one-third are green.

If both pieces of information (base rates of the two taxicab types, and witness accuracy) were considered it would be clear that the probability that the taxi was Blue is 67%. For less transparent values the information would be combined according to Bayes's Theorem in order to find the precise probability. Participants of course are not expected to utilize Bayes's Theorem. However, they might be expected to utilize both sources of information and come up with an approximation of the correct answer. Instead in most studies participants overweight the case-specific information and ignore, or at least underweight ("neglect") the base-rate information. Thus, in the simple example above, participants tend to assert that the probability is 50% since the witness is uninformative.

The robustness of base-rate neglect is not simply of academic interest. Striking examples have been reported involving assessments of school psychologists (Kennedy, Willis, and Faust, 1997), physicians (e.g., Eddy, 1982) and AIDS

counselors (Gigerenzer, Hoffrage, & Ebert, 1998). Can we learn something valuable about the variables that control base-rate neglect by adopting a behavioral approach? For example what if we had participants experience both the base rates and the accuracy of the case-cue information in a behavioral task over many trials? Would base-rate neglect still occur (in paper and pencil tasks, of course, participants are *given* the base rates and the case-cue accuracies). The difference in described contingencies and experienced contingencies is potentially profound (e.g., Fantino & Navarro, 2011). In order to investigate experienced base rates Stolarz-Fantino and Fantino (1990) suggested using a modified matching-to-sample procedure as a base-rate analogue. In the typical matching-to-sample procedure the sample appears on a single lit key and is one of two colors, here blue and green. After the sample is extinguished, two “comparison stimuli” appear, blue and green. The task of the human or pigeon participant is to pick the stimulus that “matches” the sample. In the modified procedure used in the base-rate analogues from our laboratory, however, “matching” is not necessarily the right response. Instead, selection of the blue and green comparison stimuli is each correct a certain percentage of the time.

Consider the following example, illustrated in Figure 2. Following a blue sample, selection of blue is correct 67% of the time and selection of green is correct 33% of the time. Following a green sample, selection of blue is again correct 67% of the time and selection of green is correct 33% of the time. It is evident that the sample is totally uninformative: it is not a discriminative stimulus for selecting either comparison stimulus. Note too that the values here are completely analogous to those in the taxicab problem above where the witness testimony was uninformative and where the base rate of blue cabs in the city was 67%. Thus, Tversky and Kahneman’s (1982) taxicab problem was converted into a nonverbal delayed matching-to-sample procedure.

Goodie and Fantino (1995, 1996) with humans and Hartl and Fantino (1996) with pigeons explored this behavioral base-rate problem, with a variety of values in different conditions. How did human participants do when the sample was uninformative? They should never have picked green since blue was correct more often. If participants’ choices mirrored those in the single trial paper-and-pencil version of the taxicab problem, however, we might expect that green would be chosen following a green sample on the 50% of trials. In fact green was matched on 56% of trials. These results reflect a behavioral base-rate neglect. Moreover base-rate neglect persisted over the 400 trials studied, even when the underweighting of base rates cost the participants money (Experiment 2 of Goodie & Fantino, 1995). Pigeons, however, chose optimally. The results from other conditions sup-

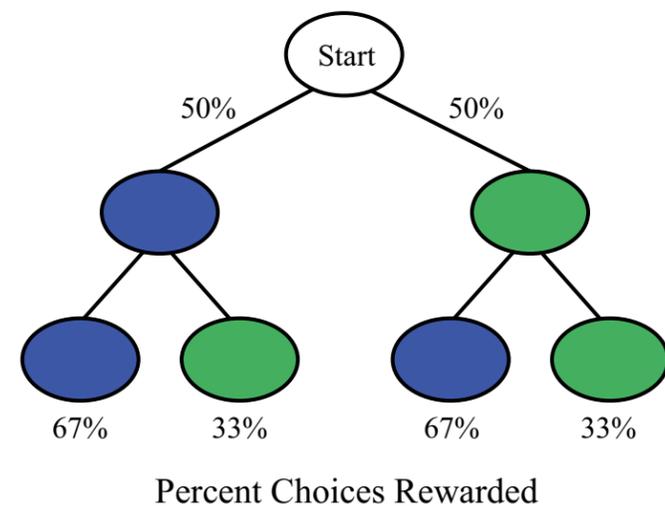


Figure 2. Standard modified matching-to-sample procedure used by Goodie and Fantino to mimic base-rate neglect. Adapted from “An Experientially Derived Base-Rate Error in Humans” by A.S. Goodie and E. Fantino, 1995, *Psychological Science*, 6, p. 103. Copyright 1995 by Sage Publications, Inc. on behalf of the Association for Psychological Science. Adapted with permission.

ported the same general pattern: for humans, sample information was over-weighted and the base-rates were neglected (though not always ignored); for pigeons, choices were appropriately controlled by both sample accuracy and base rates. In other words pigeons’ choices reflected appropriate integration of the two sources of information.

