Determinants of Experienced Utility: Laws and Implications

Manel Baucells
Rand Corporation, Santa Monica, CA; and Department of Economics and Business, Universitat Pompeu Fabra, Barcelona, Spain, manel.baucells@upf.edu

Rakesh K. Sarin
Decisions, Operations & Technology Management Area. UCLA Anderson School of Management. University of California, Los Angeles. Los Angeles, California, rakesh.sarin@anderson.ucla.edu.

Abstract

Satisfaction in experiencing the future depends on decisions made today. We consider six well-known psychological laws governing satisfaction. The laws capture habit formation, social comparison, and satiation. We show it is possible to formalize these laws by means of a utility model, and to derive implications from the laws: wanting vs. liking, crescendo, recharge periods, variety seeking, and craving. The discussion combines mathematical propositions, experimental findings in psychology, and time-honored wisdom. We discuss how the sixth law, presentism, may lead to incorrect predictions of experienced utility and suboptimal life-balance choices.

Keywords: experienced utility, time and budget allocation, adaptation, satiation, variety seeking, craving, presentism

Set-up

The concept of experienced utility has a long history in both economics and psychology. To Bentham (1789), utility referred to pleasure and pain. Edgeworth (1881, p.101) argued that, in principle, experienced utility can be measured by a psychophysical machine that registers the intensity of pleasure experienced by an individual. In the 1990s, Kahneman forcefully argued that experienced utility is empirically distinct from decision utility; though the two measurements may coincide in some situations (Kahneman, 2000; Varey & Kahneman, 1992).

In Kahneman et al. (1997), total utility of an episode (a vacation or visit to the dentist) is the sum total of experienced utility at each moment in time. The authors note that experienced utility will depend on past consumption and experiences, as well as cultural and social influences. Satiation and habit formation are two important, though not exclusive, determinants of experienced utility. The hedonic value of food is influenced by the needs of the moment and drops to zero or becomes negative when eating continues beyond satiation (Cabanac, 1971). Past consumption contributes to habit formation and, therefore, influences future satisfaction. Tastes for spicy food, opera, or golf are influenced by habit formation.

In psychology, both habit formation and satiation have been studied and observed in animals and humans (Groves & Thompson, 1970; Solomon, 1980). Read et al. (1999) state that "The most important taste change effects are habit formation and satiation." The focus of this paper is to explore the impact of satiation and habit formation on experienced utility. In the spirit of Frijda (1988), we will propose six laws that determine experienced utility. Even though these laws are well known in psychology, their joint effects produce some novel implications. These six determinants of experienced utility can be formally expressed in a relatively simple utility model. From the model, several implications follow. Some are well-known (buying on an empty stomach, variety seeking), and some are less known (preference for J-shaped sequences, optimal recharge times).

The Six Laws of Experienced Utility

Relative Comparison

> *"Annual income twenty pounds, annual expenditure nineteen six, result happiness. Annual income twenty pounds, annual expenditure twenty pounds and six, result misery."*
>
> *– Charles Dickens*

The first law states that experienced utility is determined by reality minus expectations. To express the first law, we need to introduce a comparison between what we consume during period t, denoted by x_t, and our expectation at the start of t, denoted by r_t. Our experienced utility during period t, denoted by U_t, will be a function of the difference between x_t and r_t. Mathematically, relative comparison holds if there is some strictly increasing function u such that

$$U_t = u(x_t - r_t). \tag{1}$$

We specify that $u(0) = 0$ to indicate that when reality is equal to expectations (i.e., $x_t = r_t$) then we are at some neutral state. If $x_t > r_t$, then we experience positive experienced utility; and if $x_t < r_t$, then we experience negative experienced utility.

Frijda (1988) calls relative comparison the law of change. Kahneman & Tversky (1979a) and Tversky & Kahneman (1991) demonstrate that the carrier of utility is the change from a reference level and not the final outcome. Relative comparison has a long and growing tradition in the economic modeling of habit formation (Duesenberry, 1952; Stigler & Becker, 1977; Sundaresan, 1989; Constantinides, 1990; Becker, 1996; Rozen, 2010) and social comparison (Galí, 1994; Eaton & Eswaran, 2009), or both (Abel, 1990). That satisfaction is a function of reality minus expectations, $U_t = u(x_t - r_t)$, is the fundamental equation of experienced utility. Each of the laws that we propose modifies the fundamental equation, making it more precise and applicable to a wide range of life choices.

Motion of Expectations

> *"It is not the strongest of species that survive, or the most intelligent, but the one most responsive to change."*
>
> *– Charles Darwin*

The second law of experienced utility asserts that expectations change. Three factors affect expectations. First, expectations can be a function of the consumption of our peer group (*social comparison*). Second, expectations can be a function of our past consumption (*adaptation*). Third, expectations can be changed by seeing reality in a new way (*reframing*).

Social Comparison. At any given time t, let s_t be the average consumption of our peers in that period. The common assumption is that for the so called positional or Veblen goods,

$$r_t = s_t.$$

Experienced utility for positional goods is simply $u(x_t - s_t)$. Therefore, consumption above the social comparison level produces positive experienced utility; and consumption below the social comparison level produces negative experienced utility.

Of course, s_t itself may change, as our peers themselves try to improve their social position and desire to compare favorably to the rest of us. In equilibrium, this leads to a "rat race" in which everybody squanders resources to gain status, but all end up no happier (Eaton & Eswaran, 2009).

Adaptation. The second factor influencing r_t is habit formation. For adaptive goods, r_t will denote the level of adaptation, which depends on past consumption. Suppose we maintain a constant consumption of x between 0 and t. Following Constantinides (1990) and Wathieu (1997), we propose that

$$r_t = e^{-\dot{\alpha}t} r_0 + (1 - e^{-\dot{\alpha}t})x, \tag{2}$$

in which $\dot{\alpha} \geq 0$ is the *adaptation rate*. If time is discrete, and x_0 is the previous consumption, then

$$r_1 = (1 - \alpha)r_0 + \alpha x_0, \tag{3}$$

in which α is the *speed of adaptation*. In either case, the new reference level (expectation) is a convex combination of the initial reference level and recent consumption. If $\alpha = \dot{\alpha} = 0$ then the reference level does not shift. Otherwise, the reference level tends to the level of recent consumption. The adaptation rate controls how fast one adjusts to the level of consumption. After an initial experience with an adaptive good, such as the comfort of new furniture, the wizardry of a new electronic gadget, or the feel of better clothes or jewelry, experienced utility declines because we become adapted. We will later show that a crescendo strategy (less to more) maximizes the experienced utility derived from adaptive goods.

There is considerable evidence that people get adapted to material goods as well as to life circumstances (D. Gilbert, 2006; Brickman et al., 1978). Nevertheless, there are situations in which adaptation is partial or very slow (noise, loss of a child, post-traumatic stress disorder). There are, however, goods for which satisfaction does not diminish with repetition, provided some minimum time passes between consumption. We call these *basic goods*, such as food, rest, sex, health (absence of pain), socializing with friends and family (absence of loneliness), and safety (absence of fear). We always appreciate a hearty meal when hungry or a good night's sleep when tired. We can think of basic goods as having $\alpha = 0$. Reference levels do not change, $r_t = r_0$, and constant consumption guarantees $u(x - r_0)$, which is positive if $x > r_0$ and negative otherwise. Here, r_0 is interpreted as the required level to produce a neutral effect.

Reframing. Although adaptation and social comparison are unavoidable to a certain extent, we believe that individuals do have some tools available to moderate these factors. It is possible that through spiritual practices, meditation, or prayer, one might gain a better perspective on life and reduce the harmful effects of comparison (Davidson & Harrington, 2001). We call reframing those purposeful activities that make us see reality in a different way, reset our expectations, or create new comparisons.

If utility is given by $u(x_t - r_t)$, lowering references will increase the satisfaction obtained from the same reality. Logically, there has to be a cost associated with reframing, otherwise satisfaction would be achieved easily. Our premise is that perspective-seeking practices require considerable time, effort, and discipline. Neuroscience confirms that repetition is essential for the brain to be retrained. Cellists have more developed brain areas for the fingers of their left hand, and monks have more developed activity in the left prefrontal cortex, which is associated with cheerfulness. The "reframing benefits" obtained from such practices may exhibit decreasing marginal returns. Therefore, one can maximize experienced utility by spending a moderate amount of time in reframing activities, a time that comes at the expense of work and leisure. Controlling emotions through mindful practices has been widely discussed, but not formally addressed (Kabat-Zinn, 1990; Tolle, 1999; Hanh, 2002; Seligman, 2002).

