**April 25, 2012**

**The Evolution of Hyperbolic Discounting: Implications for Truly Social Valuation of the Future**

John Gowdy, Professor of Economics and Rittenhouse Professor of Humanities and Social Science, Rensselaer Polytechnic Institute, Troy, New York USA 12140 [gowdyj@rpi.edu](mailto:gowdyj@rpi.edu)

J. Barkley Rosser, Jr. Professor of Economics and Kirby L. Cramer, Jr. Professor of Business Administration, James Madison University, Harrisonburg, VA 22807 USA rosserjb@jmu.edu

Loraine Roy, Ph.D. student in Economics, Université Lille 1, EQUIPPE, Lille, France loraine.roy@etudiant.univ-lille1.fr

**Abstract –** We explore the standard expected utility model and alternatives to it. We then examine the behavioral and neurological evidence for hyperbolic discounting. We discuss evidence related to the neurological and behavioral evolution of discounting in non-human animals and in humans. We explore new findings about the importance of sociality in human behavior and the implications for truly social time preference. Finally, we discuss the implications of the neurological evidence on discounting for social environmental valuation, in particular the implications for very long-run decisions such as those involved in climate change mitigation and biodiversity preservation.

**The Evolution of Hyperbolic Discounting: Implications for Truly Social Valuation of the Future**

**I. The Basic Economics of Discounting**

Evaluating the impacts of present activities on those living in the future is one of the most critical areas of uncertainty in environmental policy. The debate surrounding discounting is not only important to the numerical valuation of the costs and benefits of environmental policies (social benefits/costs and optimal path calculations), it is also central to designing policies that are incentive compatible with observed human behavior and evolved neurological structures and pathways. In the standard economic model—here referred to as the dynamic stochastic general equilibrium (DSGE) model—the debate about responsibility to future generations is reduced to the choice of a social discount rate (Dasgupta and Heal 1974; Hepburn et al. 2009; Pearce et al. 2003). Discounted utility (DU) refers to the discounted value of the flow of services from consumer goods over time (Ramsey 1928; Samuelson 1937). DU assumes a strict equivalence between benefits and the utility derived from those benefits. It is essentially a financial investment model showing how a perfectly rational individual should allocate investments so as to maximize expected present value of those investments. The standard DU model of environmental valuation assumes that social decision makers, like an individual making private investments, should seek to maximize the sum of present and discounted future economic welfare. The social discount rate is typically the private rate adjusted for external effects, and determining the scope of these effects is fraught with difficulties (Graaff 1987). In the DU model, the value of future welfare is usually discounted at constant percent per year reflecting among other things society’s impatience, or the preference for receiving benefits in the short run while deferring costs to the future.

In a continuous-time setting with constant population and a single consumption good, the DU approach employs the mathematics of constrained optimization to maximize the social welfare functional:

W(t) = ∫ U[C(t)] [1/(1+r)α(t)]dt (1)

In this form, *U* is instantaneous utility, *C* is the flow of consumption goods and [1/(1+r)α(t)] is the discount weight. Using a constant discount rate reduces the weighting factor used in equation (1) to[1/(1+r)t], where α(t) = t (Albrecht and Weber 1995, Cairns and van der Pol 2000). Equation (1) is a general formula that can be converted into an exponential or hyperbolic function.

In spite of sustained criticism (Bromley 1990; Frederick, Loewenstein and O’Donoghue 2002; Howarth 2009; Ludwig, Brock and Carpenter 2005) the DU model still dominates econometric work in environmental valuation including discussions of whether or not economies are sustainable (Arrow et al. 2004). Discussion of the proper discount rate was central to the controversies surrounding the *Stern Review* (Cole 2009; Quiggin 2008; Stern 2007) on the economics of climate change and The Economics of Ecosystems and Biodiversity (TEEB) initiative on the economics of biodiversity loss (Gowdy, Howarth, and Tisdell 2010). The upshot of these discussions is that there is no purely economic justification for choosing a particular discount rate. Econometric studies offer little guidance since even with fairly short-lived choices people employ a wide range of discount rates depending on framing, the nature of the product, income, and numerous other factors. For example, estimates of the discount rate for the adoption of energy saving appliances show inconsistent and widely varying time horizons. Hausman (1979) found that air conditioner purchases showed a discount rate of 25% and that the rate varied between 5% for high income households and 89% for low income households. Train (1985) found that discount rates varied considerably depending on the kind of appliance.

Discounting is particularly problematic when dealing with extremely long-lived environmental problems like biodiversity loss, climate change and the risks associated with nuclear power (Carson and Roth Tran 2009). Earlier it was sometimes argued that the discount rate should be based on the after-tax marginal rate of return on private investment as the best measure of the opportunity cost of capital, although that view has since been superseded by the view that a broader social consideration should dominate (Baumol 1968; Marglin 1963). The earlier view underlay the effort in 1970 by the Nixon Administration to impose a government-wide 10% discount rate for use in all cost-benefit analysis (based on estimates by Stockfish, 1969). In standard environmental valuation, the welfare effects of changes in an environmental attribute are evaluated based on the gain or loss of social welfare (the shadow price of the policy) with or without the environmental attribute (Barbier 2007; Mäler 1985).

A number of theoretical and behavioral economists, following influential papers by Phelps and Pollak (1968) and Laibson (1997) have called for the use of a hyperbolic discount rate on positive and normative grounds. With hyperbolic discounting α(t) is concave because the discounting factor declines as a hyperbolic function of time. α(t) can take a number of hyperbolic forms. For example, Loewenstein and Prelec (1992) propose a general form of the discount weight as 1/(1 + gt)h/g so that

α(t) = hln(1+gt)/gln(1+r) (2)

The parameter h determines the length of each perceived time period. As h approaches zero time perceived passes faster and faster so that the individual is indifferent between time periods as in the standard exponential model. As h approaches infinity perceived time does not change and so there is no discounting of the future. We will provide in this paper some empirical support for those assumptions. The parameter g shows how much the function deviates from the standard exponential model. The fundamental difference between exponential and hyperbolic discounting is that the discount rate varies over time with the hyperbolic and not with the exponential. More normative recent research on discounting long-term environmental benefits and costs (Philibert 1999) has also called for discount rates decreasing over time. Cairns and van der Pol (2000) show how various hyperbolic models such as those of Harvey (1986) and Mazur (1987) are variations of equation (2).

