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Overconsumption as a function of how individuals make choices: A paper in honor of Howard Rachlin's contributions to psychology

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Howard Rachlin's widely influential behavioral economic approach to self-control and related issues provides the model for this submission. The topic is overconsumption. Current human consumption levels are unsustainable. Explanations typically focus on societal factors, such as the seductive power of advertising and/or misguided tax policies. However, the effectiveness of these factors depends on the degree to which individuals are susceptible to the message: "consume more." Humans are not blank slates. This paper argues that how individuals frame their choices establishes the susceptibility to overconsume. According to economic theory, consumers frame their options as bundles, composed of different combinations of the available items and activities. This leads to maximizing. In experiments, participants tend to frame their options as "either-or" choices. This leads to the matching law. Mathematical models of concurrent schedule choice procedures show that (1) the matching law implies overconsumption of the most preferred option and (2) that individuals will persist in preferring their favorite option even when doing so reduces overall reward rates. Given that the matching law better describes how individuals choose than does maximizing, the mathematical models of widely used choice procedures help explain why efforts to increase consumption have been more influential than efforts to control consumption.

Key words: overconsumption, choice, matching law, maximizing, mathematical models, Rachlin

Introduction

Howie Rachlin's wide-ranging publications and entertaining talks focused on topics that have long been central to psychology, philosophy, economics, and evolutionary biology. My cohort could not have wished for a more exemplary model of how to be a behavioral researcher, spokesperson, and teacher. In that spirit, what follows emulates Rachlin's behavioral-economic approach to much-discussed issues that belong to no one discipline.

Sustainability and Overconsumption: Claims and Evidence

According to the United Nations' (n.d.) *Sustainability Goals Project*, by midcentury, three earths will be needed to sustain human life, assuming current consumption levels and population growth rates. The UN report, and the many like it (Higgs, 2014; Marín-Beltrán et al., 2022; Toth & Szigeti, 2016), emphasize the role that overconsumption plays in sustainability. The argument is that individuals consume more than they need, particularly those living in developed, industrialized countries, such as the United States (Galbraith, 1958; Schor, 2007; Veblen, 1899/1994). Although "need" is hard to define, there are well-known examples of clutter and waste that are hard to explain other than as consumption beyond need. See for example, websites such as "20 Interesting Overconsumption Facts You Should Know" (The Impact Investor, November 22, 2022). The recent history of a thriving industry that depends on individuals purchasing more than they use provides some quantitative measures that support these widely shared intuitions.

Self-storage facilities provide sheds and lockers where, as the industry puts it, people "can put the stuff that doesn't fit into their homes" (Peysakhovich, 2022). In the 1950s, self-storage centers barely existed; today there are approximately 50,000 facilities, with about one container for every 14 Americans. To put this into perspective, there are more self-storage facilities than the combined number of Starbucks, McDonald's, Dunkin' Donuts, Pizza Huts and Wendy's. Yet, according to an industry blog, 65% of the renters have a garage in their home, 47% have an attic, and 33% have a basement (Boxbee, n.d.)—and for more perspective, real estate sales data indicate that the homes of the self-storage renters are about three times larger than the ones

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they grew up in (Compass, n.d.). To be sure, there are reasons to put goods into self-storage other than having too many things, but without the tendency to acquire more than can be used, it would not be one of America's strongest growth industries. My goal in this paper is to contribute to the understanding of why individuals tend to consume more than they need.

The literature on overconsumption and sustainability is large and wide-ranging (for reviews, see Fuchs & Lorek, 2005; Higgs, 2014; Trentmann, 2004). Penn (2003), an evolutionary biologist, pointed to appetitive mechanisms that evolved under conditions of scarcity that now, in an age of plenty, are running amok. More than a century ago, Veblen (1899/1994) championed the idea that as counties grew wealthier, the motivation to consume shifted from basic needs to drives that had no limit, such as the desire for greater prestige. In an article that was well ahead of its time, Galbraith (1958) pointed to the dangers to the environment of American consumption levels. Others attributed excessive and wasteful consumption to the advertising industry (Periera Heath & Chatzidakis, 2012), television (Miller, 2007), capitalism (Sklair, 1995), and the list goes on. However, these accounts, their range notwithstanding, leave two issues hard to explain.