Aversion to Loss

> *"The dread of evil is a much more forcible principle of human actions than the prospect of good."* – *John Locke*

The third law of experienced utility says that losses are felt more keenly than equivalent gains. To incorporate this law, we require the function $u(x_t - r_t)$ to be more negative for losses than positive for equivalent gains. Formally, aversion to loss holds iff for all $x > 0$,

$$-u(-x) > u(x). \tag{4}$$

Thus, a loss of $-x$ produces more dissatisfaction than the equivalent satisfaction produced by an equivalent gain of $+x$. A second possible definition of loss aversion is $u'(-x) > u'(x)$. A simple way to satisfy both definitions is to let $u(-x) = -\lambda u(x)$, $x > 0$, $\lambda > 1$. A typical value of λ would be 2.25. Accordingly, a 10 dollar gain yields say 4 units of experienced utility or satisfaction, but 10 dollars loss robs us of 9 units of experienced utility.

This law is called the law of *Hedonic Asymmetry* by Frijda (1988) and loss aversion by Kahneman & Tversky (1979b). Chen et al. (2006) demonstrated that even non-human primates perform comparisons and are averse to losses. Ayres (2010) proposes a system to facilitate achievement of personal goals such as weight loss or smoking cessation by exploiting the idea that people will try a lot harder to avoid a loss. The idea is simple. First, you deposit some money in an escrow account and establish n control periods. If you are in the "green" zone (e.g., below or at weight target line), then you get $1/n$ of your money back. If you manage to always be in the green zone, you get back your entire initial deposit. Otherwise, the money left in the account is given to a charity.

Thaler & Sunstein (2008) have explored many ways in which loss aversion affects our lives, and how it can be used for good. For example, Thaler & Benartzi (2004) have successfully gotten employees to save more for retirement. Their scheme is based on a simple idea: employees resist putting money in their pension plans because it reduces their monthly income and creates a feeling of loss. Instead, they propose that employees commit to a plan that adds a fraction of their future salary increases to the pension plan. Foregoing a part of future gain is easier than the certainty of present loss.

Diminishing Sensitivity

> *"The quantity of happiness will not go on increasing in anything near the same proportion as the quantity of wealth."*
>
> *– Jeremy Bentham*

Experienced utility is not proportional to the difference between reality and expectation; rather, the increase in experienced utility slows as reality moves further from expectation. This implies that each additional unit of consumption gives a smaller increment of satisfaction. That is, the function u is concave for positive values and convex for negative values: $u(1) - u(0) > u(2) - u(1) >$ ... and $u(0) - u(-1) > u(-1) - u(-2) >$ .... Formally, *diminishing sensitivity* holds iff for all $x, y \geq 0$, both $u(x + y) - u(y)$ and $u(-y) - u(-y - x)$ decrease with y. For example, if $u(x) = x^{\beta}$ when $x \geq 0$, and $u(x) = -\lambda|x|^{\beta}$ when $x < 0$ is a standard such form.

Simply put, this law states that experienced utility cannot be easily taken to blissful or tragic extremes. The increase in experienced utility slows as reality moves further from expectations. It is well-known in psychophysics that doubling the stimulus does not always double the intensity of the response. A continuous and increasing function u, with $u(0) = 0$, that satisfies aversion to loss and diminishing sensitivity will be called a *satisfaction S-curve*. The curve has the same shape as the value function of prospect theory (Kahneman & Tversky, 1979b).

Satiation

> *"I went to see high mountains, I went to see oceans. Only I had not seen at my very doorstep, the dew drop glistening on the ear of the corn."*
>
> *– Rabindranath Tagore*

Satiation is the lingering effect that recent consumption has on current consumption. Recent consumption reduces the experienced utility of subsequent consumption; and recent abstinence increases the experienced utility of subsequent consumption. Graaf et al. (2004) review the relationship between psychologic and subjective measures in quantifying satiation from food intake. Smale et al. (2001) show that satiation leads to changes in brain activity. Heatherington et al. (2002) found that the desire to eat chocolate declined significantly over time, but not for bread and butter. Satiation half-life for food is short. For experiences such as a camel ride, visiting a theme park, or watching a movie, the satiation half-life could last for more than a year. The concept of diminishing marginal utility has been a corner-stone of theories both in economics and psychology. Satiation carries the principle of diminishing sensitivity to its logical conclusion: current consumption diminishes incremental utility of subsequent consumption, either immediately or in the nearby future.

To account for satiation, Baucells & Sarin (2010) introduce a satiation level, y_t. The satiation level is a stock of recent consumption that acts as if we had consumed y_t just before consuming x_t; hence, x_t's experienced utility is calculated starting at $u(y_t)$. Formally, we generalize $U_t = u(x_t - r_t)$ to

$$U_t = u(x_t - r_t + y_t) - u(y_t). \tag{5}$$

The satiation level is a discounted sum of past consumption in excess of adaptation level:

$$y_t = \gamma^t(x_0 - a_0 + y_0), \tag{6}$$

in which $\gamma \in [0, 1]$ is the *speed of satiation*. The lower the speed of satiation, the faster satiation levels go to zero after consumption. If the speed of satiation is zero, and there is no build-up of satiation. The faster the speed of satiation, the more periods it takes to bring the satiation level to zero.

Satiation for food, drink, and exercise is easily observed. The experienced utility of sugar, for example, increases in conditions of sugar depletion. When we think about how much experienced utility we derive from a particular food, it is necessary to take into account how full we are, or our "satiation level." The satiation level can be positive when we are full, zero when we are neutral (neither full nor hungry), and even negative if we are hungry. It is obvious that the satiation level depends on the quantity we recently consumed. But the satiation level also depends on the adaptation level. A person who is not accustomed to spicy food will reach his limit quickly. Others who have adapted to it can eat lots of spicy foods at every meal. Thus, adaptation mitigates satiation. For example, somebody used to classical music can listen to it for several hours without experiencing satiation.

Satiation influences experienced utility in two ways. First, high consumption today lowers the experienced utility derived from future consumption. This creates a tension between satiation and adaptation. Adaptation produces the effect of the more you get, the more you want. By contrast, satiation produces the opposite effect: the more you get, the less you want. The tension between adaptation and satiation leads to variety seeking. Second, lower consumption today increases the desire for future consumption. Abstinence leads to craving.

Presentism

> *"The great source of both the misery and disorders of human life, seems to arise from overrating the difference between one permanent situation and another."*
>
> *– Adam Smith, The Theory of Moral Sentiments*

It has been found that people are consistently biased in forecasting future satisfaction. Kahneman & Snell (2006) asked subjects to report their actual satisfaction and predicted satisfaction for ice cream and yogurt. The surprising result was that the actual satisfaction and the predicted satisfaction had a near zero correlation. We forecast that future preferences and feelings will be more similar to our current preferences and feelings than they actually will be. This implies that when we predict the satisfaction of future consumption, our prediction is not very different from the satisfaction we would experience if we were to realize this consumption now.

Suppose we plan to consume x_t at some future time $t > 0$. *Actual satisfaction* is

$$u(x_t - r_t + y_t) - u(y_t).$$

Recall that r_t and y_t are the adaptation and satiation levels in period t. The values of r_t and y_t are difficult to predict because they depend on the consumption between now and t, as given by the constraints of social comparison, adaptation, and satiation. In predicting future satisfaction, our minds may simplify the calculation and use our current expectations and satiation levels, x_0 and y_0 (Loewenstein, O'Donoghue, & Rabin, 2003). *Projected satisfaction* is:

$$u(x_t - r_0 + y_0) - u(y_0). \tag{7}$$

The predicted satisfaction is an extreme form of presentism. To modulate the effect, we define *predicted satisfaction* as a combination of projected and actual satisfaction:

$$\pi[u(x_t - r_0 + y_0) - u(y_0)] + (1 - \pi)[u(x_t - r_t + y_t) - u(y_t)]. \tag{8}$$

Here, π, a number between zero and one, is the *degree of presentism*.

The law of presentism simply says that we are not good at predicting experienced utility. This is called focussing illusion by Kahneman et al. (2006). We have adopted the term presentism used by D. Gilbert (2006). We will show that presentism leads to suboptimal decision making, to the point that a higher income may even lower experienced utility.

Implications

The focus of this section is to explore the implications of adaptation and satiation on experienced utility.

Habit Formation, Liking, and Wanting

Our laws of experienced utility explain why habits, once acquired, are difficult to overcome. For simplicity of exposition, consider one purely adaptive good ($\dot{\alpha} > 0$), and for the moment ignore satiation ($y_t = 0$). We also consider a discrete choice: x is either 0 or 1 (e.g., consume or not consume), and fix two moments in time, $t = 0$ and $t = 1$.

Assume we start with zero expectations, $r_0 = 0$, and initiate consumption by setting $x_0 = 1$. This has two consequences: we obtain utility of $u(1)$ now, but our expectations at t increase to $r_t = 1 - e^{-\dot{\alpha}t}$. At t, we can decide to repeat, $x_t = 1$, or abstain, $x_t = 0$. If we repeat, then the utility we obtain will be $u(1 - r_t) = u(e^{-\dot{\alpha}t})$, which is positive but not as great as $u(1)$. If we abstain, then the utility we obtain will be $u(-r_t) = u(e^{-\dot{\alpha}t} - 1)$, which is negative.