In terms of DSGE theory, an argument for constant discounting is that it is time consistent, that is, the passage of time does not affect the investment decision (Winkler 2006). Koopmans (1960) refers to this as the *stationarity postulate*. The preference between two outcomes depends only on the absolute time separating them, not the distance into the future. Hyperbolic discounting is time inconsistent because an optimal decision made at time *t* may no longer be optimal when re-evaluated at time *t+1* (Strotz 1956). Figure 1a shows exponential

Figure 1.a Figure 1.b

**Figure 1. Exponential and Hyperbolic Discounting**

discount curves from a Smaller-Sooner (SS) reward and a Large-Latter (LL) reward. Figure 1.b shows hyperbolic discount curves from an SS reward and a LL reward. In the hyperbolic case the smaller reward is temporally preferred for a period just before it’s available, as shown by the portion of its curve that projects above that from the LL reward (Ainslie 2005).

This brings up the more general problem with the DSGE model. It is a normative model describing how a person at a point in time *should* (not actually does) make an investment decision, neglecting thereby empirical evidence about discounting behavior that could help make policies more incentive compatible. The DSGE model assumes strict rationality on the part of agents, in the form of rational expectations and time consistency, so that hyperbolic discounting is time inconsistent. Evaluations of the worth of something at a future date will vary significantly depending on the starting point (see Ackerman and Heinzerling 2004).

In the next section we first examine the behavioral and neurological evidence for hyperbolic discounting. We then discuss alternative (non-expected utility) approaches to discounting including those allowing for time inconsistency, matching laws and similarity-based decision making. We then turn to the neurological and behavioral evidence for the evolution of discounting in non-human animals and in humans. Finally, we discuss the implications of the neurological evidence on discounting for environmental valuation, in particular the implications for very long-run decisions such as those involved in climate change mitigation and biodiversity preservation policies. The discounting discussion takes us beyond DSGE approaches underlying most of contemporary environmental theory and policy and opens the door to a broader discussion of human well-being, the social context of decision-making, and aligning environmental policies with incentives compatible with observed human behavior.

**II. Hyperbolic Discounting**

One form of a hyperbolically discounted utility function is given by Rubinstein (2003, 1207):

u(*x0, x1, ..., xt, …*) = *v*(*x0*) + *β*Σt=1,2,…*δtν*(*xt*) (3)

Utility received in periods 0, 1, 2, 3, … is discounted by 1, *βδ*, *βδ2*, *βδ3*, …, respectively. This function implies that the value of the ratio of rewards received in successive time periods becomes smaller and smaller the further in the future they occur.

Generally speaking, considerable evidence exists for some form of hyperbolic discounting in that people discount the value of delayed consumption more in the immediate future as opposed to the distant future (Cropper and Laibson 1999; Kim and Zauberman 2009; Newell and Pizer 2003; Settle and Shogren 2004; Weitzman 2001). Ainslie (2005) shows that hyperbolic discounting can explain observed irregularities in human behavior such as preference reversal and impulsive choices made when a reward is immediately available. But does this imply that individuals employ a continuous discounted utility function as implied by equation (2)? Rubenstein (2003) argues that the same evidence from behavioral experiments used to reject exponential discounting can also be used to reject hyperbolic discounting. He argues for “opening up the black box” of human decision making rather than simply modifying functional forms that can be easily accommodated in the standard welfare model. Hyperbolic discounting is “safe” because it can be incorporated into the standard economic optimization model as in the Nordhaus and Boyer (2000) climate change model. Hyperbolic discounting is frequently favored by environmental economists on ethical grounds because it gives more weight to losses suffered by future generations. But as Rubinstein (2003, 1215) observes:

[Hyperbolic discounting] goes much further than simply assigning a special role for the present. It assumes the maximization of a utility function with a specific structure and misses the core of the psychological decision-making process. Thus, I find it to be no more than a minor modification of the standard discounting approach.

Nevertheless, we note an important difference between the sort of hyperbolic discounting observed in individuals, such as the Hausman (1979) study of people buying appliances, and the sort advocated for social decision making by some environmental economists. The discount rates observed for individuals tends to take the form of very high short-term rates, with rates declining to something more like observed market rates for longer time horizons. The rates advocated by environmental economists tend to be much lower across the board, with the shorter horizon ones being nearer market rates, whereas the longer term ones decline towards zero. This reflects the “green golden rule” perspective of Chichilnisky, Heal, and Beltratti (1995) which argues that higher short term rates avoid having the future exploit the present (and also help efficiently allocate investment), while lower longer term rates guarantee that the present does not exploit the future. At the same time, none of these reflect what one observes in a normal market term structure of interest rates, wherein rates for longer term assets are usually higher than for shorter term ones, although this is conventionally explained by a rising inflation risk premium as one holds longer term assets. All this supports Frederick, Lowenstein, and O’Donoghue’s (2002) argument that there is no convincing economic case for picking a particular discount rate. An examination of the behavioral arguments for hyperbolic discounting reinforces this view.

The existence of hyperbolic discounting—broadly defined as the tendency of people to discount the immediate future more heavily than the more distant future—is well documented (Frederick, Lowenstein and O’Donoghue 2002; Kirby 1997; Kim and Zauberman 2009; Loewenstein and Prelec 1992; Thaler 1981). This phenomenon has also been found in non-human animals (Ainslie 1974; Green and Myerson 1996) suggesting that discounting the immediate future more heavily has an evolutionary basis. Numerous behavioral experiments show various forms of hyperbolic discounting. But there is substantial variation in the way the discount rate changes through time and in the discount rates for various rewards. Estle et al. (2007) compared discounting of monetary rewards and discounting directly consumable goods (candy, soda and beer) and found that monetary rewards were discounted less steeply. Findings like this are only suggestive but the authors speculate that delayed monetary rewards are different than consumable goods because they are fungible and generalized as a representation of all consumer goods. If people discount money (or anything else) differently than directly consumable food items (or anything else) this implies that the search for an empirically-revealed universal discount rate, hyperbolic or otherwise, is misplaced. However, even if there are no universal patterns, hyperbolic discounting may provide some insights for some specific aspects of decision-making and some specific types of rewards (Frederick, Lowenstein, and O’Donoghue 2002).

