On the genesis of Hedonic Adaptation

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ON THE GENESIS OF HEDONIC ADAPTATION

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Abstract. Some sensations, in addition to guide behavior, serve an extra and even more important role: as warning or defense mechanisms (e.g. pain, fever). Additionally, intense sensations are costly from a fitness point of view. With only these two biological facts we show that Nature must design utility functions with regulation mechanisms such as hedonic adaptation or expectation-based preferences. Even though they are rarely incorporated into economic models, such mechanisms are widely recognized and documented in many fields such as neuroscience and psychology. Using such utility functions economists will not only provide more accurate welfare predictions, but we will also increase the number of behavioral phenomena that we are able to explain. Finally, we provide as an application a model of the psychological defenses.

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1. Introduction

Economists usually recognize two meanings of the term "utility." On the one hand we have Bentham’s concept of "experienced utility," which refers to the actual feelings of pleasure and pain (from now on, sensations) that an organism experiences in response to certain stimuli. On the other hand we have "decision utility," which is inferred from observed choices in Samuelson’s Revealed Action spirit.

Nature designed our sensations not in a random and capricious way, but to guide our behavior. Yet economists usually claim that decision and experienced utility can be divorced for theoretical purposes: experienced utility is interesting as a cardinal measure, while decision utility only matters in an ordinal sense. In the simplest version of the argument, there are infinitely many utility functions that can represent the same preferences.

In order to better understand the relation between experienced and decision utility, Section 2 presents a model of the principal-agent problem between Nature and men as a metaphor for evolution. Some sensations not only motivate behavior, but also serve as warning or defense mechanisms (e.g. pain, fever). Additionally, the intensity of sensations can be costly from a fitness point of view. By means of these two simple biological facts we show that experienced utility must have regulation mechanisms, such as expectation-based preferences.

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We want to provide a deeper understanding of hedonic adaptation. We hope it will give support to the use of adaptive utility functions, such as expectation-based (e.g. income aspiration theory), cue-based (e.g. consumption habituation theory), etc. Furthermore, we discuss how such regulation mechanisms may induce inefficient choices: psychologists have documented that people fail to forecast that hedonic states will bounce back to normal levels, even after having experienced them in the past. As a consequence, people over-invest in activities that have relative more adaptation.

Hedonic adaptation may come in lots of different shapes, depending on the particular neurological fundamentals of each problem. Simple economic models, such as Ss investment, can provide both a good description and testable implications. In Section 3 give an application to the case of psychological defenses. The results are perfectly consistent with the region-$\beta$ paradox, one of the leading theories in psychology (Gilbert et al., 2004).

2. The Model

2.1. The genesis of sensations.

The quest for happiness is thought as the main concern for every individual. Nevertheless, we must bear in mind that happiness has been an evolutionary mean and not an end for mankind: Nature developed an incentive scheme of prizes and punishments to drive human behavior towards greater fitness. Think of evolution itself as a principal-agent problem where Nature is the principal and the individual is the agent. Nature chooses preferences for the individual through her biological design in such a way as to maximize Nature’s own preferences: reproduction and survival of the species.

The concept of utility introduced by Bentham (1789) had exactly this spirit: experiences of pleasure and pain that point out what we ought to and shall do. Nowadays most economists follow the idea of Revealed Preference, and think of "utility" or "welfare" as something abstract, disregarding any possible physical correlate. Following Kahneman et al. (1997), we will call them experienced utility and decision utility, respectively. ¹

Every single human action has associated to them a set of reactions taking place in the brain and the rest of the body designed to carefully guide human behavior: taste, hormone secretion, emotions, and so on.² Motivation is one of the biological roles of pleasure and pain in every living organism (Cabanac, 1971).

The abstraction given by the concept of decision utility is extremely useful for the analysis of a great number of problems concerning human action. However, studying the link between decision and experienced utility will increase the number of behavioral phenomena that we are able to address with the traditional toolbox. Even though economists make a great effort not to mention it explicitly, in practice the criteria to compare outcomes is either utilitarian or some

¹There are other similar definitions of decision and experienced utility, such as Beshears et al. (2008): revealed preferences and normative preferences.
²Individuals do not need to consciously and rationally maximize pleasure and minimize pain. The “optimization” can take place thorough learning or natural selection.
variation of it. Therefore, a better understanding of the link between decision and experienced utility will provide more accurate welfare analysis.

For instance, hyperbolic discounting (e.g. Laibson, 1997) is one most popular theories based on the divorce between decision and experienced utility. It increased the number of phenomenon economists were able to explain, and by doing so it also made room for new policies and practices: e.g. how self-control problems importantly influence savings choices (Angeletos et al., 2001).