The experienced utility from consuming is called *liking*, the experienced decrease in utility from not consuming is called *withdrawal*, and the difference in satisfaction between the experienced utility of consuming and not is called *wanting*. Wanting is the driver of the willingness to pay for x. Formally,

$$
\begin{aligned}
Wanting &= u(x - r) - u(-r), && (9)\\
Liking &= u(x - r), \text{ and} && (10)\\
Withdrawal &= -u(-r). && (11)
\end{aligned}
$$

Wanting is the sum of liking and withdrawal. Comparing the two periods, liking decreases from $u(1)$ to $u(e^{-\dot{\alpha}t})$. In contrast, wanting increases from $u(1) - u(0)$ to $u(e^{-\dot{\alpha}t}) - u(e^{-\dot{\alpha}t} - 1)$. To see this, recall that $\alpha = 1 - e^{-\dot{\alpha}t}$, use loss aversion, $-u(-\alpha) > u(\alpha)$, and diminishing sensitivity, $u(1 - \alpha) > (1 - \alpha)u(1)$, $u(\alpha) > \alpha u(1)$, to produce $u(1 - \alpha) - u(-\alpha) > u(1 - \alpha) + u(\alpha) > (1 - \alpha)u(1) + \alpha u(1) = u(1)$.

After repeated consumption of one unit over several periods, r_t approaches one, $u(1 - r_t)$ approaches zero, and $u(-r_t)$ approaches $u(-1)$. We get very little satisfaction from consuming, but a large withdrawal if we do not consume. Wanting can be high because of an urge to avoid the pain of withdrawal, not necessarily because of the satisfaction from consumption. Therefore, we may choose to consume to avoid withdrawal, even if satisfaction is almost absent.

Our laws imply that wanting and liking may not always go hand-in-hand. It has been shown that wanting and liking exert their influences through separate neural circuits (Berridge, 2001; Berridge & Robinson, 2003). Kahneman & Snell (2006) observed a small positive correlation between wanting and liking. Our analysis is consistent with this observation.

Partial Adaptation

For basic goods, the reference level does not change much. Therefore, income spent in basis goods leads to a permanent increase in satisfaction. Income spent in adaptive goods, however, leads to a temporary increase in satisfaction. An implication of our laws is that if an increase in income is allocated to both basic and adaptive goods, then experience utility will exhibit partial adaptation. That is, the satisfaction produced by an increase in income will decline over time, but will not revert to the previous level (see Figure B1).

[Figure 1 about here.]

vanPraag & Carbonell (2004) have studied the effects of a permanent change in income on life satisfaction. Their conclusion is that an increase in salary does translate into an increase in life satisfaction. As predicted by adaptation, most of this increase in life satisfaction is transitory. However, a small part of the increase is permanent. In other words, rather than full adaptation we have partial adaptation. They estimate that, of the life satisfaction increase initially experienced, 80% of it is transitory and 20% is permanent. Partial adaptation has also been found to apply to losses, with about 80% of the initial dissatisfaction fading over time. As expected, vanPraag & Carbonell (2004) find that losses are felt more intensely than gains, reflecting that “the income gap causes the individual more pain if he or she is on the wrong side, whilst a positive gap is a cause for less celebration if one is on the right side.”

For a poor person, an increase in income will go to basic goods, and thus increasing experienced utility permanently. For a rich person, the increase in income will go to adaptive goods and thus one will notice a relatively small increase in experienced utility after a while. In Baucells & Sarin (2008, Table 4), it is shown that the fraction of income allocated to basic goods falls as income increases. For any person, an increase in an individual’s income will produce a second permanent effect due to improved social comparison. This effect may vanish if the individual compares to wealthier people (e.g., moving to a better neighborhood). Partial adaptation will also be the pattern following income decreases (see Figure B1).

Crescendo or J-shaped

In Baucells & Sarin (2010), we show that to maximize utility in the habit-formation and satiation model, the optimal consumption pattern is either increasing or J-shaped. In several studies, it has been shown that subjects prefer an increasing sequence over a constant or decreasing sequence (Loewenstein & Sicherman, 1991; Loewenstein & Prelec, 1992). Increasing sequences are rational given we tend to compare current outcomes to previous outcomes. When it comes to consumption, our model supports the commonsense advice of frugality. It is better to postpone expensive consumption if there is a limited budget.

Intuitively, the way to counteract habit formation is either to avoid the initiation of habits or, once initiated, to increase their consumption. For durable goods (e.g., a house or a car) the optimal plan is to replace these durable goods with better ones from time to time. For nondurable goods (e.g., restaurants) and activities (e.g., vacation trips and leisure), we need to maintain a rate of consumption that increases period after period. The timing of replacement as well as the rate increments need to be carefully adjusted in order to meet budget constraints.

The higher the speed of adaptation, α, the more pronounced the crescendo needs to be and the longer we would wait to initiate the habit. In a general setup with multiple possibilities for spending our budget, one expects to find that it is best not to initiate the consumption of goods that are "too addictive" (α too high).

The laws provide prescriptive advice on how to *cope with losses*. Suppose an individual experiences a sudden and permanent drop in income. The drop is such that the individual cannot possibly sustain consumption at or above his current expectation levels. How shall he react? Consider three feasible strategies:

i) Plan for a gradual reduction of consumption over time. This may require drawing from savings or acquiring new debt.

ii) Permanent austerity, by setting a lower, but constant, consumption level.

iii) Drastic austerity for some time followed by growth in consumption. This induces a temporary increase in savings.

One may intuitively think that i) or ii) may be the optimal way to cope with losses. In a gradual reduction (i) consumption goes from more to less, and expectations are permanently above consumption. Our model predicts a sustained flow of negative emotions of moderate intensity that will last the entire episode. Under permanent austerity (ii) consumption is constant and expectations decrease until they adjust to this new level of consumption. Our model predicts intense negative emotions first, followed by neutral emotions later. In (iii), our model predicts very negative emotions first, during the drastic reduction phase, followed by positive emotions during the growth phase. Under a broad range of parameters, it can be shown that this third strategy produces highest total utility. This is consistent with Parducci (1995) and D. Gilbert (2006), who argue that past unhappiness increases future happiness. The result hinges on the utility of losses to being convex (or not too concave), and on the adaptation of expectations.

Crescendo strategies need to be modified when satiation is taken into account. Consumption might be high in the first period because we begin with a zero satiation level (Baucells & Sarin, 2007). Under satiation and habit formation, optimal sequences are J-shaped: a high initial consumption, followed by a low to high pattern. J-shaped strategies work for episodes of shorter duration such as the optimal design of a vacation plan, an MBA course, a speech, or a concert. Suppose you have 5 comparable items, valued from 1 [low] to 5 [high], and you can arrange them in the order you want to experience them. Each item will influence expectations and, under habit formation, the optimal strategy is to set them in increasing order, 1-2-3-4-5. If we account for satiation, we are more sensitive to the first item because we are "hungry", and the optimal strategy may well be 4-1-2-3-5 (or 3-1-2-4-5). The recommendation is to pay special attention to a good beginning and a great ending, and to only maintain sufficiently satisfactory levels in the middle.

Cumulative Goods: Goals and Relationships

Ryff (1989) distinguishes between "hedonic well-being" and "eudaimonic" well-being. The latter involves having a purpose in life, continued personal growth, and good relationships with others. Many other philosophers and thinkers have made this same distinction between a pleasant life and a meaningful life. Our laws, with a small modification, provide insights into some aspects of a meaningful life.

Suppose that when engaged in an activity, you feel that your efforts are being accumulated or stored, like when learning a new language, each new word becomes part of your vocabulary. In such case, the driver of experienced utility is not just the new word learned today, but the cumulation of the words learned so far, as compared to some expectation. The same activity can be viewed in a cumulative or non-cumulative way. In a well-known parable, a traveler comes upon a group of three hard-at-work stonemasons. He asks each in turn what he is doing. The first says, "I am sanding down this block of marble." The second says, "I am preparing a foundation" The third says, "I am building a cathedral." The third stonemason views his work as cumulative.

Recall the fundamental equation: experienced utility is determined by the comparison between reality and expectations. What distinguishes cumulative activities is the “reality” part of the equation. In cumulative activities, the reality part of the equation is the total effort accumulated so far. In the table below, the first column represents a less goal-oriented process. The second column represents accumulated actions.

[Table 1 about here.]

Cumulative goods and activities are similar to adaptive goods and activities, but with a key difference. Suppose that the amount devoted each period to some activity is $x = (x_1, x_2, ..., x_T)$. Let

$$X = (x_1, x_1 + x_2, ..., x_1 + x_2 + ... + x_T)$$

be the accumulation of x. A good or activity is (perceived as) cumulative if the satisfaction we obtain is given, not by $H(x)$, but by $H(X)$. That is, both consumption and adaptation are driven, not by x_t, but by $X_t = \sum_{s=1}^{t} x_s$. Formally,

$$\begin{aligned} U(X) &= \sum_{t=1}^{T} u(X_t - a_t) \\ a_t &= a_{t-1} + \alpha(X_t - a_t), \;\; t = 2, ..., T, \end{aligned}$$

and $a_1 = 0$. To gain insight, set $\alpha = 1$ and fix $x_t = 1$ in each period. In this case, the satisfaction we obtain from cumulative goods is equal to $u(X_t - X_{t-1}) = u(x_t) = u(1)$ each period. In contrast, for adaptive goods, satisfaction is $u(1)$ in the first period and zero afterward. In certain ways, accumulation counteracts the effect of adaptation.

