field of inquiry, it is easy to see how nonlinearities could come into play. Suppose that instead of the offers with $100 or $200, one had 100 or 200 seeds, and further suppose that by planting the seeds one could have 100 seeds yield 1,000 in one year. Now delaying acceptance of 100 seeds to get 200 seeds three years later is clearly foolish – one will be well ahead of the game with 100 seeds now! Here, however, one sees a difference with seeds in that they do not have so much a fixed value, as a value that itself can increase over time. Similar effects can arise for coupled resources and in cooperative systems. In a leading approximation, the simplest nonlinear modification of the equation leading to exponential discounting will generically lead to hyperbolic discounting.

How far hyperbolic discounting will ultimately go to resolve deep questions about the human will, remains to be seen, but Ainslie makes it clear that, at the very least, defining rational behavior as that which would correspond to exponential discounting (and thus to assumptions about uniformity of conditions in time and the lack of any nonlinearities) is flawed. More complex discounting algorithms are certainly conceivable, but both from general arguments and a wealth of experimental data, it seems that hyperbolic discounting goes a long way towards capturing the basic spirit of these.

This is a well organized and reasonably priced, accessible book – useful for any behavioral scientists interested in a deeply considered introduction to the topic of decision science.

Reference point-dependent tradeoffs in intertemporal decision making

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Abstract: We agree with Ainslie's general approach to intertemporal choices and self-control. However, we argue that a concept of "will" is superfluous in explaining tradeoffs between SS (smaller and sooner) and LL (larger and later) rewards in a framework of temporal goal setting and goal aggregation. We provide an alternative framework of reference point-dependent tradeoffs between SS and LL options.

Ainslie (2001) brings human choices out of the realm of rational maximization of economic goods and into a psychological world of motivation, temptation, and risk preferences. We agree with his general approach to studying risky choices and self-control in a framework of temporal goal setting and goal aggregation. Ainslie suggests that "will" can be viewed as being the effect of aggregating goals over time to determine choice. This hypothesis affords some interesting reasons as to why people would prefer smaller and sooner options (e.g., cognitive deficits that make the aggregation of goals difficult; a foreshortened sense of the future; experience with unpredictable environments; self-efficacy in achieving long-term goals, etc.).

However, we argue that in a framework of goal settings and goal aggregation, a concept of will as an explanatory construct is superfluous. We propose a new conceptual framework of reference point (goal or a minimum requirement) dependent tradeoffs between SS and LL rewards to account for intertemporal decision-making and self-control.

Ainslie's description of will as aggregated choice is a potentially rich and informative perspective. However, Ainslie's conceptualization of the will is primarily descriptive, yet the construct of will in psychology is mainly promoted as explanatory. He defines "strong" will as the aggregation of future choice points to facilitate choosing longer, later (LL) over shorter, sooner (SS). He suggests that "strong" will manifests when the SS/LL choice is viewed as a class of choices and that choosing SS at one point in time is perceived as promoting SS choices at each successive time point. Ainslie states that individual differences in aggregation rules lead to adaptive or maladaptive consequences of the functioning of the will. What we do not know is how people develop variations of these aggregation rules, how some are able to view the aggregation of choices *against* SS as more reinforcing than the current choice *for* SS. The answer to that question provides explanatory power and yet this seems largely untouched in Ainslie's conceptualization of the will.

Contrary to the assumption indicated in Ainslie's book, that LL rewards are always superior to their SS alternatives, we intend to demonstrate that some ostensibly irrational and impulsive behaviors in favor of SS rewards over LL ones can be both normative and adaptive, given that risky choices are bounded by goals and deadlines in life.

The last three decades have witnessed great theoretical and empirical developments in the studies of reference points in human decision-making regarding risk (e.g., Heath et al. 1999; Kahneman & Tversky 1979; Lopes 1987; Tversky & Kahneman 1981) and in foraging behavior of nonhuman animals (e.g., Kacelnik & Bateson 1997; Stephens & Krebs 1986).

In making intertemporal decisions between SS and LL rewards, the process of approaching a goal (G) can be viewed as a process of status quo (SQ) improvement, whereas the process of falling towards a minimum requirement (MR) can be seen as a process of SQ deterioration. As illustrated in Figure 1, when faced with SS and LL alternatives, the choice becomes a tradeoff between the amount and the delay of rewards with reference to distances to the upper- and lower-bound reference points (i.e., G and MR).

For an upward expected SQ over time, SS should be preferred to LL (SS > LL) if SS can reach a goal earlier. SS (or any choice) should be preferred whenever it will be sufficient for reaching the goal state. The upper middle arrow is LL in respect to the upper left arrow, but SS in respect to the upper right, yet in either case it should be preferred because it moves the person past the goal. Essentially, the crucial determinant is not maximizing value but minimizing the goal discrepancy as quickly as possible (cf. Carver et al. 1996). Outcomes that fall both below or both above a reference point (a goal or a minimum requirement) are expected to be more similar in their psychological values, whereas outcomes that are located on different sides of a reference point are expected to be markedly different in psychological values.