Hereafter we define sensations as normal reactions of the organism to external stimuli. We will follow everyday examples of stimuli (e.g. eating, getting injured) and sensations (e.g. taste, pain).\(^3\) Despite it might sound awkward, all sensations take place in our brains. Hirayama et al. (1995) illustrates this perfectly. They stimulate the genitals of completely paralyzed men to produce erections and even ejaculations. Since their brains never get the message, the patients find no satisfaction at all. However, the same patients can experience orgasms by just stimulating the right pleasure centers of their brains.

The information about the external environment is perceived by the individual through certain number of sensitivities. Cabanac (1971) notices that some sensitivities give rise to a phenomenon of consciousness that attaches affective aspect, described in common language as pleasure or displeasure. But not all stimuli evoke affective content. For instance, the mere action of seeing is neither pleasant nor unpleasant by itself, even though the cognitive processing of the images may carry affective content.\(^4\) In what follows we refer to sensations as the effective content of the sensitive experience.

The first building block of the model is the fact that some sensations have additional and even more important roles than guiding behavior: as warning and defense mechanisms. For example, when you touch the prickle of a rose the motivational role of pain is to provide disincentives to avoid touching it in the future. On the other hand, the warning role is to draw the attention of the individual to trigger an immediate response and then avoid being injured any further.\(^5\)

If Nature wants to guide the behavior of an individual, she has to shape the relative intensity of his sensations. An individual will follow action A instead of B because the pleasant sensation triggered by A is relatively more intense than that of action B, regardless of the absolute level of intensity. On the contrary, if Nature wants to build a warning system, she needs to provide an individual with intense sensations (in an absolute sense). The stronger the sensation the quicker the individual will react and therefore the greater the chances of preventing further harm. If pain was weak then people would fall asleep on snow and die from hypothermia, or they would frequently die from bleeding because they would not notice that they have a wound.

\(^3\)Stimuli comprise more complex external influence, like information. Similarly, as sensations you can think of complicated mental and hormonal arrangements, such as emotions.

\(^4\)Similarly, Young (1959) distinguishes between discriminative and affective dimensions of sensations. Cabanac (1971) noticed that sensitivity is objective while the affective content depends upon the environment (he called this “alliesthesia”).

\(^5\)In both cases Nature wants to make us respond to stimuli, and then there is a motivational role. However, in the first case Nature wants to motivate future actions, while in the first case Nature wants to motivate immediate action.
Indeed, Sternbach (1963) found that individuals with a very rare congenital syndrome called indifference to pain are almost all dead by their mid-thirties. Some hundreds of years ago an individual with such deficiency would not have had any chances of surviving at all, not to mention during our evolutionary time. The ability of these persons to survive is seriously impaired and depends on their ability to use other sensory cues of tissue damage. Young children with this syndrome have among other things mutilated themselves by chewing off their fingers and their tongues, and by suffering severe burns when leaning against stoves or sitting in scalding baths (e.g. Madonick, 1954).

According to Cabanac et al. (1969), the afflicted subjects feel all the stimuli applied to them, including what normal subjects describe as painful. They can detect being burning, pricked or pinched, but they do not feel such experiences as unpleasant. They have the discriminative part of the sensation, but not the affective component.6 This clearly illustrates our point: Nature needed to endow us with strong affective reactions to fulfill the warning role.

The idea behind the defense systems is similar. Take fever as an example. Its motivational role is giving incentives to avoid the kind of actions that led to the fever in the first place. However, the most important role of fever is to force the individual to rest. If fever (or any other defense mechanism) was weak, then people would be able to ignore the message from their organisms and expose themselves to serious harm.7

In modern times we can live without some defense systems: indeed, we ask doctors for drugs to ignore the messages pre-programmed by Nature (like vomit or fever), sometimes because with the modern standards of living it is indeed reasonable to ignore some messages from our body. However, the lack of defense systems would have been fatal during our evolutionary time, and even some hundred years ago.

The defense systems are "paternalistic" devices installed in humans and nonhumans to deal with limited intelligence (Perez Truglia, 2009). It is not surprising that economists have long ignored the defense roles of sensations, since even some physicians seem to ignore the defense function for diarrhea, fever, and others: Neese et al. (1994) called this the "Clinician’s Illusion."

The second building block of our evolutionary explanation is that the intensity of sensations is costly in a fitness sense. First of all, experiences of intense (positive and negative) feelings diminish our state of awareness. Among humans this is remarkable for emotions, as anyone who is coping with grief or a broken heart can tell. For instance, Sapolsky (1999) documented that intense unhappiness may have important adverse consequences for humans and nonhumans. If we experienced sensations ten times more intense than an orgasm in response to ordinary stimuli like eating a berry, we would not be able to focus properly. Not to mention during our evolutionary time, when it would have made us the perfect prey for any lucky predator.

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6 This suggests that the discriminative and affective components of the sensitive experience are probably separated at the neurological level.