Cumulative goods include those actions and contributions that get stored (stay). Most people associate higher levels of satisfaction with cumulative goods and activities. Cumulative goods include two broad categories: goals and relationships. For example, consider the time spent in reaching *goals*, say painting or hiking. For simplicity, ignore the (opportunity) cost of this time and consider the benefits of the activity. Suppose we spend G periods contributing to the goal, with one unit of time spent each period. In this case, $x = (1, 1, ..., 1, 0, 0, ..., 0)$ and $X = (1, 2, 3, ..., G - 1, G, G, ..., G)$. Evaluating $H(X)$ produces G times $u(1)$. Thus, although there is rapid adaptation, the fact of encoding reality in a cumulative way allows us to enjoy the process as if it were not adaptive.

The second observation is that when the accumulation stops, then satisfaction in the next and subsequent periods is $u(G - G) = 0$. It is commonplace to note that the satisfaction associated with attaining goals is obtained *while* progressing toward the goal, and it disappears once we reach the goal. Our model predicts just that.

Csikszentmihalyi (1998) observes that a desirable state of mind labeled "flow" occurs when one is engaged in an activity that is geared towards a goal, is neither too easy nor too difficult, and allows us to obtain frequent feedback from the progress. In our view, flow or engagement works because it is a cumulative good.

The mathematics of *relationships* is similar to those of goals. We enjoy building a relationship. Once a relationship stops growing, we cease to obtain satisfaction from it. Quitting the relationship would produce a large loss, however, and hence we stay. Still, relationships do break. Suppose we invest over G periods building a relationship. If this relationship dissolves in period $t + 1$, then we have that $X_t = G$, but $X_{t+1} = 0$. This produces a large loss of $u(-G)$, which will last for as many periods as it will take r_t to adapt to $X_t = 0$.

Sometimes relationships contain negative elements that can accumulate resentment. Those annoying habits could correspond to $x = (-1, -1, ..., -1)$. If we treat this consumption as adaptive (noncumulative), then soon r_t will have a value of -1, and we will get used to these annoyances and get $u(-1 - (-1)) = 0$. This is like ignoring the curt replies of a boss. However, resentment is the accumulation of a negative. Thus, our satisfaction may be driven by $X = (-1, -2, -3, ..., -T)$. We get annoyed every period, and total dissatisfaction is T times $u(-1)$. If we perceive the bad moments as transient then resentment will not build. Forgiveness, and attributing offenses to passing causes, is a way to neutralize the build up of negative emotions. We will be unhappy for a while, but the negative feelings will dissipate, if we let the law of adaptation follow its course.

Cumulative goods naturally produce a less to more perception. Progressing towards goals, helping with causes that transcends us, developing relationships always produce life satisfaction by gradually filling the metaphorical bucket. In cumulative activities a gap between accumulated reality and expectations ensures a constant flow of positive experienced utility.

Recharge Period

Our bodies seek food, sex, and sleep at some regular intervals. Biological predisposition and patterns of deprivation and satiation determine the need for consumption for these basic goods. But, desire to visit a museum, see a comedy, or play a sport is also susceptible to satiation. The question is: what is the optimal time period between two consumption episodes that maximizes experienced utility?

Consider two intake periods, one at time 0 and the second at time $t \geq 0$. Intake is discrete and of size $x > 0$. After the first intake, the satiation level increases to the intake value, and decays over time at a rate of γ. The half-life for satiation decay will depend on the type of consumption good and may vary from a few hours (food) to several years (a camel safari). Because of the decay in satiation, the more we wait, the more we will enjoy the second intake. There is impatience, however, that counteracts this preference for waiting. As our focus is on the trade-off between impatience and satiation, we ignore the influence of adaptation and set $\dot{\alpha} = 0$. We seek to find the optimal waiting time between the first and second intake, t, that maximizes

$$u(x) + e^{-\delta t}\left[u(x + \gamma^t x) - u(\gamma^t x)\right]. \tag{12}$$

We call this time the *recharge period*.

The recharge time might be zero if the cost of waiting due to impatience is larger than the benefit of enjoying lower satiation levels. This will happen if the speed of satiation, γ, is too high. To convey the intuition, consider the extreme case of $\gamma = 1$. Because $\gamma^t = 1$, the second unit always produces $u(2x) - u(x)$, independently of the time it is consumed. Therefore, delaying consumption reports no benefit and it is optimal to consume the two units immediately. If the speed of satiation is lower, however, then the recharge period is necessarily positive. In fact, the critical speed of satiation is given by:

$$\gamma^* = \exp\left\{-\frac{\delta}{x}\frac{u(2x) - u(x)}{u'(x) - u'(2x)}\right\}. \tag{13}$$

If the discount rate decreases, then the critical speed of satiation increases, thus expanding the range of γ for which the recharge time is positive. More generally, we will show that the recharge period increases as δ decreases; and that the recharge period tends to zero when γ is close to γ^*, or as it tends to zero.

Proposition 1 *Assume $u' > 0$ and $u'' < 0$. If $0 < \gamma < \gamma^*$, then the recharge period, t^*, is strictly positive and increasing with δ.*

[Figure 2 about here.]

Figure B2 illustrates the relationship between the recharge interval and the speed of satiation. Note that t^* rapidly increases near the origin, increases up to a point, and reverts to 0 at $\gamma = \gamma^*$. We expect the recharge time to be unimodal under a broad set of conditions, but finding such set remains an open problem.

Craving

Abstaining from consumption creates a need that has been dammed up. Thus a large amount of satisfaction is experienced when consumption satisfies this unmet need. Consider a good for which an individual has developed a habit, e.g., golf. At the neutral reference level, the experienced utility from consumption, x, is $v(x)$. Abstinence, however, produces a stock of negative satiation and therefore the experienced utility from its consumption, x, which is $v(x+y) - v(x)$, may be larger than $v(x)$. We call this phenomenon *craving*.

Specifically, let $r_0 > 0$ be some initial reference level. Set consumption levels to zero up to time T, $x_t = 0$, $t \in (0, T)$. Now, consider a discrete intake of size $x > 0$ at T. Our focus will be on the evolution of satiation levels, and the satisfaction from consumption after some time has passed. As we abstain from consumption, the reference level decays over time, $r_t = r_0 e^{-\dot{\alpha} t}$, $t \in [0, T)$. Because consumption is below the reference level, satiation levels decrease, possibly taking negative values, and eventually goes to zero. For convenience, write $\gamma = e^{-\dot{\gamma}}$, in which $\dot{\gamma}$ is the satiation decay rate. If $\dot{\alpha} \neq \dot{\gamma}$, then

$$y_t \quad = \quad y_0 e^{-\dot{\gamma} t} - r_0 \frac{e^{-\dot{\alpha} t} - e^{-\dot{\gamma} t}}{\dot{\gamma} - \dot{\alpha}}, t \geq 0.$$

Satiation levels decay and take negative values starting at $t_c^0 = \frac{\ln\left(1 + \frac{y_0}{r_0}(\dot{\gamma} - \dot{\alpha})\right)}{\dot{\gamma} - \dot{\alpha}}$, reach a negative peak, and revert to zero. The largest negative value is attained at

$$t_c^* = t_c^0 + \frac{\ln \dot{\gamma} - \ln \dot{\alpha}}{\dot{\gamma} - \dot{\alpha}}.$$

If $\dot{\alpha} = \dot{\gamma}$, then $y_t = e^{-\dot{\gamma} t}(y_0 - r_0 t)$, $t_c^0 = y_0 / r_0$, and $t_c^* = t_c^0 + 1/\dot{\gamma}$.

The consumer will experience *craving* if the satisfaction obtained from a unit of consumption is higher than at neutral levels. Clearly, if $y \geq 0$, then $u(y + x) - u(y) \leq u(x)$ and craving is not possible. Under quite general conditions, craving occurs if and only if satiation levels are negative. Moreover, the lower the satiation levels, the higher the satisfaction.