The Idea That How People Make Choices Helps To Explain the "Outsized" Influence of Progrowth Forces

First, overconsumption is an age-old topic. In ancient Greece, the Delphic oracles preached "nothing in excess." Centuries later, but millennia before the rise of capitalism and advertising agencies, Socrates and Plato complained that their fellow Greeks were intemperate (Kelly, 2019; Trimble 2014). Fast forwarding to the middle of the 19th century, J. S. Mill (1871/1986) proposed that the great increase in wealth that attended the Industrial Revolution should serve as the basis for an Edenic, stationary-state economic equilibrium. He argued that now that technological advances in agriculture and manufacturing could meet basic human needs, his readers should turn to "higher" goals, such as better social relations, self-improvement, recreation, and preserving Nature. In recent times, environmental groups, such as the Sierra Club, make similar arguments. Second, despite the general respect that voices of temperance have earned, it is the claims of unlimited economic growth, lavish life styles, and waste which have flourished. There are, I believe, no voices on the side of unlimited growth that can match the respect earned by the Delphic oracles, Socrates, Plato, and Mill, yet growth has proved the dominant principle. A hypothesis that fits these trends is (1) individuals have a proclivity or bias for excess, and (2) this tendency has become more influential as access to desirable goods and activities has increased. These two points, I argue, reflect how individuals make choices.

Two Approaches to the Understanding of How Choices Are Made: Economics and the Experimental Analysis of Behavior

Two research traditions inform my analysis of choice: economics, as presented in introductory text books, and the experimental analysis of behavior, which got its start with B. F. Skinner's (1938) studies of reinforced behavior and was developed further by quantitatively oriented behavioral psychologists.

Economics and Maximizing

According to economics text books, consumers, households, and firms distribute their choices among the available options so as to maximize the overall available benefits. Given this assumption, the economist's task is to identify what is maximized. For example, do the subjects in choice experiments maximize overall reward, the immediacy of reward, or "bundles" composed of different amounts of reward and leisure time? Two passages from the introductory pages of a once widely used microeconomics text explain the relation between the consumer's "psychology" and the economist's methods (Ferguson & Gould, 1975):

> Economists frequently assume that consumers attempt to maximize satisfaction and businessmen or entrepreneurs attempt to maximize profit. So defined, the goals of economic agents provide the economist with a frame of reference that permits systematic analysis of individual economic behavior (p. 2).

Then a few paragraphs later, the authors rationalize starting with assumptions rather than observation:

> A person observing the real world of economic phenomena is confronted with a mass of data that is, at least superficially, meaningless. To discover order in this morass of facts and to arrange them in a meaningful way, it is necessary to develop theories to explain various aspects of human behavior, and thus to explain the otherwise meaningless data.

By "theory" Ferguson and Gould mean the mathematics of maximizing and its elaborations. But notice that the first step in economic analyses is theory, not observation. In contrast, the history of physics and biology teaches us that approaches based on rational first principles gave way to approaches based on observation and experiment. Newtonian physics replaced Aristotelian physics (e.g., Weinberg, 2015), and experiment-based models of how genes work replaced mathematical models of how genes work (e.g., Cobb, 2015). Nevertheless, economics is a vibrant field, and for the purposes of this paper, the assumption that individuals maximize "utility" proves most helpful. It defines the most efficient allocation of choices for a given set of alternatives. Thus, textbook economics provides a standard for measuring wastefulness and, as we will see, overconsumption.

Experimental Psychology and the Matching Law

Experimental psychologists also worried about a "real world. … morass of facts," but they responded differently. They arranged simplified economic worlds, in which it was possible to manipulate controlling factors and precisely measure the relations between choices and their consequences. As in other experimental disciplines, the psychologists assumed that simplification would eventually yield general principles that held beyond the conditions of the lab. This has proven true for experiments on choice. The initial studies were quite humble, yet they led to quantitative principles that have proven quite general.

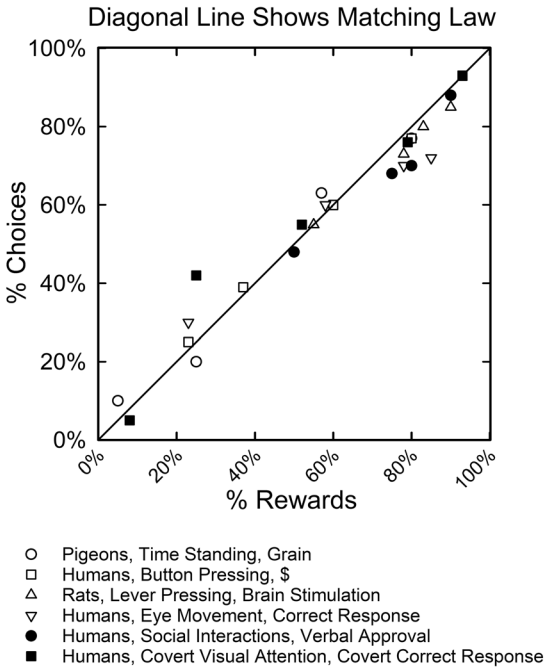
The matching law describes the relation between choices and their consequences under a yet-to-be delimited set of conditions. The subjects have included pigeons, rats, monkeys, humans, and species rarely studied by psychologists, such as coyotes and cows (Gilbert-Norton et al., 2009; Matthews & Temple, 1979). The rewards have included those that are consumed and those that are not, such as verbal praise (Conger & Killeen, 1974) and brain stimulation (Arvanitogiannis & Shizgal, 2008; Conover et al., 2001). The settings have included conventional behavioral research laboratories, a Cambridge Massachusetts attic that housed a small flock of pigeons (Baum, 1974), open fields near Oxford University that were home to pied wagtails (Houston, 1986), sports arenas (e.g., Falligant et al., 2016), and psychiatric clinics (e.g., Reed et al., 2013). A recent study extended the matching law to mental processing. Sebastian Moncaleano and I developed a procedure for quantifying covert shifts in visual attention (Heyman & Moncaleano, 2021). We projected two small images in a manner that precluded the role of eye movements, and, on the basis of a mathematical model of the procedure, calculated the trial-to-trial shifts in covert attention. The matching law described the relations between shifts in attention and correct answers (which were also delivered covertly). Figure 1 provides some representative examples of the results from matching law experiments.