7 Once again, technically they are both motivational roles. However, in the former Nature wants to motivate future decisions while in the latter Nature needs to "enforce" an immediate reaction.
There are further reasons why the intensity of sensations is costly. Sensations involve chemical reactions (e.g. the release of neurotransmitters), and more intense sensations would simply imply a waste of energy. But that is only the beginning. Extra activity in the brain produces heat, and one key goal throughout the brain evolutionary history has been exactly to minimize heat production.\footnote{In that sense the microprocessor in your PC is an extremely inefficient computation machines, because it gets very hot by solving simple problems (Montague, 2006).}

Neuroscientists recognized long ago the presence of inhibitory neurotransmitters. For instance, without the GABA inhibition, neurons would send out actions potentials continuously and would "eventually literally fire themselves to death" (LeDoux, 2002).

At first you may not realize how costly intense sensations can be, simply because Nature did a great job. Your sensations are not a function of stimuli (e.g. consumption), but a function of deviations with respect to a benchmark (e.g. consumption aspirations). In this way Nature can shape incentives in spite of using sensations with "bounded" intensities.

Now we can finally put the pieces together. When designing the systems of pleasure and pain Nature faces a problem of asymmetric information, as the organism may be exposed to diverse scenarios (e.g. abundance of scarcity of food, bad or good weather). We will not study the process of natural selection itself, but we will describe the limiting outcome by means of the principal-agent problem, as in Samuelson (2004), Becker et al. (2005), Smith et al. (2007) and Perez Truglia (2009).

Nature must choose a utility function for an individual, $U(c)$, where $c \in C$ is the consumption vector for the individual. Such vector comprises all the outcomes achieved by the decisions of the individuals ($x \in X$), given the characteristics of the environment ($z \in Z$). The function matching actions and environment to outcomes is: $c = f(x, z)$. The characteristics of the environment ($z$) are only known to the individual.\footnote{We use a utility function over goods that are only intermediate from a biological viewpoint. The reason why Nature would do this is not trivial at all. For more details see Robson (2001a, 2001b).}

In the general case $U(c)$ is a vector, where each one of its elements corresponds to a different sensation. Indeed, later we will show that the divorce between decision and experienced utility is embedded in the multi-dimensionality of sensations. Let's start with a one-dimensional example. The fitness function for Nature is given by $V(c)$, which is always of dimension one.\footnote{You can take any monotonically increasing transformation of $V(c)$ and it would still represent the same fitness function.} In what follows we assume that $f(\cdot)$ and $V(\cdot)$ are such that the problem for Nature has a unique global maxima in $X$ for every possible $z \in Z$.

Humans lived as hunter-gatherers for the vast majority of their evolutionary history: the genus Homo has existed for about 2 million years. Agriculture originated only 10,000 years ago and has been practiced by the majority of the world’s population for just 3,000 years, a relatively brief period of time for selection to act (Ehrlich, 2000). If you want to accompany our model with a story, you should think about our ancestral hunter-gather environment.
For instance, imagine Nature designing a primitive hunter, who can spend different amounts of time hunting \((x)\). If he hunted all the time, his organism would eventually collapse. If he did not hunt at all, he would starve to death. There is an optimal effort on hunting from a fitness point of view, which depends on the characteristics of the environment of that particular subject: \(z\) could represent the abundance of prey or climate conditions.

Some components of \(c\) may be the nutrients obtained from the food and the physical harm caused by hunting. Up to this point, Nature would simply choose \(U(c) = V(c)\) (or any monotonic transformation): since the individual maximizes \(U(f(x, z))\), he would choose exactly the consumption that maximizes fitness. You can clearly appreciate the advantage of having rational individuals: Nature can reach optimal fitness despite not observing \(z\).

Suppose now that feeling pain or pleasure is costly. As a consequence, the fitness function is: \(V(c) - L(U(c))\), where the function \(L(\cdot)\) is the shadow cost in fitness from experiencing intense sensations. The function \(L(\cdot)\) is nonnegative (both positive and negative sensations are costly) and convex: the marginal harm would be practically zero if sensations were mild, but if the individual was about to pass out from pain, the marginal harm would be rather large.\(^{11}\)

There are two consequences from \(L(\cdot)\)'s convexity. If it was concave, then Nature would find optimal to design a system of "stochastic" sensations (i.e. you would feel almost infinitely-intense pleasure with almost zero probability). Later we will explore the duration of sensations as another important dimension of the model. If \(L(\cdot)\) was not convex, then Nature would find optimal to hard-wire sensations with infinitely large intensities but infinitely short length.

Facing the fitness cost given by \(L(\cdot)\), Nature would simply pick \(U(c) = \alpha V(c)\), where \(\alpha\) is an scalar arbitrarily close to zero.\(^{12}\) Since all the relevant information is ordinal, Nature can avoid fitness costs by simply normalizing the individual’s utility function. Nevertheless, that is not going to be possible when some sensations play a secondary role: the fitness of the organism depends directly on the intensity of sensations with defense roles, and thus weak sensations would compromise its survival.