Proposition 2 *Let v be loss averse ($-v(-x) > v(x)$, $x > 0$). If one experiences abstinence for at least t_c^0 time units, satiation levels will be negative. A sufficiently large intake, $x > e^{-1}r_0/\dot{\alpha}$, at any such time will produce craving, or $v(x + y_t) - v(y_t) > v(x)$. Moreover, if $v'(-x) > v(x)$, $x > 0$, and $x > 2e^{-1}r_0/\dot{\alpha}$, then satisfaction will increase as satiation decreases, and instant satisfaction will be maximized by resuming consumption at $t = t_c^*$.*

While consuming x at $t = t_c^*$ maximizes instant satisfaction, it may not be overall optimal, as one is experiencing withdrawal during abstinence. Figure B3 shows a typical pattern of satiation levels under abstinence (left), and how the resumption of consumption will provide a high level of satisfaction (right). Notice that, for craving to occur, abstinence from consumption should be neither too short nor too long. If abstinence is too short, then there is no build-up of negative satiation. If abstinence is too long, then the adaptation and satiation levels revert to zero and craving dissipates.

[Figure 3 about here.]

Scitovsky (1976) argues that pleasure results from intermittent satisfaction of desires. An outing to celebrate an anniversary is made more enjoyable if one chooses a simple and routine life for a few days before the big event. Fasting before a fancy meal exacerbates hunger and heightens the pleasure from subsequent meals. Marketers use promotional tools, such as a brief stay in a luxury resort, to create desire. It is possible that in relationships some degree of abstinence creates a heightened satisfaction when reuniting, but too much abstinence may weaken the connection.

Variety Seeking

In a number of studies, the preference for variety has been demonstrated (Scitovsky, 1976; McAlister, 1982; Ratner et al., 1999). Satiation has the negative effect of lowering the experienced utility of repeated consumption, but the positive effect of mitigating withdrawal. This can be seen in the reaction "I don't mind skipping tennis today, because I have been playing all week."

To illustrate the role that satiation has on variety seeking, consider the case of two periods ($T = 2$) and a menu with two activities ($K = 2$) that exhibit adaptation and satiation. To gain insight, we make these activities *symmetric*: they share the same speed of adaptation, speed of satiation, and satisfaction S-curve (for $k = 1, 2$, $\alpha^k = \alpha$, $\gamma^k = \gamma$, and $u^k = u$).

Assume that each period we can engage in just one activity: either A or B. With discrete choice and symmetric goods, the relevant question is to determine which is best: to stay with one activity (AA) or to seek variety (AB). During the first period, we consume A for either AA and AB. This consumption, which produces $u(1)$, sets the adaptation and satiation levels for A at α and γ, respectively. Total experienced utility is:

$$U(AA) = u(1) + u(1 - \alpha + \gamma) - u(\gamma), \text{ and} \tag{14}$$

$$U(AB) = u(1) + u(\alpha - \gamma) - u(\gamma) + u(1). \tag{15}$$

The term $u(1 - \alpha + \gamma) - u(\gamma)$ in (14) is the experienced utility from consuming A during the second period. Note that this term is less than $u(1)$ and decreases as γ increases. The term $u(\alpha - \gamma) - u(\gamma)$ in (15) is the withdrawal from not consuming A, which is negative. The withdrawal from A is compensated by $u(1)$, the novelty of consuming B. Observe how the withdrawal decreases as γ increases. Intuitively, if γ is large, then satiation dominates and we want to seek variety. In contrast, if α is large, habit formation dominates and we want to maintain the habit. In Baucells & Sarin (2010), we demonstrate the following proposition:

Proposition 3 *If $\gamma \geq \alpha$, then $H(AB) \geq H(AA)$ and AB is optimal. Conversely, if $\gamma \leq \alpha$, then AA is optimal.*

The result is intuitive. If γ is large, then satiation dominates and we seek variety (choose AB). If α is large, habit formation dominates and we want to maintain the habit (choose AA).

In Baucells & Sarin (2010), we perform numerical calculations of optimal sequences for $T = 12$ for up to $K = 3$ activities. An example is given in Table C2. We fix the adaptation rate at $\alpha = 0.2$, and vary γ. If the speed of satiation is low, $\gamma \leq 0.54$, then we stay with one activity. For intermediate values of the speed of satiation, $0.55 \leq \gamma \leq 0.7$, we engage in two activities. If the speed of satiation is high, $\gamma \geq 0.71$, we engage in all three activities. The sequencing of these alternatives is calculated optimally, and may not have a regular pattern. Note that, to maximize experienced utility, we abstain from consumption in some early periods. In all the parameter combinations that we tried, generally the lower the α and the higher the γ, the more variety is sought (number of different activities present in the optimal sequence). Our optimal sequences support Lyubomirsky et al. (2005), who argue that the pernicious effects of adaptation can be attenuated by attending to the timing and variety of consumption.

[Table 2 about here.]

If we extend the number of periods, what is the optimal pattern of consumption over time? Baucells & Sarin (2010) observe that the optimal pattern has a phase of *exploration* (variety seeking) followed by a phase of *exploitation* (habit formation). An example may be switching between playing golf and tennis, playing golf with increasing frequency until ultimately switching solely to golf. More broadly, casual observation indicates that people seek variety in their activities and relationships when they are young, and as they age tend to settle on a few, very well-established habits.

Life Simplicity

An important qualitative conclusion of our model is that total experienced utility may be maximized by deliberately choosing only a few habituating goods. Withdrawal is zero for goods for which consumption, and thus habit, has not been initiated. Hence, initiating a habit for a good that we do not plan to consume with sufficient frequency may be suboptimal, as it will produce withdrawal. If we abandon an activity, the withdrawal will decay to zero over time, as the adaptation level reverts to zero. This observation points to the optimality of *life simplicity*. In order to gain further insight, let's consider rotating sequences, that is, a particular permutation of ℓ goods is repeated again and again. Because only one good is consumed during a period, each good will necessarily have $\ell - 1$ periods of withdrawal when it is not consumed.

Baucells & Sarin (2010) show that the optimal ℓ is finite. That is, even with plenty of available periods and goods, it is optimal to consume only a limited number of them. Formally,

Proposition 4 *Assume u is a satisfaction S-curve, and let $\gamma, \alpha \in (0, 1)$. Consider a consumption sequence in which a particular permutation of ℓ goods is repeated again and again. For any given good, and for sufficiently large ℓ, the $\ell - 1$ periods of withdrawal do not compensate for the one period of satisfaction from consumption. Hence, the optimal permutation contains less than ℓ goods.*

The optimal number of habits, given by the length of the rotating sequence, depends on the curvature of u and the values of γ and α. Variety may be the spice of life, but too much variety reduces overall satisfaction. In Figure B4, we calculate the total experienced utility associated with rotating sequences of varying length. We fix $\alpha = 0.04$ and vary γ. For a low speed of satiation, $\gamma = 0.5$, it is better to stay with one habit. For an intermediate speeds of satiation, $\gamma = 0.75$, the optimal number of habits is three. For a high speed of satiation, $\gamma = 0.9$, it is better to rotate among ten habits. In all cases, experienced utility decreases if we go past the optimal number of habits.

[Figure 4 about here.]

Total utility is, therefore, maximized by deliberately choosing only a few habituating goods. That may why some parents try to keep children from acquiring time-consuming or expensive habits.

The Effects of Presentism

The implications explored so far apply to a rational consumer who experiences habit-formation and satiation, correctly predicts the evolution of these state variables for any consumption allocation, and chooses the allocation that maximizes utility. Cognitive constraints, however, limit the ability to predict future reference levels and satiation levels. Presentism is one form of capturing these limitations. We now explore the implications of presentism.

Buying on an Empty or on a Full Stomach

It has been well documented that shoppers who are hungry overbuy food (Nisbett & Kanouse, 1968; D. T. Gilbert et al., 2002). If we are hungry, eating now gives us a lot of experienced utility. Because of presentism, we forecast the same experienced utility into the future, without considering that our satiation levels will increase. In reality, we will not be as happy as predicted when eating all this food. This effect is often used as a marketing tool. For instance, at the beginning of the ski season, when people are "hungry" for skiing, people predict that they may go skiing more often than they actually do. Hence, they may find an offer of ten ski passes attractive. When planning for vacations, consumers may overpurchase vacation days on cruise ships or resorts as one does not anticipate correctly the satiation associated with staying in the same place for several days.

In contrast, after an abundant meal, such as a turkey for Thanksgiving, we forecast that we will not get much satisfaction out of eating turkey in the future. In reality, satiation levels will decay and we will again enjoy turkey sooner than expected. One consequence of failing to foresee that satiation levels will decay, is to predict a preference for more variety than in actual practice. Simonson (1990) and D. Gilbert (2006) observe that, when asked in advance, subjects prefer consumption sequences with variety. When actually choosing, however, they prefer the same consumption good, presumably because the actual satiation level has waned. For instance, subjects today express a preference for peach yogurt tomorrow after consuming strawberry yogurt today, but end up actually consuming strawberry yogurt again tomorrow.

For simplicity, consider the familiar case of two periods and two discrete goods: AA vs. AB. Using (7), the projected total experienced utility of consuming AA is $\widehat{H}(AA) = u(2)$; and the projected total experienced utility of consuming AB is $\widehat{H}(AB) = 2u(1)$. By diminishing sensitivity, $2u(1) > u(2)$, which means that that variety is always best in projection. In reality, variety is best only if $\gamma \geq \alpha$ (see Proposition 3). If $\gamma < \alpha$, predicting that AA is best becomes difficult if the degree of presentism is high.