The solid line traces out the original and simplest version of the matching law. In words, it says that choice proportions approximate reward proportions. Importantly, in these procedures, choice proportions were free to vary widely and had little influence on reward proportions (which were established by the experimenter). That is, matching reflected how the subjects accommodated to the procedure, and was not a trivial consequence of procedural constraints.

To appreciate what matching is telling us about choice, consider the experiment which first introduced the finding. Richard Herrnstein (1961) fitted a small chamber with two illuminated response buttons and an opening in which grain could be delivered by a hopper. The subjects were pigeons, and they could earn a small serving of grain by pecking at the buttons. Each button was associated with its own, independent, variable-interval reinforcement schedule. When an interval elapsed, the next response at the button linked to the elapsed timer earned access to the grain hopper. The intervals approximated a Poisson distribution and were arranged so that they would (1) pay off frequently enough to maintain relatively constant rates of responding,

Figure 1

A Sampling of Concurrent Variable-Interval Choice Studies



Note. The diagonal line is the matching law predictions. The studies reflect the range of conditions under which the matching law equation accurately describes the relations between choice and reward.

and (2) provide rewards at different rates, both within and between conditions. That is, one button typically provided a higher rate of reward than the other, and over sessions the ratios were varied. However, regardless of the interval durations, it was always possible for the poorer alternative to have primed a reward that was waiting to be collected. Thus, at any moment, a reward was available at one, both, or neither button.

In contrast to the situation for the consumer in economics text books, the guiding principles were unknown. Analogously, for the subjects there were few clues as to how to behave. Typically, animals navigate environments which are packed with useful information. Time of year, time of day, changes in the color and size of vegetation, the presence of other creatures provide clues as to when and where to find resources. Both evolutionary history and their kin "tutor" animals as to how to forage and what to eat (e.g., Hailman, 1969). Similarly, culture, social institutions, and their representatives help shape human choices. But in the lab experiments in which matching was first observed, there were no such aides. Nevertheless, as shown by Figure 1, the correlation between choices and their consequences proved very orderly. The relative frequencies of responding matched the relative frequencies of reward. What rule or rules were guiding behavior?

The Behavioral Etiology of Matching: Matching and Maximizing Are Not the Same

Implicit in this question is the distinction between matching as a description of the relation between choices and outcomes and the process which yields matching. In this paper, I take the view that matching follows from what I call "local bookkeeping" (see below). In contrast, most early accounts of matching tried to show that it was the allocation of choices that maximized overall reward, counting all options together as a single package (Baum, 1981; Rachlin, 1978; Staddon & Motheral, 1978). But as will become clear in the next graph, matching and maximizing differ; they are not the same. Thus, the study of choice yields two fundamental principles: maximizing and matching. Maximizing is the essence of efficiency, assuming the outcomes under consideration, thereby providing a standard by which to measure wastefulness and, as described below, overconsumption. Matching, as described by Figure 1, is what individuals do under a wide range of conditions. Taken together, they reveal important features of choice—features which help us better understand destructive consumption patterns. (This is not to say that other choice principles might not also prove relevant.)

Local and Global Bookkeeping in Elementary Economies

Figure 2 shows the relation between choice and reward in four elementary economic environments. Appendix 1 lists the equations that generated the curves and references to the papers that provide their empirical and mathematical bases. The panels in the top row describe the relation between choice and reward in concurrent variable-interval procedures of the sort used in most matching law studies, including Herrnstein's initial experiment; the second-row panels describe the relation between choice and

reward in concurrent variable-interval, variable-ratio schedules, which have been used to test whether matching was a form of overall reward maximizing (Herrnstein & Heyman, 1979; Heyman & Herrnstein, 1986); in the third row, rewards are a linear function of choice, as discussed in some detail below and in Appendix 2, and the fourth row displays an environment in which choices at the preferred option drive down the value of the competing options, what economists label a "negative externality."