To unfold the rest of the argument, first we need to understand why experienced utility, \(U(c)\), is multidimensional. From the perspective of decision theory, we know that under regularity conditions preferences can be represented by a one-dimensional utility function. However, the model assumes that the individual knows his own preferences. The multiplicity of sensations arises for practical reasons: the individual needs to infer causal links between his decisions and his sensations.

Suppose there was a one-dimensional experienced utility. If the individual took on two consumptions activities at the same time, he would not be able to distinguish what is the marginal contribution to the experienced utility from each activity on a separate basis. Or consider activities with delayed rewards. If the individual took one consumption activity after another, and

\(^{11}\)Nature’s goal may not be to completely neutralize sensations: in term of fitness it may be optimal to provide on average positive or negative amounts of some sensations to the individual. This could be easily modeled by translating \(L(\cdot)\).

\(^{12}\)We could scale \(V(c)\) directly.
some time later perceived that his experienced utility rose, he would not be able to distinguish which activity triggered the increment in utility. We could continue with an extensive list of examples of this kind. Experienced utility must be multi-dimensional in order to allow the individual to "know" his own preferences. This is implicitly embedded in the very definition of economics goods.

Moreover, we may ask why we seem to have a finite number of sensations. In the first place, natural selection needs long periods of time to develop sensations. But even if time is not the limitation, having additional sensations is costly in terms of fitness (because complexity always is). Additionally, the processing capacity of our brain is limited. For example, our eyes can transmit between 1.6 and 3 million bits of information per second, thousands of times more information than our brains can process (Scitovsky 1976).

For the sake of simplicity, consider a bi-dimensional experienced utility. The second element of decision utility, \( U_2(c) \), will have a defense/warning role. The first element, \( U_1(c) \), will not have such secondary roles. Since experienced utility is multi-dimensional, there must be a one-dimensional "hedonic metric" representing preferences over sensations, \( S(U(c)) \). In this way people can make meaningful trade-offs between different sensations. We consider a straightforward case: \( S(U(c)) = U_1(c) + U_2(c) \).\(^{13}\) If the individual maximizes \( \sum_{i \in I} U_i(c) \) it does not mean that the utility function is separable in the usual sense, since each \( U_i(c) \) can depend on overlapping subsets of \( c \). The systems of sensations are closely interrelated: marginal pleasure from sugar may depend (say) on sexual activity, and vice versa. In economic terms, some cross elasticities implies that different reward systems are closely related. Theories and evidence from neuroscience suggest that such interrelations do exist (e.g. Camerer et al., 2005). Notice also that \( S(U(c)) \) (or any monotone transformation) is the decision utility.

We need to model the fact that defense and warning roles depend directly on the intensity of sensations. The simplest way to do so is by assuming that for such sensations the intensity is fixed in the values required by the warning and defense roles: \( U_2(c) = U_f^2(c) \).\(^{14}\) For example, if \( U_2(c) \) is fever or pain then \( U_f^2(c) \) is intense enough such as the individual will be compelled to rest when sick or injured. As a consequence, in our principal-agent problem Nature can only choose \( U_1(c) \).

We can now write the fitness function in the following way: \( V(c) - L(U_1(c)) \).\(^{15}\) Nature will want to set \( U_1(c) = V(c) - U_f^2(c) \), so that the individual maximizes \( S(U(c)) = V(c) \). Note that we can no longer multiply \( U_1(c) \) by an arbitrarily small scalar, since it would lead to a very inefficient allocation of effort.

\(^{13}\)Some authors (see Cabanac, 1971) suggested that people may use a metric like the money-metric to make decisions. We can interpret our hedonic metric as a money-metric where all the "prices" are one.

\(^{14}\)Suppose that when the only concern of Nature is the defense/warning mechanism, the optimal utility function is \( \tilde{F}(c) \). In a more general model we would write a second fitness cost, increasing in the level of deviations with respect to such optimal sensations, \( |F(c) - \tilde{F}(c)| \). The case studied here corresponds to the extreme situation where an infinitesimal deviation from \( \tilde{F}(c) \) is infinitely punished, and then Nature will always set \( F(c) = \tilde{F}(c) \). However, none of the results change for the more general model.

\(^{15}\)We omit \( L(U_f^2(c)) \) because we assumed above that \( U_f^2(c) \) is "fixed."
Nature can still avoid some of the fitness costs associated to $L(\cdot)$: we cannot scale $U_1(c)$, but we can translate it arbitrarily. For instance, define $U^u_1(c) = V(c) - U^u_2(c)$, and let $\hat{c}(z) = \arg \max_{x \in X} U^u_1(f(x,z))$. Set $U_1(c)$ in the following way: $U_1(c) = U^u_1(c) - E_z[U^u_1(\hat{c}(z))]$. The term $E_z[U^u_1(\hat{c}(z))]$ is the hedonic benchmark. The individual is still maximizing $V(c)$, yet the expected value of $U_1(c)$ is zero. This implies much less fitness costs from $L(\cdot)$. Intuitively, the goal of the benchmark is to center $U_1(\cdot)$ such as on average the sensations are zero. This is the very essence of the model: regulating the intensity of sensations.