Proposition 5 *If $\gamma \geq \alpha$, then the optimal choice is AB and the consumer will correctly predict this choice for all $0 \leq \pi \leq 1$. In contrast, if $\alpha > \gamma$, then the optimal choice is AA, but if*

$$\pi > \frac{H(AA) - H(AB)}{H(AA) - H(AB) + 2u(1) - u(2)},$$

then the subject will incorrectly predict that AB is better (and make the correct prediction otherwise).

A consumer preyed on by presentism may predict that AB will be preferred, when AA actually will be. Of course, the consumer could revise his choice in period 2 and implement the optimal sequence, AA. In practice, however, the consumer may have committed to AB.

Life Balance

Time is the ultimate finite resource; therefore, its allocation between work and leisure (e.g., social relationships, family, and rest) is critical to improving experienced utility and life satisfaction. Time spent at work provides income, which can then be spent on consumption of goods and services. Because of the law of presentism, a misallocation of time between work and leisure may occur. There is some evidence that in the past few decades work hours have increased and sleep hours have decreased (Schor, 1992; Putnam, 2000; Layard, 2005, p. 50).

Consider two periods, $t = 0, 1$. In each period, an individual divides one unit of time between work, w_t, and leisure, ℓ_t. Work produces income at a rate of μ units of money per unit of time spent at work. The individual derives utility both from consumption (i.e., necessities and conveniences of life) and leisure (e.g., time spent with friends and family, active and passive sports, rest, etc.). Leisure is a basic good, whereas consumption is assumed to be adaptive. Thus, realized experienced utility over two periods is equal to

$$u(\ell_0) + v(c_0) + u(\ell_1) + v(c_1 - \alpha c_0), \ \ \alpha > 0.$$

As there is just one unit of time available per period, the individuals faces two obvious time constrains: $\ell_0 + w_0 \leq 1$ and $\ell_1 + w_1 \leq 1$. Assume μ is constant over time, zero interest rate for borrowing and lending, and unit consumption price for both periods. The budget constraint is

$$c_0 + c_1 \quad \leq \quad \mu w_0 + \mu w_1.$$

People underestimate adaptation and changes in peer group (Schkade & Kahneman, 1998; Loewenstein & Schkade, 1999; Loewenstein, Read, & Baumeister, 2003; D. Gilbert, 2006). Under presentism, the predicted satisfaction is

$$u(\ell_0) + v(c_0) + u(\ell_1) + \pi v(c_1) + (1 - \pi) v(c_1 - \alpha c_0), \ \ 0 < \pi \leq 1.$$

We assume individuals maximize predicted satisfaction, and compare allocations of time and money under presentism with rational allocations. It is easy to show that a rational individual, $\pi = 0$, allocates the same amount of work and leisure in each period, saves money to plan for increasing consumption and is dynamically consistent. Realized satisfaction is equal to predicted satisfaction, and increases with the wage rate μ.

Proposition 6 *Under the law of presentism, $\pi > 0$, an individual plans for an equal amount of work and leisure in each period and saves money to plan for increasing consumption. The first period consumption is higher than optimal. Upon reaching the second period, the individual will consume and work more than originally planned. Predicted satisfaction is increasing in μ. The realized satisfaction is less than the predicted satisfaction, and may decrease with μ.*

[Figure 5 about here.]

Figure B5 shows the effect of wage rate on total satisfaction. A rational individual will always experience a higher satisfaction with a higher wage rate by judiciously allocating time between work and leisure. Under presentism, it is not trivial to achieve a harmonious balance between work and leisure. Realized satisfaction might even decrease with income. Using multiple periods, this paradoxical situation occurs under a relatively wide range of parameter values. The main reason for this paradox is mis-allocation of time between work and leisure under presentism. There will be a tendency to allocate more time to work at the expense of leisure in the hope of improving predicted satisfaction, but the realized satisfaction will be lower because of adaptation to the goods money can buy.

Conclusions

The concept of experienced utility has been found useful in both economics and psychology and serves as a measure of satisfaction from consumption. In this paper, we propose six laws that determine experienced utility. A simple utility model formally captures these laws and from the model several implications follow.

Present consumption influences the experienced utility of future consumption in two ways: satiation and adaptation. Satiation is governed by the parameter γ and adaptation by the parameter α. Thus, the optimal consumption plan that maximizes experienced utility depends on the relative values of γ and α.

A key model result is that, because of shifting expectations, a crescendo (less to more) strategy in which consumption is increasing over time maximizes experienced utility. If the initial satiation level is zero, then a high initial consumption, followed by a low to high pattern, is optimal. Such a plan is akin to providing a good beginning for a speech or a concert, maintaining satisfactory levels in the middle, and ending well.

Our laws imply that desirability (wanting) and satisfaction (liking) may not always go hand-in-hand. Desirability may be high because of an urge to avoid the pain of withdrawal. Thus, once a habit is initiated, it is difficult to abandon it. One result of our model is that experienced utility is maximized by deliberately choosing only a few habit forming goods. Thus, variety may be the spice of life, but too much variety (except during the exploratory stages) may subtract from experienced utility and life satisfaction.

Satiation has two key effects. One, it reduces the experienced utility of future consumption. Therefore, consumption needs to be spaced and there is an optimal recharge period. Second, abstinence creates negative satiation and the maximum experienced utility is produced when the dammed up need is satisfied. There is an optimal period of abstinence because of diminishing sensitivity even in the negative region in which consumption is below the reference level.

A key insight from our laws comes from the observation that people do not naturally maximize experienced utility. Of course they may intend to, but the law of presentism misleads. Thus, we may predict that variety will produce higher expected utility when in fact it may not because of our failure to account for waning satiation. A more serious consequence of presentism is failing to account for shifting expectations. This may lead us to misallocate time between income generating activities (work) and leisure (social relationships, family, and rest).

Experienced utility is often taken as a primitive (Kahneman et al., 1997). In this paper, we have examined laws that determine the experienced utility of a generic time stream of consumption. We also show some implications of these laws to consumption decisions and life choices. Clearly, there are other factors that affect experienced utility. We hope that our work will encourage the exploration of the anatomy of experienced utility.

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Appendix A
Appendix: Proofs

Proof of Proposition 1. Let $\dot{\gamma} = -\ln\gamma \geq 0$. The first order condition has t as the implicit solution of $F(t) = 0$, in which

$$F(t) = \dot{\gamma}\gamma^t x[u'(\gamma^t x) - u'(\gamma^t x + x)] - \delta[u(\gamma^t x + x) - u(\gamma^t x)].$$

First, note that $\lim_{t\to\infty} F(t) = \dot{\gamma}\lim_{y\to 0} yu'(y) - \delta[u(x) - u(0)] = -\delta u(x) < 0$. Therefore, utility necessarily decreases if t is sufficiently large. If $\gamma < \gamma^*$, then $F(0) = \dot{\gamma}x[u'(x) - u'(2x)] - \delta[u(2x) - u(x)] > 0$. Therefore, utility necessarily increases close to $t = 0$. By continuity, there exists a local optimum at some $t > 0$ solving $F(t) = 0$.

t^* increases with δ: By the implicit function theorem, the sign of $\partial t/\partial\delta$ is given by the sign of $\partial F/\partial\delta = -[u(\gamma^t x + x) - u(\gamma^t x)]$, which is strictly negative.

■

Proof of Proposition 2. First, we claim that, for $t \geq 0$, y_t stays above $-e^{-1}r_0/\dot{\alpha}$. To see this, use $y_0 e^{-\dot{\gamma}t} \geq 0$ and $1 - e^{-x} \leq x$ to note that $y_t \geq -r_0 e^{-\dot{\alpha}t}\frac{1-e^{-(\dot{\gamma}-\dot{\alpha})t}}{\dot{\gamma}-\dot{\alpha}} \geq -r_0 e^{-\dot{\alpha}t}t$. This lower bound takes its minimum at $t = 1/\dot{\alpha}$, producing $y_t \geq -r_0 e^{-1}/\dot{\alpha}$, $t \geq 0$. If $x > r_0 e^{-1}/\dot{\alpha}$, then $x + y_t > 0$, $t \geq 0$. Hence, in the range $t > t_c^0$ we have that $y_t < 0$ and $x + y_t > 0$. By the concavity of v for gains, $v(x + y_t) > v(x) - v(-y_t)$; and by loss aversion, $-v(y_t) > v(-y_t)$, yielding $v(x + y_t) - v(y_t) > v(x) - v(-y_t) + v(-y_t) = v(x)$, i.e., craving.