In the interest of generality, I refer to the *y*-axes as value, whereas economists would label them "utility," and other psychologists might label the *y*-axes "reinforcement rate." The *x*-axes index the proportion of time the subjects spent responding at the preferred option, where "preferred" is defined as the option that has the highest value at $p = 0$. For example, in the panels that show the relation between choice and reward in interval and ratio reinforcement schedules, the variable-interval 25 s schedule is the preferred option. As shown next, identical economic relations can yield very different outcomes as a function of how individuals frame the available options.

The frame of reference for the right-side column is based on economics textbooks. The authors assume that consumers compare varying combinations of the available items. For example, Samuelson and Nordhaus (2009) imagined households comparing bundles composed of different proportions of shelter and groceries and then choosing the best bundle that they can afford. Other texts offer identical or similar examples (e.g., Frank & Cartwright, 2010). Thus, following the texts, the *y*-axes in the right-side panels of the top two rows track the value of all possible bundles of left-side and right-side rewards. That is, according to this approach, a subject in a concurrent schedule choice experiment chooses between different combinations of left and right rewards, not a left side reward or a right side reward. It is convenient to refer to this approach to choice as "global bookkeeping."

Global bookkeeping implies maximizing. Assuming that more food is better than less food, framing the available options as bundles drives preference to the peak of the curve that traces out the value of each possible bundle—this is the highest possible reward rate. Thus, the textbooks tell a consistent story: consumers frame their options in just the way that yields maximizing—and maximizing is what the textbooks assume. Also notice, as will be touched on in the last section of this paper, maximizing is in reference to the available options. It is always possible to imagine a more optimal set of options.

The frame of reference for the left side mirrors how experimenters describe concurrent schedule experiments, and it is also the frame of reference which yields the matching law. In these panels, the subjects are choosing between the two options. For example, in Rows 1 and 2, the *y*-axes show reward rates at each response manipulandum taken separately (i.e., the number of rewards at an option, divided by the amount of time spent at the option). It is convenient to refer to the left-side frame of reference as "local bookkeeping."

The crossing points are equilibria. This is where a local bookkeeper will necessarily end up. For example, if responding at the preferred option moves preference to the right of the crossing point, the less preferred option now has a higher local reinforcement rate, which will cause a reversal in the allocation of choices, pushing preference back to or past the crossing point (assuming the subject switches between the competing alternatives from time to time). The crossing points are also the matching law predictions. Notice that where the value lines cross, the local value of each option is the same; hence, at this choice allocation, reward proportions necessarily equal choice proportions—which is the matching law. Thus, just as global bookkeeping yields maximizing, local bookkeeping yields the matching law.

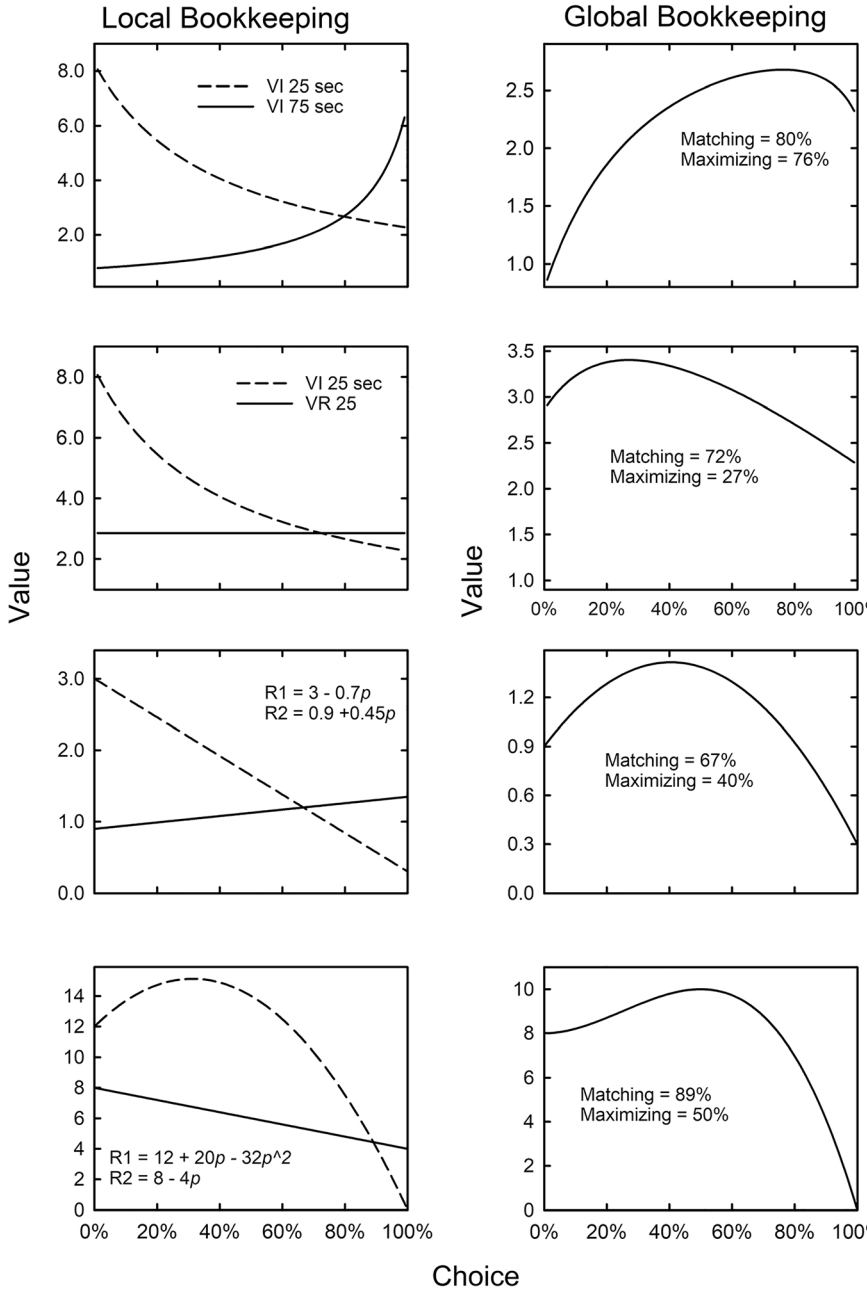
This last point requires comment. Vaughan (1981) and Herrnstein and Prelec (1992a) explain matching as a consequence of local reinforcement rate control of responding. Their account is the same as what I am calling local bookkeeping, but with differences in regard to the role of motivation (see Gallistel et al., 2002, and Heyman, 1982, for details). However, this difference plays no role in this paper.