Another variation is the perceived time model (Kim and Zauberman 2009). In this model hyperbolic discounting occurs because people show *diminishing sensitivity* to longer time horizons and because of *time contraction* (one year is perceived to be less than four times three months). Related to this is Hernstein’s matching law. In binary choice experiments people match their responses proportionately to reinforcement proportions rather than choosing the outcomes with the highest expected probable payoff (Ainslie 2005; Fantino 1998; Herrnstein 1961). Ainslie (2005) points out that the hyperbolic discounting curve is a variant of Herrnstein’s matching law described by the formula:

Value = Value at no delay / [constant + (impatience factor X delay)]

The constant is a small number describing the “failure of values to approach infinity as delays approach zero” (Ainslie 2005, 636). By varying only the impatience factor, this simple formula can describe intertemporal choice in a wide variety of circumstances for a variety of rewards for both human and animal subjects.

Ainslie (2005) argues that hyperbolically-based uncertainty about the future leads people to see current choices as “test cases” that establish a mental “model of willpower”. According to him (Ainslie 2005, 636) his model explains “…how intertemporal bargaining leads to compulsive side effects and how a hyperbolically based impulse toward premature satiation of appetite gives emotions their quasi-voluntary quality and motivates the social construction of facts, the quest for vicarious experience, and indirect approaches to goals.” He puts an interesting twist on hyperbolic discounting with his idea of “the self as a population”. People have a variety of sometimes complementary and sometimes contradictory preferences that become dominant or submissive depending on social context, timing, and reward structures.

An agent who discounts a reward hyperbolically is not the straightforward value estimator that an exponential discounter is supposed to be. Rather, she will be a succession of estimators whose conclusions differ; as time elapses these estimators shift their relationship with one another from cooperation on a common goal to competition for mutually exclusive goals. Ulysses planning for the Sirens must treat Ulysses hearing them as a separate person, whom he must influence if possible and forestall if not. If what you do in a situation regularly gets undone later, you’ll learn to stop doing it in the first place—but not out of agreement with the later self that undoes it, only out of realism. Meanwhile you’ll look for steps toward getting what you want from the earlier vantage point, steps that won’t be undone, because they forestall a future self who will try to undo them. You’ll be like a group of people rather than a single individual; subjectively, however, the results of learning to do this may feel like no more than having to plan for self-control. (Ainslie 2005, 637)

Ainslie calls his approach *picoeconomics*, because individual choice is a kind of intertemporal bargaining involving “the strategic interaction of successive motivational states within the person.” Even single individuals are collections of biologically mediated and socially constructed “selves”. Multiple self theories are supported by neurological studies showing that different parts of the brain are involved, for example, in valuing immediate returns and delayed returns (McClure et al. 2004). It is also supported by behavioral studies showing that consumers’ preferences do not necessarily match citizens’ preferences (Sagoff 1997).

The question of discounting not only moves quickly from economics to ethics, it also leads to the search for the “deep structures” of human society and human reasoning. An evolutionary perspective requires going beyond proximate causes of economic outcomes (discount rates, prices and markets) to examine ultimate causes (institutional responses to resource availability and biophysical constraints and opportunities). The critical environmental choices we make today will affect humans living hundreds of generations in the future. Can we make decisions on behalf of future generations without knowing what sorts of economic and social value systems they will have? Will they think about numbers and discounting in the same ways we do? Numbers—meaning a working language system of words and symbols for exact quantities—probably emerged with agriculture and trade and are therefore no more than a few thousand years old. Theories of time and number perception have gotten a boost in recent years from cross-cultural studies of hunter-gatherer groups isolated from predominantly agricultural and industrial societies.

**III. The Evolutionary Origins of Discounting**

The discounted utility approach assumes that people are rational and consistent in choosing a single discount rate that will maximize the present discounted value of a stream of future returns to investments. The lack of consistency in observed discount rates, the fact that individuals use different discount rates for different categories of things to be discounted, and the evidence for hyperbolic discounting, suggests that the standard approach is missing some deeper level of causality in explaining how people value the future. As mentioned above, a useful tool of evolutionary biology is the distinction between ultimate and proximate causation (Tinbergen 1963). This concept asserts the need for two separate and complementary explanations for all products of genetic and cultural evolution. Ultimate causation explains why a given trait exists, compared to many other traits that could exist, based largely on the winnowing action of selection. Proximate causation explains how the trait exists in a mechanistic sense. It is especially important to recognize the many-to-one relationship between proximate and ultimate causation, whereby many functionally equivalent solutions can evolve in response to a given environmental challenge (Wilson and Gowdy 2010). There are certainly economic reasons for why people discount the future—for example, the existence of investment opportunities for money received today. But an examination of the anthropological and neurological literature reveals another, deeper and more universal, explanation of discounting.

The ability to express numbers exactly (cardinally) seems to be a cultural artifact, not something we naturally acquire. A hunter-gatherer tribe deep in the Brazilian Amazon, the Mundurukú, has received considerable attention in recent years because they do not have an exact number system. In fact they lack words for numbers above 5. The Mundurukú do not use numbers to refer to precise quantities. The word “five”, for example, can mean 5, but also 6, 7, 8 or 9 (Pica et al. 2004). Like people in literate cultures, the Mundurukú have a nonverbal number sense. They can distinguish between groups of different sizes: “They can mentally represent very large numbers of up to 80 dots, far beyond their naming range, and so not confuse number with other variables such as size and density. They also spontaneously apply concepts of addition, subtraction, and comparison to these approximate representations” (Pica et al. 2004, 503). Also like people in literate cultures, they exhibit a distance effect in comparing quantities; accuracy in comparing quantities improves as the ratio between the numbers to be compared increases.

Pierre Pica tested the Mundurukú’s spatial understanding of numbers by testing how they visualized numbers on a computer screen.

Each volunteer was shown an unmarked line on a screen. To the left side of the line was one dot, to the right ten dots. Each volunteer was then shown random sets of between one and ten dots. For each set the subject had to point at where on the line he or she thought the number of dots should be located. Pica moved the cursor to this point and clicked. Through repeated clicks, he could see exactly how the Mundurukú spaced numbers between one and ten. (Bellos 2010, 5)

The Mundurukú spaced the numbers so that the interval between numbers became smaller and smaller as the numbers increased. When the test is given to American adults they space the numbers at equal intervals. Stiegler and Booth (2004) found that kindergarten pupils, Like the Mundurukú, spaced numbers logarithmically. First grade students begin to space the numbers more equally, and by the second year of school student space the numbers equally along a line. These results are, of course, very tentative but suggest that some variation of hyperbolic valuation may represent some “deep structure” of human reasoning.