The idea of happiness, health perception and other hedonic states bouncing back to a reference level is shared among social and natural sciences, and they are widely documented for humans and non-humans. But there is much less discussion about the actual mechanisms that make the adjustments happen, and almost no discussion about why the adjustments happen in the first place.

Once we answered the second question it is easier to answer the first. Now we will pin down some ways in which a reward system may regulate its intensity: hedonic adaptation and expectation-based preferences. This division coincides with that proposed by Kahneman (2000): the "hedonic treadmill" of Brickman et al. (1971), based on the notion of adaptation level of Helson (1964), and the "satisfaction treadmill," which invokes the notion of changing aspiration levels.

### 2.2. Hedonic adaptation.

People may adapt to emotional stimulus brought on by life events just like the pupil of the eye adjust to light changes in the environment. That is to say, sensations may be regulated automatically, in a homeostatic fashion, hard-wired inside the systems of rewards and punishments themselves.

In terms of the model, Nature can take advantage of time regularities in $z$ to create a better benchmark.

Consider the simplest case: an individual lives two periods, and $z$ does not change from one period to another. Nature can set: $U_{1,t=1}(c) = U^u_1(c)$ and $U_{1,t=2}(c) = U^u_1(c) - U^u_1(c_1)$, where $U^u_1(c_1)$ is the sensation attained in the first period. Provided the individual does not anticipate hedonic adaptation, $U^u_1(c_1)$ does not modify the maximization problem of the agent in any period. As a result, the individual maximizes fitness but yields exactly zero sensations in the second period.

If we are making the evolutionary argument for animals it is reasonable to assume no anticipation. If we focus on humans we should only consider the evolutionary history as hunter-gatherers during the last couple of million years (as we already mentioned, agriculture has only existed for the last couple of thousand years). It is very reasonable to assume no anticipation in hunter-gatherers and previous hominids. After all, not even modern scientists with all the accumulated knowledge can agree about the existence of hedonic adaptation.

Later we will discuss whether people do or do not anticipate hedonic adaptation in modern times (the evidence suggests that they do not). In any case, it should be clear that for the
theory on the genesis of hedonic adaptation we only need the assumption to be true during our evolutionary history.\(^{16}\)

As long as \(z\) describes a regular pattern over time, Nature can exploit an adaptive mechanism to achieve hedonic adaptation. Intuitively, when an individual faces greater consumption Nature "learns" about the new situation and updates the utility function as to minimize the fitness costs related to the intensity of sensations. If instead of costly sensations you prefer to think about bounded sensations, the story is the same: Nature translates the utility function to center the utility function and make the boundaries irrelevant.

There are plenty of studies on hedonic adaptation (see Frederick et al. 1999 for an extensive review). Just to give some examples, Tyc (1992) did not find any differences in psychiatric symptomatology in young patients who had lost limbs to cancer compared with those who had not. Clark et al. (2008) used fourteen waves of a German panel data and find evidence of adaptation to life events such as unemployment, layoffs, marriage, and divorce. And Bottan et al. (2009) show that adaptation may take place from one day to the following.

Hedonic adaptation is a homeostatic process, an "inviolable neurological fact of life" (Seligman, 2002). The reward system adapts just like the human olfactory system adapts to continuous stimuli, so that the odor becomes unnoticed.

Unfortunately, in the literature there is plenty of confusion about what is hedonic adaptation and what is not. For instance, some authors use addiction or relative deprivation almost as interchangeable with hedonic adaptation. That is very misleading.

It is true that the benchmark does not have to depend directly on past utility. For instance, we would arrive to the very same conclusions using a consumption benchmark instead: \(U_{1,t=2}(c) = U_1^u(c_2 - c_1) - U_1^u(0)\), where \(c_2\) is current consumption and \(c_1\) is past consumption (and we need organisms not to anticipate habit formation). However, in models of addiction the marginal utility and not only the level of utility is usually changing with the cue (Laibson, 2001). As we saw above, it is only the level of utility that matters for hedonic adaptation.

For example, Jones et al. (1979) gave to a group of people equal doses of heroin every day. Although the effects were euphoric at the beginning, they decreased over time and by the 19th day were almost nonexistent. Is in that sense that we see hedonic adaptation. However, there is a second phenomenon: the marginal utility from heroin goes up, which has nothing to do with hedonic adaptation.\(^{17}\)

Similarly, consumption of other individuals in the group can also be used to form a benchmark. If \(c\) is the consumption of the individual and \(c_p\) the mean consumption of her peers, then \(U_1(c) = U_1^u(c - c_p) - U_1^u(0)\) can do the trick. Even though relative concerns under some circumstances can achieve hedonic adaptation, their evolutionary origin responds to very different

\(^{16}\)Because of evolutionary inertia, it could be enough if the assumption was true for earlier hominids and more ancient points in our evolutionary timeline.