Reward Value Functions and Their Implications for Overconsumption

The graphs reveal three findings relevant to excess and sustainability. First, matching is not necessarily the maximizing solution. Moreover, the two can differ by a great deal. Second, the matching law equilibrium is always to the right

Figure 2

Predicted Relations Between Choice and Reward Rate for Four Different Economic Environments



Note: The two columns show the predicted relations between choice and reward rate for four different economic environments. In each environment there are two nominal options. The text provides the details of the contingencies linking reward and choice. The left column shows the results for subjects who frame their choices as one option or the other: local bookkeeping. The crossing point is the matching law prediction. The right column shows the results for subjects who frame their options as bundles composed of different proportions of the two options: global bookkeeping. The curves peak at the overall maximum reward rate. The options in Row 1 are two variable-interval schedules. The options in Row 2 are a variable-interval and a variable ratio schedule. In Rows 3 and 4, the equations describe the relations between reward and choice, where p is the proportion of time spent responding at the preferred option (R1). Appendix 1 lists the equations that generated the curves for the variable interval and variable ratio schedules in Rows 1 and 2.

of the maximizing equilibrium. Since the *x*-axis measures preference for the preferred option, this means that in these four cases, matching entails choosing the preferred option more than is predicted by maximizing. Or put another way, choosing too much of what is liked best. Thus, the comparisons provide a quantitative measure of overconsumption, using maximizing as the standard. Third, the bottom panel predicts that consumers who are local bookkeepers will continue to prefer their favorite option even when its value decreases and even when consuming their favorite option drives down the value of the competing, less preferred options. Points two and three are discussed next.

The graphs show that in four different economic environments, individuals who allocate their choices as predicted by the matching law consume too much of their favorite option. If this were to be true for all settings, regardless of the contingencies between choices and outcomes, then the choice proportion that satisfies the matching law will always exceed the choice proportion that satisfies the maximizing equilibrium, assuming the coordinates of Figure 2, which is to say, matching would always entail consuming too much of the favored option. Appendix 2 tests whether this is the case for all possible versions of the simplest reward functions, the linear relations in the third row of Figure 2. The calculations include the following quantities: (1) the choice proportion that satisfies matching, (2) the derivative of the function that generates overall reinforcement rates, and (3) the choice proportion at which the derivative equals zero. As suggested by the graphs, the proof shows that when reward is a linear function of choice, it is always the case that the choice proportion that satisfies the matching law exceeds the choice proportion that maximizes reward (assuming an initial preference for one or the other option). As noted in Appendix 2, the generality of this result to nonlinear reward functions, as in rows 1, 2, and 4 has yet to be fully explored.