For a downward expected SQ over time, LL options should be

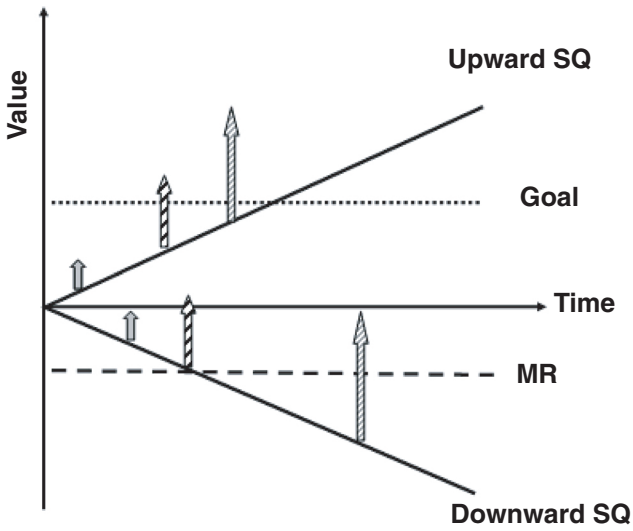

Figure 1 (Wang & Simons). Expected future gains on top of either an upward status quo (SQ) trajectory or a downward status quo trajectory. The length of the arrows represents the amount (value) of rewards (gains) at different time points. MR = minimum requirement.

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preferred to the SS alternatives (LL > SS), provided that the delay will not allow the person to fall or remain below the MR. However, SS options should be preferred when they can keep the SQ above the MR or bring the SQ above the MR sooner than LL alternatives. In the case illustrated in the lower part of the figure, the medium gain would be superior to the largest gain (SS > LL) because survival cannot be delayed. A starved man needs any food that can feed him instead of a delayed larger supply. As the SQ approaches the MR in time, the temporal difference is vital, but the amount difference is functionally null.

This analysis suggests that some impulsive behavior such as drug use and unprotected sex may not be simply a result of intoxication or cognitive deficit, but adaptive reactions to perceived goal distance and to subjective estimation of SQ trajectory, which may or may not be accurate. That is, if one is below, or perceived to be falling below a MR, the option that most quickly returns the person to above the MR should be favored. Though the projected outcome of the LL may be superior, the individual is unable to be sustained below the MR to reach the LL choice point in time.

Hyperbolic discounting functions provide a general mathematical expression of psychological mechanisms of intertemporal decision-making. However, the functions themselves are not psychological mechanisms and seem not to be congruent with a framework of reference-dependent decision-making.

Author's Response

A bazaar of opinions mostly fit within picoeconomics

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Abstract: The will has generated a wider range of opinions than most phenomena, lacking as it does both an animal model and consistent behavioral correlates. It has even been held not to exist. The commentators approached my intertemporal bargaining (picoeconomic) model from many angles. Doubts about the existence of the underlying phenomenon, hyperbolic discounting, were still raised by some, but other commentators added to the evidence for it, which I regard now as overwhelming. Where mechanisms of self-control were specified, I found it possible to place them within a picoeconomic framework.

R1. Introduction

My purpose has been to show the feasibility of a bottom-up model of choice-making, one that starts with the simple reward-seeking processes observable in most animals and combines these processes by simple principles so that, once a capacity for foresight and self-perception is added, it predicts the familiar nuanced experience of an autonomous ego. The commentators have made useful suggestions about each stage of this model, and have given me occasion to clarify many aspects of it in ways I had not thought of before. Most of their analyses start with the seminal empirical finding of hyperbolic discounting, which still seems to be controversial. Section R2 concerns the intertemporal conflict implied by this finding, and several commentators' critiques of the idea that internal interests based on conflicting rewards create a self in the form of a marketplace (discussed further in sect. R3). One commentary encouraged my alternative approach to classical conditioning (sect. R4). The greatest number of commentators addressed the capacity of a modified repeated prisoner's dilemma game in this marketplace to generate strength of will (sect. R5), a mechanism that also gives a rationale for the experience of freedom of will (sect. R6). My suggestion that thought experiments can provide valid data on this kind of recursive internal process was addressed in the case of the least straightforward of my examples, Newcomb's problem (sect. R7). Finally, since most of the commentators deal in one way or another with the empirical status of my approach, I review the present status of research on this topic (sect. R8). The main topic of the last third of the target book, hyperbolically driven impatience for premature satiation of appetites and its likely consequences, was, perhaps wisely, left alone.

R2. Hyperbolic discounting

The most important consequence of hyperbolic discounting is that it may cause the value of a small, sooner (SS) reward to spike above that of a larger, later (LL) one temporarily, when the SS reward is imminently available. **Bridgeman** says that the hyperbolic model will not work because, among other problems, hyperbolic curves go to infinity at zero delay; but the empirically derived curve I propose does not go to infinity. **Arló-Costa** suggests that Rubinstein's (2003) "similarity relations" mechanism contradicts hyperbolic discounting. However, those experiments mostly show that subjects ignore very small differences, which at most suggests a supplementary principle to the robust hyperbolic curves that have been observed in both human and nonhuman experiments. One of Rubinstein's experiments unwittingly replicates Kirby and Guastello (2001): A preference for $997 now over $1,000 a month later, but not for four $997's at monthly intervals over four $1,000's, each a further month later, does not refute hyperbolic discounting, but rather demonstrates the mechanism by which it permits willpower – the predicted increase in preference for LL rewards when choices are bundled into series (*Breakdown of Will*, Ainslie 2001, pp. 82–84).

Green & Myerson refer to data, much of it their own, that support a specifically hyperbolic shape. They argue for a credible refinement that improves its already superior fit with choice data by raising the denominator of the value equation to a power, an adjustment first suggested for the matching law in general by Baum (1974). I have not examined this suggestion at any length because, as Green & Myerson point out, it does not change the strategic implications of the basic hyperbolic curve for intertemporal bargaining. However, this added bit of precision clearly supports the basic hyperbolic shape of the discount curve, as does the finding of Green et al. (in press) that the choice between two non-immediate rewards is also evaluated hyperbolically. Ainslie and Haendel reported temporary changes of preference between two non-immediate alternatives as early as 1983, but the parametric work of Green and his colleagues argues much more strongly for hyperbolic discounting in all delay periods (cf. Ainslie & Haendel 1983).

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