\(^{17}\)It is not surprising that addiction is so strongly associated with hedonic adaptation: since marginal utility is increasing over time, without hedonic adaptation the level of utility would achieve very high levels. When there is addiction hedonic adaptation is particularly important, but not the other way around.
2.3. **Expectation-based Preferences.**

Let’s go back to the static model, but suppose that the individual have can predict \( z \). Denote \( c^\ast(z) \) to the consumption that maximizes \( V(f(x, z)) \). The individual then knows that he will achieve \( c^\ast(z^e) \), where \( z^e \) is given by expectations. We can simply write the utility function as follows: \( U_1(c) = U_1^u(c) - U_1^u(z^e) \). If \( z^e \) is accurate, the individual will yield exactly zero sensations. This is possible only because we were built with serious limitations for self-deception (or else we would lower our expectations indefinitely in order to boost happiness). However, this strategy has limitations since people can only predict \( z \) imperfectly.

In this case the adaptation mechanism is not homeostatic, since it works outside the reward system itself: it may involve people’s beliefs and perceptions about their environment and themselves, which may be stored in other regions of the brain.

Expectation-based preferences are very easy to recognize. Imagine that you are on a plane travelling from point A to point B. Minutes before landing the pilot says that there are serious technical difficulties, that you may hear strange sounds, and that a successful emergency landing depends on everybody remaining calm. Everything goes exactly as any other normal flight. However, if I measure how happy you feel after getting off the plane, you would feel probably much happier than if the pilot had not made the announcement.

Landing does not make you cry of happiness, not even smile, because it is practically always safe. However, as soon as you learn that the probability of a plane crash is significant, a successful landing becomes the largest boost in happiness in months. The reason is that most of your feelings are not a function of stimulus alone, but they also involve your mental model of the world and the probabilities that such model assigns to events.

Contrary to economics, the role of expectations in the reward system is part of the mainstream in neuroscience. Take as an example dopamine, a neurotransmitter present in a wide variety of animals that fulfills a motivational role. Dopamine neurons encode the rewards in electrical impulses, which are then distributed throughout the brain (for a non-technical introduction see Montague, 2006). For instance, drugs like amphetamine and cocaine boost happiness in part by prolonging the influence of dopamine on target neurons.

Recent physiological work identified the working of dopaminergic neurons in primates. Figure 1, taken from Schultz et al. (1997), shows the typical activity of a dopamine neuron. In the top panel, the subject receives a drop of appetitive fruit juice (denoted as R), which activates the dopamine neuron one instant later.

The medium panel shows what happens when subjects are given a conditioned stimulus that predicts rewards (e.g. ringing a bell). After some learning, the dopamine neuron is activated by the reward-predicting stimulus (denoted CS), but fails to be activated by the reward itself.

Finally, the bottom panel shows a situation in which the conditioned stimulus is given but the reward is not. As in the previous situation, the activity of the dopamine neuron increases...
with the conditioned stimulus, but then the dopamine depressed exactly at the time when the reward should have occurred.

Intuitively, bursts of impulse activity mean that the reward is more than expected, a pause means that the reward is less than expected, and no change means reward is just as expected. The dopamine system is just one of the many neurological mechanisms that neuroscientists are beginning to unveil. However, we suspect that the principle above is present in many other reward systems in the brain.

Life is full of examples of expectation-based preferences. When a small sports team tie against a big team, the fans of the small team are happier than the fans of the big team. When Apple advertises its new laptop, consumers are suddenly less happy with their current computer. And so on.

We need to understand better the formation of expectations. Once we accomplish that, there are many applications for expectation-based preferences. For instance, advertising (more than 2% of GDP in the US) works in part by manipulating people’s expectations. Research in some industries (like the pharmaceutical) may consist on a treadmill of expectations, resulting in both excessive consumption and excessive R&D investment.
It is not trivial why Nature may be interested in establishing benchmarks in one way or the other. For instance, the storage of detailed information on expected consumption may be costly for the organism, while the information on past sensations may be readily available. Maybe the organism is less prone to self-deception than anticipating hedonic adaptation, etc. Moreover, each reward system may combine more than one adaptation process.

2.4. Discussion.

Even though the metaphor for evolution is useful to illustrate the whole idea, the reader should not think about organisms with and without regulation systems competing with each other. Hedonic adaptation and expectation-based preferences are not a secondary feature of the brain, but a deep consequence of its foundations.

Since most of our sensation-centers share the design with the most primitive brains, the reader should think about the brain as a computation device, and the intensity of sensations as a waste of energy and a production of heat. Since the upsurge of the first multi-cellular organisms the brain has been evolving as an extremely elegant organ: today’s supercomputers, such as Blue Gene, can achieve the same number of operations per second than the brain but consuming as much power as 1,200 US households, while the brain only consumes 100 watts (as much as a laptop computer).