The bottom row panels include a negative externality. Preference for the preferred option (R1) reduces the value of the less-preferred option. For a local bookkeeper the situation is disastrous. Assuming their initial values at $p = 0$, the matching law equilibrium yields about a 67% decrease in the value of the preferred option and about a 45% decrease in the value of the less preferred item. In contrast, since global bookkeeping keeps track of combinations of both options, the negative externality does no overall damage. Thus, negative externalities and local bookkeeping combine to yield an inferior yet preferred outcome. Herrnstein and Prelec (1992b) introduced a graph like that of the bottom panel to explain addiction, and in a series of papers I have elaborated on their ideas (e.g., Heyman, 2018). Although seemingly contradictory, experimental tests support the predictions of the bottom panel.

Herrnstein and his colleagues (1993) arranged a series of experiments in which Harvard undergraduates played economic games that included negative externalities (which they refer to as "internalities" as they were modeling drug use)—and "third parties" (the victims of externalities) were not involved. The reward was money, and in some conditions there were stimuli and incentives that emphasized the differences between local and global bookkeeping. As the incentives for local bookkeeping increased, more students matched, and under all conditions some students matched, despite earning less money by doing so. Brian Dunn and I repeated this study (Heyman & Dunn, 2002). The subjects included a group of long-term, in-treatment, illicit drug users. We also found individual differences. Illicit drug users were significantly more likely than the non-clinic subjects to approximate the matching law predictions, thereby reducing the overall amount of money they earned. Moreover, there was a correlation between years of drug use and approximations to matching. Thus, (1) the matching law predicts that individuals will continue to choose an initially favored option that is linked to a negative externality even though doing so drives down its absolute value and the overall absolute value from all available options, and (2) this prediction was supported by laboratory experiments.

Why Doesn't Maximizing Dominate Matching?

First, a common feature in the settings in which matching takes place is that the options are "elementary kinds": left button versus right button, a red light versus a green light, top row versus bottom row, one foraging patch versus another foraging patch, and so on. Each option has a readily discernible,

physical basis. In contrast, global bookkeeping entails comparing entities that do not have simple physical bases—they are abstract. In the experiments referenced by Figure 2, there are no cues that correspond to global bookkeeping bundles, the graphs notwithstanding. Everyday choices offer the same challenge. To maximize utility, households have to compare different combinations of shelter, clothing, recreation, and so on, yet these combinations only exist on paper, in a spread sheet, or imagination; they are abstractions. Baumol and Blinder's (2015) introductory text asks the reader to imagine families choosing between bundles composed of cheese and rubber bands. This rather strange example may be the authors' nod to the difference between textbook consumers and actual consumers—or a joke—but in any case, it emphasizes the abstract quality of economic bundles. Put more generally, local bookkeeping options conform to natural fracture lines of the world, whereas global bookkeeping options require the creation of abstract categories that do not have obvious physical counterparts.

Second, global bookkeeping is more complex than local bookkeeping. This can be demonstrated in two ways. The process of creating bundles entails an "and" operation and an "or" operation. First to create the bundles, the options need to be combined ("and"), and then to choose among the bundles, the consumer needs to compare them ("or"). In contrast, local bookkeeping requires only comparing the competing, ready-made, concrete options. Corresponding to this point, equations for the maximizing equilibria are more complex than the equations for the matching law equilibria (see Appendix 2).

Third, matching and maximizing create dilemmas whose solutions favors matching. Imagine that individuals do not stick to just one frame of reference, but are both local and global bookkeepers, depending on circumstances (and likely these are endpoints of a continuum, since the temporal and spatial domain over which choices are measured is flexible). From a local bookkeeping perspective, Figure 2 shows that in order to maximize overall value, it is often necessary to choose the least favored option. Of course, this problem does not exist from a global bookkeeping perspective. However, for individuals who can take both a local and global perspective, the situation is fraught, and likely biased in favor of the local frame of reference, since its rewards are more visceral and immediate.

Thus, it is not surprising that in the experiments conducted in both lab and nonlab settings, we observe matching not maximizing, which is to say, we observe overconsumption of the favored option and a blind-eye to negative externalities.

Teaching Subjects Not to Match

Given the intimate connection between how individuals frame their options and matching and maximizing, it should be possible to teach maximizing by teaching global bookkeeping. Rachlin (1995) did just this, although he refers to it as patterning.

In a representative patterning experiment, college students played an economic game that included a negative externality and a novel spacing of choice trials (Kudadjie-Gyamfi & Rachlin, 1996). There were two buttons, presses on each earned the same amount of money, but at different delays. At one, the delays were always shorter but choosing this button increased the delays on both buttons on future trials. Conversely, choosing the button with the longer delay on the current trial reduced the delays on both buttons. Overall earnings were inversely related to the delays, so that global bookkeeping avoided the penalty of increased delays and thereby earned more money. In one condition the trials were presented in triplets with a long intertrial interval, whereas in other conditions the intertrial intervals were fixed or unpatterned. Patterning significantly increased preference for the option that was better from a global perspective, but worse from a local perspective. Rachlin's (1995) explanation was that patterning "tends to cause a series of momentary choices to be perceived as a unitary, temporally extended event". Or in the language of this essay, patterning induces global bookkeeping.