If $x > 2e^{-1}r_0/\dot{\alpha}$, then $x + y_t > -y_t$, $t \geq 0$. By loss aversion and the concavity of v for gains, $v'(y_t) > v'(-y_t) > v'(x + y_t)$, and $\partial[v(x + y_t) - v(y_t)]/\partial y_t = v'(x + y_t) - v'(y_t) < 0$. ■

Proof of Proposition 5. Let $\widehat{H}$ denote predicted satisfaction, as defined in (8). We have that

$$\widehat{H}(AB) - \widehat{H}(AA) = \pi[2u(1) - u(2)] + (1-\pi)[H(AB) - H(AA)].$$

Suppose $\gamma \geq \alpha$ so that $H(AB) \geq H(AA)$. Because the term $2u(1) - u(2)$ is positive, for all $\pi \in [0,1]$, $H(AB) \geq H(AA)$ implies $\widehat{H}(AB) \geq \widehat{H}(AA)$. Now suppose $\alpha > \gamma$ so that $H(AA) > H(AB)$. We will make a wrong prediction if $\widehat{H}(AA) - \widehat{H}(AB) = H(AA) - H(AB) - \pi[H(AA) - H(AB) + 2u(1) - u(2)] < 0$, or π is larger than the proposed term. ■

Proof of Proposition 6. We maximize predicted utility under presentism in period 0. The rational case corresponds to $\pi = 0$. Let $\ell_i = 1 - w_i$, $i = 0, 1$. The first order conditions with respect to w_1, w_2, c_1, and c_2 are

$$\begin{aligned}
&u'(1 - w_0) = \lambda\mu,\\
&u'(1 - w_1) = \lambda\mu,\\
&v'(c_0) = \lambda + \alpha(1-\pi)v'(c_1 - \alpha c_0), \text{ and}\\
&\pi v'(c_1) + (1-\pi)v'(c_1 - \alpha c_0) = \lambda.
\end{aligned}$$

Note that $u'(1-w_0) = u'(1-w_1)$. Hence, $w_0^\pi = w_1^\pi$ and $\ell_0^\pi = \ell_1^\pi$. If $\pi = 1$, then $c_0^1 = c_1^1$. Because v' is decreasing, $v'(c_1) < v'(c_1 - \alpha c_0)$. If $0 < \pi < 1$ and $\alpha > 0$, then $v'(c_1) < \lambda < v'(c_1 - \alpha c_0)$ and

$$v'(c_0) > v'(c_1) + \alpha(1-\pi)v'(c_1) = v'(c_1)[1 + \alpha(1-\pi)] \geq v'(c_1).$$

As v' is decreasing, $c_0^\pi < c_1^\pi$. If either $\alpha = 0$ or $\pi = 1$, then $c_0^\pi = c_1^\pi$.

Set $w_1 = w_0 = w$ and $c_1 = 2\mu w - c$. Use $\hat{c} = c_1 - \alpha c$. We write

$$\begin{aligned}
&u'(1-w) - \lambda\mu = 0, \\
&v'(c) - \lambda - \alpha(1-\pi)v'(2\mu w - (1+\alpha)c) = 0, \text{ and} \\
&\pi v'(2\mu w - c) + (1-\pi)v'(2\mu w - (1+\alpha)c) - \lambda = 0.
\end{aligned}$$

Let $(\pi; y) = (\pi; w, c, \lambda)$ so that $DF(\pi; y)$ is given by

$$\left[\begin{array}{c|ccc}
0 & -u''(1-w) & 0 & -\mu \\
\alpha v'(\hat{c}) & -2\mu\alpha(1-\pi)v''(\hat{c}) & v''(c) + \alpha(1+\alpha)(1-\pi)v''(\hat{c}) & -1 \\
v'(c_1) - v'(\hat{c}) & 2\mu\pi v''(c_1) + 2\mu(1-\pi)v''(\hat{c}) & -\pi v''(c_1) - (1-\pi)(1+\alpha)v''(\hat{c}) & -1
\end{array}\right].$$

By the implicit function theorem, $\partial y/\partial\pi = -[DF(y)]^{-1}[DF(\pi)]$, or

$$\begin{aligned}
|F(y)| \begin{bmatrix} \partial w/\partial\pi \\ \partial c/\partial\pi \\ \partial\lambda/\partial\pi \end{bmatrix} &= -\begin{bmatrix} -a_{22} + a_{32} & -\mu a_{32} & \mu a_{22} \\ a_{21} - a_{31} & -a_{11} + \mu a_{31} & a_{11} - \mu a_{21} \\ a_{32}a_{21} - a_{31}a_{22} & -a_{32}a_{11} & a_{22}a_{11} \end{bmatrix} \times \begin{bmatrix} 0 \\ \alpha v'(\hat{c}) \\ v'(c_1) - v'(\hat{c}) \end{bmatrix} \\
&= \begin{bmatrix} \mu a_{32}\alpha v'(\hat{c}) + \mu a_{22}[v'(\hat{c}) - v'(c_1)] \\ a_{11}[(1+\alpha)v'(\hat{c}) - v'(c_1)] - \mu v'(\hat{c})(a_{31}\alpha + a_{21}) + \mu a_{21}v'(c_1) \\ a_{11}\alpha v'(\hat{c})(a_{32} + a_{22}) - a_{22}a_{11}v'(c_1) \end{bmatrix},
\end{aligned}$$

in which $a_{12} = 0, a_{23} = a_{33} = -1, a_{13} = -\mu$,

$$\begin{aligned}
a_{11} &= -u''(1-w) > 0, \\
a_{21} &= -2\mu\alpha(1-\pi)v''(\hat{c}) > 0, \\
a_{22} &= v''(c) + \alpha(1+\alpha)(1-\pi)v''(\hat{c}) < 0, \\
a_{31} &= 2\mu\pi v''(c_1) + 2\mu(1-\pi)v''(\hat{c}) < 0, \text{ and} \\
a_{32} &= -\pi v''(c_1) - (1-\pi)(1+\alpha)v''(\hat{c}) > 0.
\end{aligned}$$

Because $a_{31}a_{22} > a_{32}a_{21}$, $|F(y)| = a_{32}a_{11} - a_{11}a_{22} + \mu(a_{31}a_{22} - a_{32}a_{21}) > 0$; and because $a_{21} + \alpha a_{31} = 2\mu\alpha\pi v''(c_1) < 0$, $\partial c/\partial\pi > 0$. Hence, $c_0^\pi > c_0^0$. The sign of $\partial w/\partial\pi > 0$ and $\partial\lambda/\partial\pi > 0$ is unclear.

Assume we implement ℓ_0^π, w_0^π and c_0^π, and reach period two. If $\pi = 0$, ℓ_1^0 and c_1^0 maximize the second period satisfaction, $u(\ell_1) + v(c_1 - \alpha c_0)$, subject to the remaining budget, $w^0 + w_1 - c_0^0$. Hence, predicted satisfaction agrees with realized satisfaction.

If $\pi > 0$, then w_1^π and c_1^π does not maximize $u(1-w_1)+v(c_1-\alpha c_o^\pi)$ subject to $c_1 \leq \mu w_1+\mu w_0^\pi - c_0^\pi$. Taking first order conditions, the individual will choose the allocation $w_{1,r}$, $c_{1,r}$ that solves $u'(1-w_1) = \lambda\mu$ and $v'(c_1 - \alpha c_0^\pi) = \lambda$, i.e., set

$$u'(1 - w_1) = \mu v'(c_1 - \alpha c_0^\pi).$$

Using the first and second period budget constraint, we obtain: $c_1^r - c_1^\pi = \mu(w_1^r - w_0^\pi)$. Assume $c_1^r \leq c_1^\pi$ and, necessarily, $w_1^r \leq w^\pi$. Because $\pi > 0$, $c_1^r - \alpha c_0^\pi < c_1^\pi - \alpha(1-\pi)c_0^\pi$. Therefore, $v'(c_1^r - \alpha c_0^\pi) > v'(c_1^\pi - \alpha(1-\pi)c_0^\pi)$, and

$$u'(1 - w_1^r) = \mu v'(c_1^r - \alpha c_0^\pi) > \mu v'(c_1^\pi - \alpha(1-\pi)c_0^\pi) = u'(1 - w^\pi),$$

implying $w_1^r > w^\pi$, a contradiction. Hence, $c_1^r > c_1^\pi$ and $w_1^r > w^\pi$.