Would base-rate neglect eventually disappear with a sufficient number of trials beyond the 400 employed by Goodie and Fantino (1995)? Goodie and Fantino (1999) studied participants for a grueling 1600 trials and found a gradual diminution of base-rate neglect. In a sense this is uninteresting, however: Life does not typically offer 1600 trials (or even 400!). The important conclusions to be drawn from these experiments are that base-rate neglect occurs not only in paper-and-pencil tasks but also in behavioral tasks wherein the accuracy of the sample (“witness”) and the base rates are directly experienced.

Hartl and Fantino (1996) and Stolarz-Fantino and Fantino (1995) proposed that differences in learning histories between humans and pigeons may have been responsible for the differences in the results between the two species. That is, from early childhood, humans are exposed to many situations in which matching items that are in some way the same are reinforced. Laboratory pigeons lack a comparable history, which enables them to learn the optimal pattern of choice in tasks such as that of Hartl and Fantino without bias. In order to strengthen this interpretation it would be desirable to show that humans will not neglect base rates when tested on

problems where prior learning is not likely to interfere and that pigeons would show base-rate neglect if given, for example, a history of matching that we presume humans have.

Support for this possibility with human participants was generated by Goodie and Fantino (1996, 1999), in which they demonstrated that humans would not display base-rate neglect when symbolic matching-to-sample tasks were used in place of the usual identical matching-to-sample tasks used in the prior research. For example, when the sample was a line orientation (vertical or horizontal) and the comparison stimuli were colors (blue and green) base-rate neglect did not occur. When the symbolic matching-to-sample task involved a learned relationship, however, base-rate neglect occurred (for example when the sample was the word “blue” or the word “green” and the comparison stimuli were blue and green). Similarly, when humans were given exposure to base rates without samples (that is when there were no competing sources of stimulus control), they later were sensitive to base rates when a matching-to-sample procedure was introduced (Case, Fantino, & Goodie, 1999).

To complete the story that base-rate neglect may result from prior learning, Fantino, Kanevsky, and Charlton (2005) gave pigeons an extensive history of pretraining (more than 100 sessions) with informative case cues. During trials in these sessions, sample accuracy was 100%— that is, the pigeons’ matching responses were always reinforced and non-matches were never reinforced. Following this pretraining, the pigeons displayed base-rate neglect when confronted with problems that varied base rates and sample accuracy. As Fantino et al (2005) concluded: “After a substantial history of matching, pigeons are likely to neglect base rates, whereas the relatively “uneducated” pigeon is aptly sensitive to the multiple sources of stimulus control present in the matching-to-sample task” (p. 825).

Research by Zentall and Clement (2002) uncovered an additional factor that contributes to base rate neglect by pigeons. Under some conditions, the frequency with which a sample occurs can bias matching-to-sample performance; this becomes evident when other factors (e.g., the probability of reinforcement associated with each comparison) are held equal and when a delay occurs between presentation of the sample and the comparisons, thus increasing the relative importance of memory. This finding is congruent with results of studies of base rate neglect in humans (e.g., Tversky & Kahneman, 1982).

Conclusion

In many decision-making settings organisms choose optimally. These findings gave rise to quantitative theories that provide good accounts of choice, as, for example, in operant analogues to foraging (including the optimal diet

model and delay-reduction theory). Despite this comforting display of optimality, it remains a source of consternation that human decision-making is often dramatically non-optimal. We reviewed the observing-response literature which suggests that humans and non-humans share an aversion to “bad news” and shun it in favor of “no news” or unreliable information. Finally we discussed behavioral approaches to two infamous examples of defective decision-making in humans, the sunk-cost fallacy and base-rate neglect. The experimental stories that we have narrated both demonstrate the utility of studying classic phenomena in judgment and decision-making from a behavioral perspective. We could have selected other phenomena as well. But the point is that a behavioral approach can shed light on the factors that lead to our making good and bad decisions. We selected the two phenomena we did because they not only point to the utility of a behavioral approach to decision-making but they also highlight the value of conducting inter-species comparisons. In the case of the sunk-cost effect humans and pigeons behaved in a comparable manner, strengthening the generality of our conclusions. In the case of base-rate neglect the different initial results obtained with humans (non-optimal) and pigeons (optimal) led to testable hypotheses about the conditions promoting base-rate neglect. In both cases, maladaptive decisions resulted from the misapplication of previously acquired strategies (for example, inappropriate persistence in the sunk-cost effect and an excessive focus on case cues in base-rate neglect).

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