In an analogous experiment with pigeons, Larry Tanz and I (Heyman & Tanz, 1995) taught pigeons to deviate from matching toward maximizing in a left/right, two-button procedure. We provided the subjects with stimuli that were correlated with the relation between bundles of left and right responses and bundles of left and right rewards. For instance, the stimuli signaled when left and right response

proportions deviated from left and right reward proportions, which is to say, the stimuli were correlated with deviations from matching. Under these conditions, the pigeons allocated their pecks as predicted by global bookkeeping. Thus, by creating conditions that favor global bookkeeping, it is possible to shift choice towards maximizing.

Limitations in the Present Analyses

Consumption involves tangible goods and activities that are embedded in a rich historical, cultural, and social fabric. In contrast, the primary data for this report were provided by pigeons pecking at two discs for food in small, stark chambers. The analyses were likewise bareboned: mathematical functions that modeled abstract reward contingencies and rates of responding. Thus, it is reasonable to have doubts about the relevance of the graphs to the phenomena that motivated the paper: acres of self-storage lockers and the various other symptoms of a shrinking planet. Nevertheless, there are reasons to have faith in the relevance of the analyses and data summarized in Figures 1 and 2.

Sustainability requires an abstract account. Overconsumption is a general phenomenon, not specific to a particular historical period, culture, or even commodity. Related to this point, and as mentioned, the matching law has proven quite general. It applies in laboratory experiments, as well as in settings that are peculiar to humans. The latter include board games, baseball diamonds, football fields, and psychiatric clinics (Cero & Falligant, 2020; Falligant et al., 2016; Vollmer & Bourret, 2000).

However, the analysis presented here does not explain historical changes in rates of consumption, particularly the large increases of the second half of the 20th century that continue to today. As noted in the Introduction, overconsumption has many causes. The point of this paper is to establish why individuals have been more influenced by those championing growth and consumption than those championing sustainability and frugality. My thesis is that (1) this reflects general characteristics of how individuals make choices, and, (2), some features of making choices, such as local and global bookkeeping, are quite general, applying to both humans and nonhumans.

A second limitation has to do with the distinction between maximizing and optimal choice. The graphs illustrate the rewards that the experimenters arranged and labeled. Analogously, textbooks typically list obvious options, such as food, shelter, clothing, recreation, and so on. Not listed are less visceral yet important options, such as the welfare of grandchildren, the plight of redwood forests, the future of elephants. That is, there may be a more optimal array of options. A supply chain researcher puts this issue as follows (Speer, n.d.):

> A warehouse worker whose bonus hinges on the number of orders packaged per day will likely reach for the closest box versus the one that most closely matches the size of the product being shipped. That adds up to a lot of expensive shipped air, and more transportation, gasoline, and packaging to handle more boxes. It is maximization working at cross purposes to the optimization of the whole enterprise.

Analogously, the analysis presented here has nothing to say about what the choices should be, yet the issue is highly relevant to sustainability.

Some Conclusions and Relations to Rachlin's Work

Although this report does not suggest what should be on the table, it does include a demonstration of how to avoid the potentially toxic effects of local bookkeeping. When Rachlin and his colleagues provided conditions that emphasized the interdependencies between choices and outcomes, individuals selected their favored outcome (from a local bookkeeping perspective) less frequently. The situation bears some similarity to policies that add taxes to goods with negative externalities, such as fossil fuels. Patterning, like taxes, makes the connections between the favored good and its negative externality more salient, which in turn makes the favored good less desirable.

Howie Rachlin and I took different approaches to the relation between matching and maximizing (e.g., Rachlin, 1978) and to addiction (e.g., Heyman, 2018; Rachlin, 2007). He put much more emphasis on the immediate benefits of drug use and the delayed benefits of controlled use than I have. My approach has been influenced by the impression that heavy drug users often have to plan ahead and establish enduring social relations

in order to maintain their addiction, whereas Rachlin and perhaps most students of addiction have not thought this relevant or have quite different impressions regarding the behavioral patterns of heavy drug users. On the other hand, what I call global bookkeeping, Rachlin would, I believe, think of as an instance of "temporal patterning," which he considered a key component of self-control (Rachlin, 1995).