By the envelope theorem, predicted satisfaction increases with μ. Similarly, predicted satisfaction increases as π increases. It follows that predicted satisfaction at $\pi > 0$ is higher than predicted satisfaction at $\pi = 0$, which is the optimal satisfaction. By definition of the optimal plan, the revised plan produces less utility than the optimal plan. Hence, $U_{Realized} < U_{Optimal} < U_{Predicted}$. ■

Appendix B
List of Figures

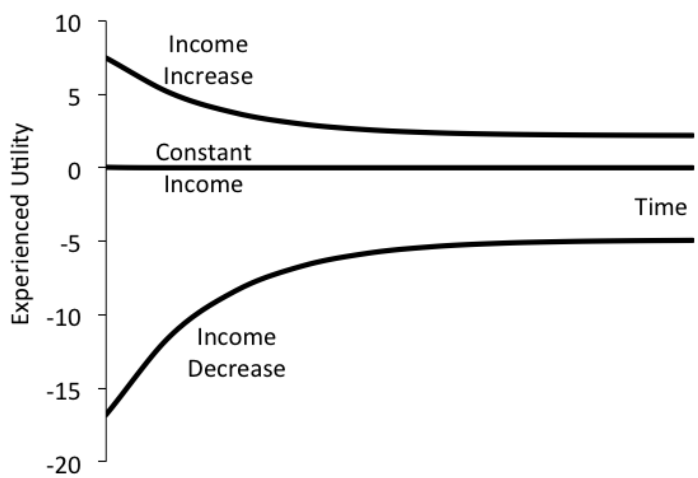

Figure B1. Illustration of partial adaptation. Following an income increase, satisfaction increases, then settles to a level somewhat higher than before the increase. A symmetric pattern holds for losses.

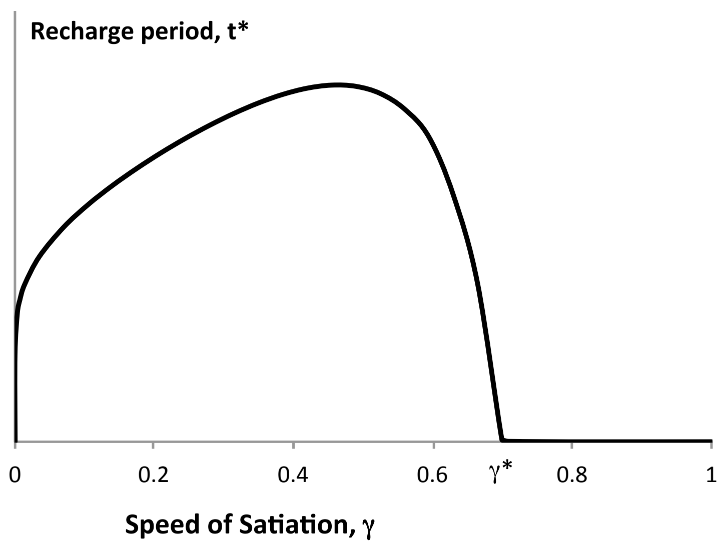

Figure B2. Recharge period as a function of the speed of satiation, γ [$u(x) = x^{0.8}$, $\delta = 0.05$, $x = 1$, and $\gamma^* = 0.7$].

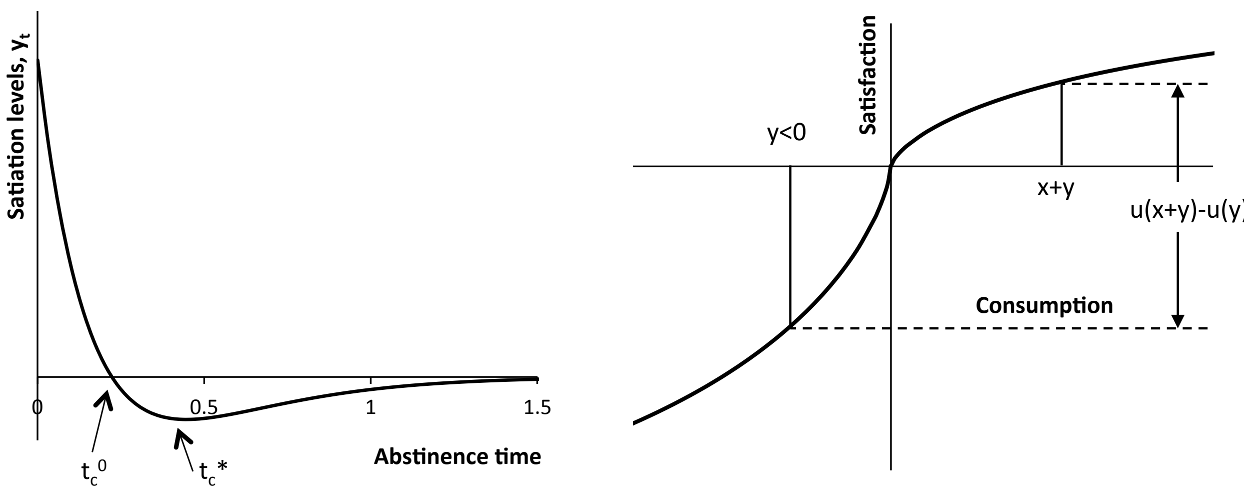

Figure B3. Craving occurs after accumulating negative levels of satiation

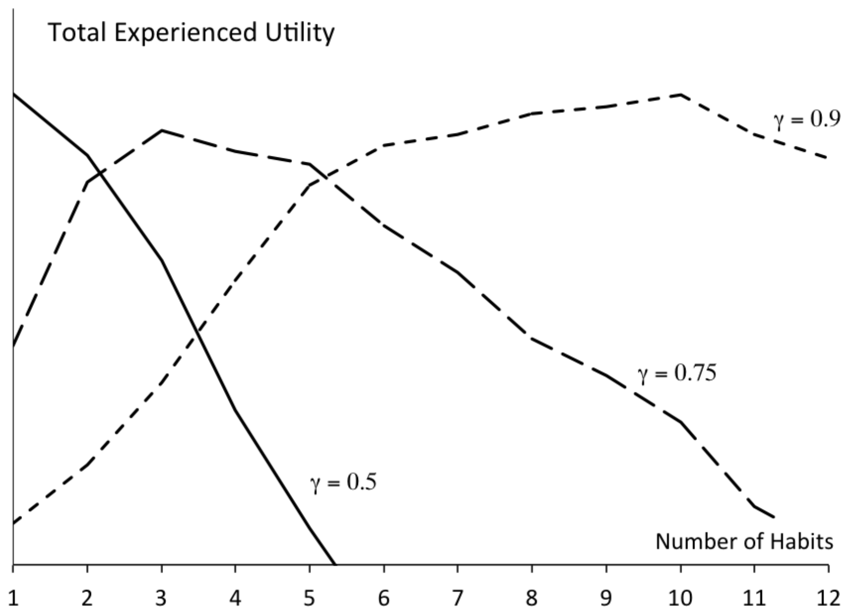

Figure B4. Total utility associated with the number of different habits [$T = 120$ periods, $\alpha = 0.04$]

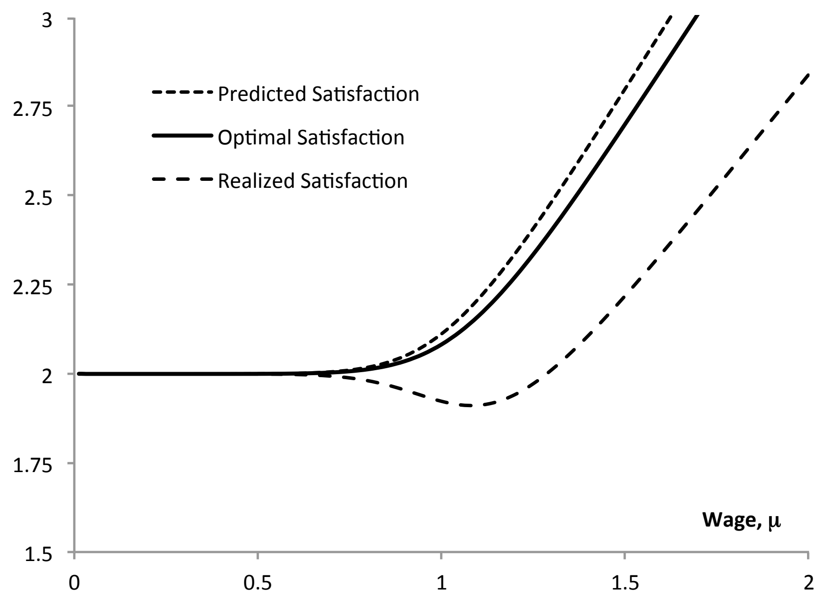

Figure B5. $u(\ell) = \ell^{\beta}$ and $v(c) = c^{\beta}$, $\beta = \pi = \alpha = 0.9$. Predicted, optimal, and realized satisfaction as a function of the wage, μ. For $\mu \in (0, 1.1)$, higher wages decrease realized satisfaction.

Appendix C
List of Tables

Table C1: Cumulative View of Reality

Stream (water poured today)	Stock (water stored so far)
job	career
study	earn a degree
activity	project
practice sports	skill building
play an instrument	accumulate learning
disconnected joys and sorrows	life narrative
entertainment sex	building a relationship
child caring	raising a family
keeping a gadget	creating a collection
profit	net worth

Table C2: Optimal sequencing of homogeneous activities.

γ^k	α^k	1	2	3	4	5	6	7	8	9	10	11	12
0.5	0.2	A	-	A	-	A	A	A	A	A	A	A	A
0.6	0.2	A	B	-	A	B	A	B	B	A	B	A	B
0.8	0.2	A	B	C	-	A	B	C	A	B	C	A	B