The behavior of non-human animals has also proved to be fertile ground for insights into how people value future rewards. In general, researchers have found that animals discount rewards hyperbolically (Green, Myerson and Calvert 2010), that humans discount delayed rewards significantly less steeply than do other animals (Jimura et al. 2009), and that humans discriminate between reward amounts more than other animals do (Green and Myerson1996). The view is widespread that animal behavior justifies the economic rational actor model. Gintis (2006, 7) argues that the assumption of choice consistency among humans is justified by animal behavior. “Economic and biological theory thus have a natural affinity; the choice consistency on which the rational actor model of economic theory depends is rendered plausible by biological evolutionary theory, and the optimization techniques pioneered by economic theorists are routinely applied and extended by biologists in modeling the behavior of a vast array of organisms.” It is true that the standard rational optimization model has been applied successfully by biologists, for example, to examine optimal foraging strategies. In a classic optimal foraging study, Harper (1982) tested the ability of a flock of ducks to achieve a stable Nash equilibrium when fed balls of bread. Two researchers stood on the bank of a duck pond threw out 5 balls of dough at different intervals. The ducks acted according to expected utility theory and re-arranged their numbers efficiently as the payoffs were changed. In another animal experiment chimpanzees, unlike humans, appear to be rational maximizers in the ultimatum game (Jensen, Call and Tomasello 2007). But contrary to Gintis’ assertion, humans do not exhibit the regularities in choice that other animals do. Regarding economists’ claims for human “rationality”, it is ironic that a large body of evidence suggests that “lower” animals seem to act more in accordance with the economic model of rational choice than do humans.

Both the duck pond experiment and the Mundurukú may be examples of the evolutionary advantage of recognizing ratios. McComb et al. (1994) performed an experiment with a pride of lions in the Serengeti. The researchers played a loudspeaker of the sound of one lion roaring as a single lion walked by on a path. In this case the lioness kept walking. When five lions were walking by, McComb et al. played the sound of three lions roaring and the five lions charged into the bushes to attack. The researchers postulated that lionesses were comparing relative quantities in their heads. One lion versus one other lion meant it was too risky to attack, but with a five to three advantage, the lions realized that an attack could be successful in driving the other animals away. Bellos (2010, 7) writes:

The precedence of approximations and ratios over exact numbers, Pica suggests, is due to the fact that ratios are much more important for survival in the wild than the ability to count. Faced with a group of spear-wielding adversaries, we needed to know instantly whether there were more of them than us. When we saw two trees we needed to know instantly which had more fruit handing from it. In neither case was it necessary to enumerate every enemy or every fruit individually. The crucial thing was to be able to make quick estimates of the relative amounts.

As mentioned above, Herrnstein’s matching law has been found to hold in animal behavior. In his experiment (Herrnstein 1961) pigeons were given the choice of two buttons to peck with different rates of food reward for each choice. The pigeons tended to pick the button that gave the greatest reward but they were also influenced by the rate at which the reward was given—that is, they did not make decisions according to the expected payoff. But humans do not consistently behave according to the matching law (Bradshaw, Szabadi, Bevan 1976). Compared to other animals, humans generally take more account of the future consequences of their actions when making temporal decisions (Frederick, Lowenstein and O’Donoghue 2002). It has been argued that animals are “stuck in time” without the ability to anticipate long-term future events (Roberts 2002). But this observation is not without caveats. Bonobos and chimpanzees show a degree of patience not present in other animals, humans are less willing to wait for food than are chimpanzees, and humans are more willing to wait for money than for food (Rosati et al. 2007).

Comparing discount rates between humans and other animals is complicated by the fact that animal studies rely solely on food rewards. A study comparing humans and other animals receiving delayed real liquid rewards showed a marked decrease in the delay humans were willing to accept compared to other animals (Jimura et al. 2009). McClure et al. (2004) used fMRI imaging to show that separate neural systems in the brain value immediate monetary rewards and delayed monetary rewards. That is, two separate neurological systems are involved in discounting money depending on the time length of the delay of the reward. An on-going debate is whether two distinct and competing brain systems are responsible for self-controlled or impulsive behavior or whether a single integrated system mediates subjective delay and the perceived value of outcomes (Wittman and Paulus 2009).

In summary, evidence suggests that hyperbolic discounting has an evolutionary basis. It may be speculated that an ultimate cause is the survival advantage of being able to quickly access ratios—the probably of relative amounts of food in foraging patches or the relative size of rival groups. A limitation of discounting studies is that they focus exclusively on individual discount rates. Even so-called social discount rates are simply individual rates adjusted for spillover effects. We conceive of social discounting as a process influenced by human sociality, in the case of individual discounting because individuals are members of particular social group and develop in their individual behavior a social dimension, or in the case of collective discounting because it emerges from a collective deliberation of a group. Current evidence from various fields points to the uniqueness of humans among mammals as social animals. Our success as a species is apparently due to our ability to cooperate and to make collective decisions for the good of the group (Nowak and Highfield 2011; Sober and 1998; Henrich and Henrich 2007). This is especially relevant to the valuation of likely future environmental outcomes because our viability as a species may depend on our ability to forge collective solutions to global problems like climate change and biodiversity loss.

**IV. Social Discounting**

What economists usually refer to as “social discounting” is really not social in the sense discussed above, except in the framework of the DSGE model where decisions are confined to the world of perfectly rational self-regarding agents operating under conditions of competitive equilibrium. In this world, the social discount rate (usually denoted by r) is “the appropriate value of r to use in computing present discount value for social investments” (Gruber 2007). Justifications for discounting in public decisions mainly rely on the opportunity cost of the capital that will be spent for social investments. Indeed, especially for long-term environmental issues, public decisions deal with intergenerational equity and a positive pure time preference is rejected by some on the basis that “people’s welfare should not be valued less simply because they live at a different time” (Philibert 2006; Ramsey 1928). Also, the assumption that the wealth effect will make future generations better off than the current generation as result of the economic growth might be incorrect, for example, if the environmental costs to be borne by future generations are extremely high, or when the beneficiaries in the future of current investments are from developing countries while the “investors” are from developed countries (Philibert 2006). So in the standard economic model, the rate of return on the private financial benchmark investment is often reinterpreted as the social discount rate, which corresponds to a financial accounting approach (Pannell and Schilizzi 2006). Thus, the social rate of discount is far from reflecting how individuals value the future as members of a particular social group. Rather, it normatively imposes the self-regarding rational representative agent standard which cannot alone represent the whole set of human individual and social behaviors.