In sum, my goal was to explore the role of choice in overconsumption and sustainability. My approach closely follows Herrnstein and Prelec's (1992b) analysis of addiction and my earlier extensions of their reasoning to many of the unique features of addiction (e.g., Heyman, 2009, 2018). In these analyses, individual or "one-party" negative externalities, as in the bottom panels of Figure 2, played a central role. In contrast, in this paper, I have focused on overconsumption, where overconsumption is defined by the relation between the maximizing equilibrium and the matching equilibrium. Using maximizing as a standard, the data presented here show that matching implies overconsumption of the favored options. Although the degree of overconsumption, as so defined, is often quite small, it is easy to imagine that small differences accumulate, and that this bias is readily exploited by the more obvious drivers of consumption, such as government economic policies, increases in wealth, advertising, and the like. Thus, the pitfalls of voluntary behavior are not restricted to drugs, but apply to any item or activity that we like a lot.

A Personal Note

My interactions with Howie Rachlin were primarily at meetings, most often at the annual conferences of the Society for the Quantitative Analyses of Behavior. Most memorable were a postconference afternoon at the San Antonio's Museum of Art and the thought problems he posed in his presentations and our dinner conversations. The puzzles revealed a playful, engaging approach to long-standing moral and philosophical problems. "Imagine that you and your spouse have had a long, loving, fulfilling marriage, with wonderful children, close mutual friends, memorable vacations in far-away, exotic settings: an altogether joyous meeting of mind and body—beyond what anyone could reasonably hope for. Now, the end of your lives approaching, you discover she is not a person but a robot. Would you regret all that you have shared?" Howie, thought "no" and so did most of those at the table. However, now, having spent the last several years teaching a large introductory course titled "Brain, Mind, & Behavior," the robot creators in Howie's story deserve a shout out; it would be most remarkable to be able to build such an amazing creature.

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Appendix 1

Equation A1 calculates the overall reward rate for a concurrent variable-interval schedule. At each schedule there are two ways to earn a reward: A reward can set up at a schedule while the subject is responding at the schedule, or it can set up while the subject is responding at the other schedule, and remain available until the subject returns. In the numerators, p is the probability that the subject is at VI_1 and $1-p$ is the probability of being at VI_2. The denominators list the average programmed interreinforcement interval, the average interresponse time, and the average visit times at each side. The constant I indexes the overall tendency to switch from side to side (*inertia*). The empirical bases and logic that generated this model are in Heyman & Luce (1979) and Heyman (1982). The basic assumption is that subjects have an approximately constant probability of switching between sides, thereby yielding a Poisson distribution of visit times. Tests of the model reveal that it accurately describes the relations between preference, changeover rate, and obtained reinforcement rates. The empirical parameters (I and irt) faithfully reflect laboratory findings

$$R=\frac{p}{VI_1+irt_1}+\frac{1-p}{VI_1+\frac{I}{p}}+\frac{1-p}{VI_2+irt_2}+\frac{p}{VI_2+\frac{I}{1-p}} \tag{A1}$$

Equation A2 calculates the overall reinforcement rate for a concurrent variable-interval, variable-ratio schedule. Like Equation A1 it accurately describes the relation between reinforcement rate, response rate and changeover rate. For example, the interresponse times used to calculate the curves in Figure 2 are based on observed values, as are the interchangeover times (I/p and $I/(1\text{-}p)$). For details and discussion, see Herrnstein & Heyman (1979) and Heyman & Herrnstein (1986)

$$R=\frac{p}{VI+irt_{vi}}+\frac{1-p}{VI+\frac{I}{p}}+\frac{1-p}{VR\times irt_{vr}} \tag{A2}$$

Appendix 2

Figure 2 lists four different economic environments, as described in the text. Nevertheless, in each of the four settings, the choice proportion that satisfies matching is larger than the choice proportion that satisfies maximizing. We can test whether

this is generally true for contingencies in which reward rate is a linear function of response rate, for example, the third row panels of Figure 2. Let

$$R_1 = a + bp,\ b < 0 \tag{B1}$$

$$R_2 = c + dp, \tag{B2}$$

At matching B1 = B2, thus we can solve for the choice proportion that satisfies matching by setting B1 equal to B2, and rearranging terms.

$$p_{match} = \frac{c - a}{b - d} \tag{B3}$$

The equation for overall reinforcement rate is:

$$R = p(a + bp) + (1 - p)(c + dp) \tag{B4}$$

This is simply the local reinforcement rates weighted by the time spent at each alternative (p and $1\text{-}p$). The maximum of this function is obtained by taking its derivative and setting it to zero.

$$(a + 2bp + d - c - 2dp) = 0 \tag{B5}$$

To determine its relation to the choice proportion that satisfies matching, we can solve for p.

$$p_{max} = \frac{c - a - d}{2(b - d)} \tag{B6}$$

Inspection reveals that p_{max} is necessarily smaller than p_{match}. Thus, for linear reward functions, matching necessarily involves spending more time at the preferred option than predicted by maximizing. The graphs suggest that this result also applies to nonlinear value functions, but this has not been rigorously tested.