We can generalize the results by adding a further sensation without a defense role, $U_3(c)$. The fitness cost would not be $L(U_1(c) + U_3(c))$. As studies from neuroscience show, there is not such a thing as a single continuum from good to bad feelings. People can feel sad and happy at the same time, and an increment of pleasure does not cancel out an equal increment of pain (Larsen et al., 2001).

It would be straightforward to show that each sensation will have its own regulation mechanism (e.g. the gustative pleasure from eating will adapt separately from sexual pleasure). Besides, there may be extra advantages from regulating sensations. The fitness cost may not only depend on the absolute intensity of each sensation, but also on the "divergence" of sensations: $||U_1(c)| - |U_3(c)||$. If the individual feels more than one sensation simultaneously, having divergent sensations would make it difficult for the individual to recognize the weakest one. When sensations are regulated both $U_1(\cdot)$ and $U_3(\cdot)$ are close to zero, and therefore the divergence will be close to zero as well.

Even though we keep mentioning the human olfactory and the pupil, those are sensory habituations and then should be interpreted only as metaphors. At this point you should understand this difference. Sensory habituation is when someone immerses his foot in very cold water and after a couple of minutes stops feeling pain. Under situations of extreme pain, the body releases endorphin to block the pain messages coming from the body. This does not mean that $U_2(\cdot)$ is adapting, because minutes is not the time scale of our model.

Adaptation to $U_2(\cdot)$ would be if someone immerses his foot a couple of minutes every day for a month and after the 31st day he immerses his foot and he does not feel pain anymore (notice that this would be fatal from a fitness point of view). And the same distinction is true.
for sensations in $U_1(\cdot)$: if someone consumes three cups of coffee and enjoys relatively less the third cup, that is not adaptation (in a daily consumption model it would be decreasing marginal utility). We have adaptation if someone consumes a cup of coffee every day and the 30th day he does not feel happier after drinking a coffee, although he would feel unhappy about not drinking one (i.e. because he expects to drink a coffee).

We have intentionally omitted the duration of hedonic experiences. Sensations are not instantaneous, and our hedonic metric values more lasting and frequent sensations. Some sensations may yield delayed rewards, which may be smoothed over minutes, days or even months.\footnote{For instance, Diener et al. (1991) argue that the sensations we recognize as happiness is more about frequency than about intensity.}

Sensations with secondary roles have restrictions on the length of the hedonic states they trigger. For instance, an organism should detect right away that it is on fire: it would be fatal if pain was delayed just a matter of seconds. There are also restrictions on sensations that have no secondary roles, as their timing must allow the individual to easily distinguish a causal link between stimuli and sensations. In the extreme case, if all sensations were evenly "smoothed" over the life-cycle, it would be literally impossible to discover our own preferences. We do not explore this dimension simply because it is not crucial to the main argument of the paper.

Notice that we can replace the idea of rational individuals endowed with preferences by less sophisticated decision mechanisms (e.g. Perez Truglia, 2009) and our model would be applicable to even the simplest animals. Adaptation is indeed widely studied in animals. For example, Yadid et al. (2001) suggests that limbic dopaminergic adaptation is the homeostatic process behind depression in rats.

Finally, we must refer to Becker and Rayo (2005), who asked the very same question that we address. Their beautiful model provides a deep understanding of the principal-agent metaphor between Nature and the living organisms. However, we argue that their model start out with and assumption that is not valid: they take as given that people cannot perceive small differences in sensations.

That cannot be taken as an assumption. On the contrary, it is one of the results of our model. Intuitively, there is an optimal intensity of pain and other defense and warning sensations due to the secondary roles, $U_2^f(c)$. The remaining sensations are determined as "proportional" to the former: e.g. $U_1(c) = V(c) - U_2^f(c)$. As a consequence, Nature should not spend energy in developing a sensation-center capable of perceiving differences in sensations that are extremely small with respect to the intensity of $U_2^f(c)$.\footnote{It is true that there may be physical and chemical boundaries in the sensation-centers such as it is impossible to detect extremely weak sensations (e.g. neurotransmitters cannot be the size of a hydrogen atom). In any case, the evolutionary cost of developing and maintaining accurate sensations is of second order to the discussion. We saw that sensations with defense and warning roles, $U_2^f(c)$, must be intense in an absolute sense. Nature will then design them much more intense than the physical and chemical boundaries. Recall that the remaining sensations are defined with respect to $U_2^f(\cdot)$: e.g. $U_1(c) = V(c) - U_2^f(c)$, which is then translated to minimize $L(\cdot)$. By the same argument than before, the physical and chemical boundaries are far from binding for sensations in $U_1(\cdot)$ as well. We can even give a rigorous definition of the "accuracy" of the sensation-center: the individual will not detect variations in sensations that are extraordinarily small fractions (e.g. $10^{-10}$) of the intensity given by a typical pain.}

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Without the right starting point, Becker and Rayo (2005) cannot realize that the multi-dimensionality of experienced utility is critical to understand the mechanism behind hedonic adaptation: e.g. a good sensation and a bad sensation cannot cancel each other out. Among other departures, they assume that experienced utility is always "costly" when exactly the opposite is true for sensations with defense or warning roles (e.g. a high intensity of pain is "beneficial" from a fitness point of view due to warning and defense roles).