Fiske and Tetlock (1997) provide empirical support of the impossibly of characterizing human behavior by a single rational calculative process. They highlight four different spheres of social relationships among which we find communal sharing (CS) and market pricing (MP) relationships. They underline how those four spheres are based on drastically different inherent logic, motives, normative forces, affective tones, moral foundations, metric and language and how trade-offs requiring using the language of one sphere for dealing with another sphere appear unintelligible or even degrading for people. They conclude by arguing that empirical evidence exists that individuals establish an ordinal ranking of those spheres as following: Communal Sharing > Authority Ranking > Equality Matching > Market Pricing, underlying the non-substitutability of market and other relational approaches and especially the strong inadequacy of applying market logic to communal/social sharing affairs.

Whether the social discount rate is defined by a normative approach relying on benchmarking with the market interest rates, or by a more positive approach like hyperbolic discounting, the extent to which public decisions ought to be based on individuals’ discounting behaviors remains unsolved. The major assumption of the standard economic approach--that social welfare measurements are based on summing individual preferences--legitimates the recourse to individuals’ discounting behaviors as basis for social discounting. However, many problems have emerged from this approach. First, what *is* (positive) should not necessarily be the standard for what *ought* to be (normative), while it can help policies to be incentive compatible. Reasons for public investment decisions “run from the future back to the present, and not the other way around” (Bromley 2006). Second, the issue of intergenerational distribution (and the willingness of members of the current generation to pay for actions that reduce risks faced by future generations) is different from the issue of present value maximization within one generation (and the impatience of members of the current generation) (Howarth 1996; Schelling 1995). Using the latter context for the former situation is problematic. Finally, as empirical results supporting hyperbolic discounting show, individuals fail to apprehend very-long term horizons and can be subject to preference reversals and time inconsistencies; characteristics that may be undesirable for public policies, already subjected to time inconsistencies resulting from political turnover. Another technical consideration for the proper role and use of social discount rates is that considerable ambiguities can arise with discount rates that can go against our usual expectations. For example, it is generally argued that since lower discount rates, hyperbolic or otherwise, give more value today for things happening far in the future than higher discount rates, using lower discount rates in intertemporal environmental decision making will lead to more environmentally friendly or ecologically sustainable outcomes. However, this may not always be the case, or at least not so unambiguously, particularly when there may be important opportunity costs of capital involved or complicated streams of net benefits over time (Tisdell 2005). Ambiguity of the first sort was identified by Farzin (1984) for the case of nonrenewable resources in the context of the Hotelling Theorem for their efficient intertemporal extraction. This involves considering capital-intensive extraction processes compared to some backstop substitute resource. A rise in the discount rate could increase the cost of extraction sufficiently to offset the time preference effect so that less might be extracted. Such offsets are more likely to occur when the resource is either very abundant or very scarce, which in the latter case could lead to the outcome that a lower discount rate could lead to the accelerated extraction of the scarce resource. But Hannesson (1987) showed that the above perverse effect could work in the case of renewable resources as well, particularly fisheries, so that if fishing is capital-intensive, a lowering of the discount rate could increase the threat of species extinction of a fish of low population size. In the renewable resource case Colin Clark (1990) showed that a sufficiently high discount rate might make it economically rational to harvest a species to extinction.

These cases share similarities with the problems that arise when net benefit streams over time can move from negative to positive to negative again, or exhibit even more complicated patterns. That this can lead to ambiguities was understood as far back as by Irving Fisher (1930) who identified such phenomena as leading to “multiple roots.” The general issue was recognized among environmental and resource economists by Herfindahl and Kneese (1974), Fisher (1981), and Porter (1982), the latter noting the ambiguity such problems could imply for “preservation.” While wilderness and endangered species might be valued more at lower discount rates, they might also benefit from the use of very high discount rates, such as the 10% rate imposed early in the Nixon Administration, which caused many environmentally damaging dam-building projects to fail cost-benefit tests due to their high upfront capital costs.

As this involves situations where one alternative is preferred at both low and high discount rates compared with another that is preferred at intermediate ones. This has led some observers to identify this issue with that of reswitching in the Cambridge controversies in the theory of capital (Sraffa 1960; Harcourt 1972), which involves precisely such paradoxes. The first to make this connection using an example of using machinery versus animals in certain agricultural practices was Peter Albin (1975). Prince and Rosser (1985) make a similar argument in comparing strip mining of coal with cattle grazing in the U.S. Southwest using realistic numbers and finding such reswitching within ranges of discount rates used in public policymaking, with the upfront and delayed costs of coal strip mining making it the activity preferred at intermediate discount rates. Finally, Asheim (2008) also made such an analysis using the example of high upfront and distant costs of nuclear power. This suggests that considerable caution is due in making simple generalizations about the effect of different discount rates on environmental outcomes.

**V. The Social Brain and Social Valuation of the Future**

Many animals are exceptional in their degree of sociality but scientists are just beginning to discover the uniqueness of humans in this regard. Unlike other primates, humans are able to form long-term cooperative bonds with non-kin. Hill et al. (2011) looked at co-residence patterns in foraging societies and found that humans, compared to other primates, are unique in that (1) either sex may remain with their parental group, (2) adult brothers and sisters may co-reside, (3) most members of a residential group are unrelated, and (4) preferential bonds are maintained with spouses’ relatives and relatives’ spouses. Generally, primary kin make up only 10% of a residential human band while in other primate groups most members are closely related. Human cooperative groups apparently have characteristics that enhance individual judgments. Woolley et al. (2010) found evidence for a “collective intelligence factor.” In their study, groups of two to five people were assigned a variety of tasks then the groups were ranked according to their performance of these tasks. The researchers found that a collective intelligence factor explained differences in the groups’ performance. Most importantly, this factor was not strongly correlated with individual characteristics such as IQ but rather the composition of the group (for example, the percentage of females) and the social sensitivity of group members.

The uniqueness and importance of human sociality has also been confirmed and enriched by neuroscience. The way the brain is organized and develops provides evidence of human sociality (Wexler 2006). Most of the neurons in the human brain develop after birth and the way they are configured depends critically on how a child is socialized. It is another way that variability can be introduced into evolutionary mix. An important finding from neuroscience is the presence in the human brain of *Von Economo* neurons (VENs) that apparently evolved to enable people to make rapid decisions in ambiguous social contexts (Sherwood, Subiaul, and Zadwidski 2008). VENs are located in cortical areas that are positioned at the interface between emotional and cognitive processing. Allman et al. (2005) speculate VENs are designed for quick signaling of an appropriate response in the context of social ambiguity, an ability that would be particularly important in the context of communities whose composition and hierarchical social arrangement is continually changing. The existence of VENs is interesting not only because they provide physical evidence that preferences are genuinely other-regarding, but also because they imply that being strictly self-regarding is not the best way to make decisions. Indeed, if human evolution has led to the positive selection of VENs, which allow us to make fast intuitive assessments of complex social situations (Sherwood, Subiaul, and Zadiszki 2008) then automatic responses, quick intuition and emotions must be critical to the human decision-making process. VENS might be related to the way humans view the distant future as in the intuitive logarithmic numerical scale identified by Pica and his colleagues (Pica et al. 2004). The distance effect and the reduced emotional involvement of individuals with far distant futures (cognitive capacities being more involved than impulsive capacities for long-term horizons) (Schmidt 2010) might explain why individuals barely distinguish time intervals in the far distant future. This supports hyperbolic discounting for mid- and long-term futures.

Numerous authors argue that cooperation and compassion for others, not competition, explains the success of our species (Henrich and Henrich 2007; Nowak and Highfield 2011; Sober and Wilson 1998). Foraging in human societies is an evolved social process and how we value resources cannot be fully understood without recognizing the importance of cooperation and rules for group survival in resource management. In our 200,000 year history humans have thrived in a variety of environments using a dazzling array of cooperative institutions to sustainably manage local resources. This research suggests that a strong case can be made for valuation processes allowing for interaction and deliberation among individuals (Gowdy and Parks 2012; Howarth and Wilson 2006). Such deliberation can capture information and deal with uncertainty in ways that isolated individuals cannot. There may also be an “ideal” composition of groups for making critical decisions. This raises many intriguing questions. For example, is there an ideal mix of selfish individuals and altruists in collective decision making? What role does gender play in successful group composition? Does voting based on isolated individual decisions preclude solutions based on group deliberative valuation that might result in better outcomes?

**VI. Conclusion – From Hyperbolic Discounting to Truly Social Valuation of the Future**

Neuroscience, behavioral, and evolutionary studies provide support for the introduction of hyperbolic discounting as appropriate for some valuation and discounting situations. In addition, it seems to be able to grasp some social dimensions of human decision making. However, many hypothesis and restrictions are necessary to apply hyperbolic discounting which reduces complex valuation decisions and human behavior to a functional form that can be easily accommodated in the standard welfare model (Rubinstein, 2003). We have exposed reasons for social discounting, or more broadly social valuation of the future, to be more than an aggregate of individual choices, and reasons for defending that what *is* (positive) should not necessarily be the standard for what *ought* to be (normative). Social discounting is a socially mediated construct based on cultural traditions that evolved under a variety of environmental conditions, perhaps most notably the climatic uncertainty of the succession of ice ages in human prehistory (Richerson and Boyd 2005). Discounting finds its financial justification in the social opportunity cost of capital but once it is used for social investments, this justification hardly manages to offset the ethical implications of discounting regarding intergenerational equity and its required synthetic representation of major environmental issues. Especially for long-term threats like climate change and biodiversity losses, environmental valuations to be discounted suffer from our current lack of knowledge, high uncertainty and our weaknesses to act as regent of future generations’ needs (Bromley 2007; Gowdy 2000). As a result, current economic approaches providing discounted environmental values provide more an uncertain digest of partial information than a basis for well-informed efficiency evaluation.

In the DSGS framework, the social good is maximized by decisions of isolated individuals making selfish choices in competitive markets. This framework has been consciously used to dismiss any sort of cooperative, collective public policy. Bromley (2007, 677) is critical of the takeover of reasoned public discourse and democratically chosen public policies by the individual-acting-in-the-market mentality: “It is a quest for public policy in which applied micro-economics is deployed as the only way to impose ‘rationality’ on an otherwise incoherent and quite untrustworthy political process.” Effective social and economic policies require drawing upon aspects of human nature emphasizing cooperation, non-market values, and a shared sense of responsibility. Greed and accumulation are only a part of the richness of human behavioral patterns. Types of behavior conducive to cooperation, doing with fewer material possessions, and recognizing the necessity of shared sacrifice, are also part of the human experience and these behaviors should certainly be taken into account in any intergenerational policy decisions.

**References**

Ackerman, F. and L. Heinzerling. 2004. *Priceless*. New York: The New Press.

Ainslie, G. 1974. Impulse control in Pigeons. *Journal of the Experimental Analysis of Behavior* 21, 485-489.

Ainslie, G. 2005. Précis of *Breakdown of Will*. *Behavioral and Brain Sciences* 28, 635-673.

Albin, P.S. 1975. Reswitching: An empirical observation, a theoretical note, and an environmental conjecture. *Kyklos* 28, 149-153.

Albrecht, A. and M. Weber. 1995. Hyperbolic discounting models is prescriptive theory of intertemporal choice. *Zeitschrift für Wirtschafts- und Sozialwissenschaftten* 115, S535-S568.

Allman, J., McLaughlin, T., and A. Hakeem. 2005. Intuition and autism: a possible role for Von Economo neurons. *Trends in Cognitive Science* 9, 367-373.

Arrow, K., P. Dasgupta, L. Goulder, G. Daily, P. Ehrlich, G. Heal, S. Levin, K-G. Mäler, S. Schneider, D. Starrett and B. Walker. 2004. Are we consuming too much? *Journal of Economic Perspectives* 18(3), 147–172.

Asheim, G.B. 2008. The occurrence of paradoxical behavior in a model where economic activity has environmental effects. *Journal of Economic Behavior and Organization* 65, 529-546,

Barbier, E. 2007.Valuing ecosystem services. *Economic Policy* (January), 177–229.

Baumol, W.J. 1968. On the social rate of discount. *American Economic Review* 58, 788-802.

Bellos, A. 2010. *Here’s Looking at Euclid*. New York, Free Press.

Bradshaw, C., E. Szabadi, P. Bevan. 1976. Behavior of humans in variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior* 26, 135-141.

Bromley, D. 1990. The ideology of efficiency: Searching for a theory of policy analysis. *Journal of Environmental Economics and Management* 19, 86-107.

Bromley, D. 2006. *Sufficient Reason*. Princeton and Oxford: Princeton University Press.

Bromley, D., 2007. Environmental regulations and the problem of sustainability: Moving beyond

“market failure. *Ecological Economics* 63, 676-683.

Caines, J. and M. van der Pol. 2000.Valuing future private and social benefits: The discounted utility model versus hyperbolic discounting models. *Journal of Economic Psychology* 21, 191-205.

Carson, R. and B. Roth Tran. 2009. Discounting Behavior and Environmental Decisions. *Journal of Neuroscience, Psychology, and Economics* 2, 112-130.

Chichilnisky, G., G. Heal, and A. Beltratti. 1995. The green golden rule. *Economics Letters* 49, 175-179.

Clark, C.1990. *Mathematical Bioeconomics*. New York: John Wiley.

Cole, D. 2008. The *Stern Review* and its critics: Implications for the theory and practice of benefit-cost analysis. *Natural Resources Journal* 48, 53-90.

Cropper, M. and D. Laibson 1999. The Implications of hyperbolic discounting for project evaluation. Chapter 16, Portney, Paul and John Weyant, eds. (1999). *Discounting and Intergenerational Equity*. Washington, DC: Resources for the Future.

Dasgupta, P. and G. Heal. 1974. The optimal depletion of exhaustible resources. *The Review of Economic Studies* Symposium Issue, 3-28.

Estle, S., L. Green, J. Myerson, and D. Holt. 2007. Discounting of monetary and directly consumable rewards. *Psychological Science* 18, 58-63.

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

Farzin, Y.H. 1984. The effect of the discount rate on depletion of exhaustible resources. *Journal of Political Economy* 92, 841-851.

Fisher, A.C. 1981. *Resource and Environmental Economics*. Cambridge: Cambridge University Press.

Fisher, I. 1930. *The Theory of Interest*. New York: Augustus M. Kelly.

Fiske, A. P. and P. E. Tetlock. 1997. Taboo trade-offs: Reactions to transactions that transgress the spheres of justice. *Political Psychology* 17, 259-294.

Frederick, S., G. Lowenstein, and T. O’Donoghue. 2002. Time discounting and time preference: a critical review. *Journal of Economic Literature* 40, 351-401.

Gintis, H. 2006. Cultural Darwinism. *Boston Review*. http://bostonreview.net/BR23.1/Gintis/html

Gowdy, J. 2000. Terms and concepts in ecological economics. *Wildlife Society Bulletin* 28, 26-33.

Gowdy, J., R. Howarth and C. Tisdell. 2010. Discounting, ethics, and options for maintaining

biodiversity and ecosystem services. Chapter six in *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Pushpam Kumar (ed.) London: Earthscan, 257-283.

Gowdy, J. and S. Parks. 2012. Behavioral Arguments for Deliberative Valuation” In *Ecosystems and Biodiversity.* Paulo Nunes and Pushpam Kumar (eds.), Cheltenham, UK: Edward Elgar.

Graaff, J. de V. 1987. Social cost. In *The New Palgrave Dictionary of Economics* vol. 4, pp. 393-395, J. Eatwell, M. Milgate and P. Newman (eds), London, Macmillan.

Green, L. and J. Myerson. 1996. Exponential versus hyperbolic discounting of delayed outcomes: Risk and waiting times. *American Zoologist* 36, 496-505.

Gruber, J. 2007. *Public Finance and Public Policy*. New York: Worth, chapter 8,

Green, L., J. Myerson, and A. Calvert. 2010. Pigeons’ discounting of probabilistic and delayed reinforcers. *Journal of the Experimental Analysis of Behavior,* 94, 113-123.

Hannesson, R. 1987. The effect of the discount rate on the optimal exploitation of a renewable resource. *Marine Resource Economics* 3, 319-329.

Harcourt, G.C. 1972. *Some Cambridge Controversies in the Theory of Capital*. Cambridge: Cambridge University Press.

Harper, D., 1982. Competitive foraging in mallards: “Ideal free” ducks. Animal Behavior 30-584.

Harvey, C. 1986. Value functions for infinite period planning. *Management Science* 32, 1123-1139.

Hausman, J. 1979. Individual discount rates and the purchase and utilization of energy using durables. *Bell Journal of Economics* 10, 33-54.

Henrich, N. and J. Henrich. 2007. *Why Humans Cooperate: A Cultural and Evolutionary Explanation*. Oxford: Oxford University Press.

Hepburn, C., P. Koundouri, E. Panopoulou, and T. Pantelidis. 2009. Social discounting under uncertainty: A cross-country comparison. *Journal of Environmental Economics and Management* 57, 140-150.

Herfindahl, O.C. and A.V. Kneese. 1974. *Economic Theory of Natural Resources*. Columbus: Charles Merrill.

Herrnstein, R. 1961. Relative and absolute strength of responses as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior* 4, 267-272.

Hill, K., R. Walker, M. Božičević, J. Elder, T. Headland, B. Hewlett, M. Hurtado, F. Marlowe, P. Wiessner, B. Wood. 2011. Co-residence patterns in hunter-gatherer societies show unique human social structure. *Science*  331, 1286.

Howarth, R. 2009. Rethinking the theory of discounting and revealed time preference. *Land Economics* 85, 24-40.

Howarth, R. and M. Wilson. 2006. A theoretical approach to deliberative valuation: aggregation by mutual consent. *Land Economics* 82, 1-16.

Jensen, K., J. Call and M. Tomasello. 2007. Chimpanzees are rational maximizers in the ultimatum game. *Science* 318, 107-109.

Jimura, K., J. Myerson, J. Hilgard, T. Braver, and L. Green. 2009. Are people really more patient than other animals? Evidence from human discounting of real liquid rewards. *Psychonomic Bulletin & Review* 16, 1071-1075.

Kim, B. and G. Zauberman. 2009. Perception of Anticipatory Time in Temporal Discounting. *Journal of Neuroscience, Psychology, and Economics* 2, 91-101.

Kirby, K. 1997. Bidding on the future: Evidence against normative discounting of delayed rewards.  *Journal of Experimental Psychology: General* 126, 54-70.

Koopmans, T.C. 1960. Stationary ordinal utility and impatience. *Econometrica* 28, 287-309.

Laibson, D. 1997. Golden Eggs and Hyperbolic Discounting. *Quarterly Journal of Economics* 112, 443-477.

Loewenstein, G. and D. Prelec. 1992. Anomalies in intertemporal choice: Evidence and an interpretation. *Quarterly Journal of Economics* 107, 573-597.

Ludwig, D., W. Brock, and S. Carpenter. 2005. *Ecology and Society* 10(2): online URL: http/www.ecologyandsociety.org/vol10/iss2/art13/

Maler, K-G. 1985. Welfare Economics and the Environment. In: A.V. Kneese and J.L. Sweeney, eds., *Handbook of Natural Resource and Energy Economics* Amsterdam: North Holland.

Marglin, S.A. 1963. The social rate of discount and the optimal rate of investment. *Quarterly Journal of Economics* 77, 95-111.

Mazur, J. 1987. Tests of an equivalence rule for fixed and variable reinforce delays. *Journal of Experimental Psychology* 10, 426-436.

McClure, S., D. Laibson, G. Lowenstein, J. Cohen. 2004. Separate neural systems value immediate and delayed monetary rewards. *Science* 306, 503-507.

McComb, K., C. Packer, A. Pusey. 1994. Roaring and numerical assessment in contests between groups of female lions, *Pantheraleo*. *Animal Behavior* 47, 379-387.

Newell, R. and B. Pizer. 2003. Discounting the distant future: How much do uncertain rates increase valuations? *Journal of Environmental Economics and Management* 46, 52-71.

Nordhaus, W. and J. Boyer. 2000. *Warming the World: Economic Models of Global Warming*. Cambridge: MIT Press.

Nowak, M. with R. Highfield. 2011. *Super Cooperators: Altruism, Evolution, and Why we Need Each Other to Succeed.* New York, Free Press.

Pannell, D. and S. Schilizzi (eds.). 2006. *Economics and the Future*, Cheltenham, UK: Edward Elgar.

Pearce, D., B. Groom, C. Hepburn, P. Koundouri. 2003. Valuing the Future: Recent advances in social discounting. *World Economics* 4, 121-141.

Phelps, E. and R. Pollak. 1968. On second-best national saving and game-equilibrium growth. *Review of Economic Studies* 35, 201-208.

Philibert, C. 1999. The economics of climate change and the theory of discounting. *Energy Policy* 27, 913-927.

Philibert, C. 2006. Discounting the future. In *Economics and the Future*. D. Pannell and S. Schilizzi (eds.), Cheltenham, UK: Edward Elgar.

Pica, P., C. Lemer, V. Izard, and S. Dehaene. 2004. Exact and approximate arithmetic in an Amazonian indigene group. *Science* 306, 499-503.

Porter, R.C. 1982. The new approach to wilderness through benefit cost analysis. *Journal of Environmental Economics and Management* 9, 59-80.

Prince, R. and J.B. Rosser, Jr. 1985. Some implications of delayed environmental costs for benefit cost analysis: A study of reswitching in the western coal lands. *Growth and Change* 16, 18-25.

Quiggin, J. 2008. Stern and the critics on discounting and climate change: An editorial essay. *Climatic Change* 89, 195-205.

Ramsey, F.1928. A mathematical theory of saving. *Economic Journal* 38, 543-49.

Richerson, P. and R. Boyd. 2005. *Not by Genes Alone: How Culture Transformed Human Evolution*. Chicago: University of Chicago Press.

Roberts, W. 2002. Are animals stuck in time? *Psychological Bulletin* 128(3), 473-489.

Rosati, A., J. Stevens, B. Hare, and M. Hauser. 2007. The evolutionary origins of human patience: Temporal preferences in chimpanzees, bonobos, and human adults. *Current Biology* 17, 1663-1668.

Rubinstein, A. 2003. Economics and psychology? The case of hyperbolic discounting. *International Economic Review* 44, 1207-1216.

Samuelson, P. A. 1937. A Note on Measurement of Utility. *Review of Economic Studies* 4, 155–61.

Schelling, T. 1995. Intergenerational discounting., *Energy Policy* 23, 395-401.

Schmidt, C. 2010. Neuroéconomie, Odile Jacob Ed.

Settle, C. and J. Shogren. 2004. Hyperbolic discounting and time inconsistency in a native exotic species conflict. *Resource and Energy Economics* 26, 255-274.

Sherwood, C., Subiaul, F., and Zadiszki, T. 2008. A natural history of the human mind: tracing evolutionary changes in brain and cognition. *Journal of Anatomy,* 212, 426-454.

Sober, E. and D.S. Wilson. 1998. *Unto Others: The Evolution and Psychology of Unselfish Behavior*. Cambridge, MA: Harvard University Press.

Sraffa, P. 1960. *Production of Commodities by Means of Commodities: A Prelude to a Critique of Economic Theory*. Cambridge: Cambridge University Press.

Stern, N.2007.*The Economics of Climate Change. The Stern Review.* Cambridge: Cambridge University Press.

Stockfish, J.A. 1969. *Measuring the opportunity cost of government investments*. Washington, D.C.: Institute for Defense Analysis.

Strotz, R. 1956. Myopia and inconsistency in dynamic utility maximization. *Review of Economic Studies* 23, 165-80.

Thaler, R. 1981. Some empirical evidence on dynamic inconsistency. *Economic Letters* 8, 201-207.

Tinbergen, N. 1963. On aims and methods in ethology. *ZeitschriftfürTierpsychologie* 20, 410–433.

Tisdell, C. 2005. *Economics of Environmental Conservation,* Second Edition, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Train, K. 1985. Discount rates in consumer' energy related decisions: a review of the literature. *Energy* 10, 1243-53.

Weizman, 2001. Gamma discounting. *American Economic Review* 91, 260-271.

Wexler, B. E. 2006. *Brain and Culture*. MIT Press: Cambridge, MA.

Wilson, D.S. and J. Gowdy. 2010. The relevance of evolutionary science for economic theory and policy. White paper for NSF SBE Program Initiative “Framing Research for 2020 and Beyond”. Available at http://evolution-institute.org/files/NSF-EvoEco-White-Paper.pdf

Winkler, R. 2006. Does ‘better’ discounting lead to ‘worse’ outcomes in long-run decisions? The dilemma of hyperbolic discounting. *Ecological Economics* 57, 573-582.

Wittmann, M. and M. Paulus. 2009. Intertemporal choice: Neuronal and psychological determinants of economic decisions. *Journal of Neuroscience, Psychology, and Economics* 2, 71-74.

Woolley, A., C. Chabris, A. Pentland, M. Hashmi, and T. Malone 2010.Evidence for a collective intelligence factor in the performance of human groups. *Science* 330, 686-688.