2.5. Welfare Implications.

The question is whether people in modern times do or do not anticipate adaptation (recall that this is not relevant for the evolutionary argument). If adaptation is significant but people do not recognize it, then people will make excessive effort/consumption in the activity/good that is subject to adaptation. See for example the case of "projection biases" introduced by Loewenstein et al. (2003).

The evidence suggests that people do not anticipate that their hedonic state will bounce back to "normal" levels after a bad or good event, even after having experienced such bounces more than once. For example, Riis et al. (2005) found that hemodialysis patients, after a while, have a level of happiness similar to that of healthy people, but at first, when trying to forecast, fail to anticipate this bounce-back in well-being.

Denote naïve agents (i.e. do not anticipate hedonic adaptation) and sophisticate agents (i.e. anticipate adaptation) using superscripts $n$ and $s$, respectively. Since the sensations associated with working are closely related to the warning and defense mechanisms (e.g. pain, stress), we will assume that they do not adapt. Since most of the consumption activities trigger sensations that are not related to secondary roles (e.g. eating, having fun), we will model them as subject to hedonic adaptation.

The agent chooses effort ($l_t$) and consumption ($c_t$) in every period. Let $\delta$ denote the discount factor, and let $0 \leq \gamma \leq 1/\delta$ be the parameter that measures hedonic adaptation. A naïve maximizes his perceived lifetime utility from consumption: $U(c_t) + \delta U(c_{t+1}) + \delta^2 U(c_{t+2}) + (...)$. We will focus on the simplest hedonic habituation: for every unit of utility from consumption this period Nature will "subtract" $\gamma$ units in the next period. Therefore, a sophisticate agent maximizes: $U(c_t) + \delta \left[ U(c_{t+1}) - \gamma U(c_t) \right] + (...)$, which happens to be the true lifetime utility.

The flow of (dis)utility from working is $-P(l_t)$. Assume $U(\cdot)$ and $P(\cdot)$ satisfy the Inada conditions. The total utility is simply the utility from consumption plus the (dis)utility from working. Denote $C = \{c_s\}_{s=1}^\infty$ and $L = \{l_s\}_{s=1}^\infty$. Let $BC$ be the set of consumption and labor decisions $\{C, L\}$ that satisfy the intertemporal budget constraint and such as work effort and consumption are always non-negative. We assume that $BC$ is such as the solution to the problem is interior. The problem for type $i \in \{n, s\}$ is:

$$\max_{(C,L) \in BC} \sum_{s=1}^{\infty} \kappa^s U(c_t) - P(l_t)$$

---

20For example, in absence of the Inada conditions a corner solution may appear for the sophisticate if $\gamma$ is high enough (e.g. he would never work nor consume).
Where $\kappa^a = 1$ (naïve), and $\kappa^s = 1 - \gamma \delta$ (sophisticate). Firstly, note that if all sensations are subject to the same rate of adaptation, then even if people neglected adaptation they would make efficient choices. Secondly, notice from the First Order Conditions that the condition of inter-temporal consumption (i.e. Euler equation) is not affected by $\kappa^i$.

The only difference between naïve and sophisticate arises in the intra-temporal allocation between consumption and labor (more generally, between activities subject and not subject to hedonic adaptation). Because people do not anticipate that a share $\gamma$ of the pleasure from consumption will bounce back, the naïve agent engage in excessive effort and consumption.

It is very difficult to test whether people anticipate hedonic adaptation. After all, not even modern scientists agree about the existence of hedonic adaptation.\(^{21}\) We provide an explanation for the puzzle: Nature could have hard-wired us in such a way that it is difficult for us to outsmart the system (see Appendix 1).

Finally, the same idea is extensible to the case of expectation-based preferences. People may fail to account (at least partially) that some hedonic states are functions of expectations, and thus they will over-engage in such activities. The naïve agent chasing higher and higher expectations may end up less happy than a sophisticate agent who decided to settle for a lower standard of living.

2.6. A test.

We already mentioned that, as a result of hedonic adaptation or expectation-based preferences, there is a lot of evidence on adaptation to many sensations. A key prediction of the model is that we should not find much adaptation for sensations with defense and warning roles. First of all, you should remember that we are not studying sensory habituation: it makes perfect sense if we immerse our feet in cold water and feel no pain after a while. However, it makes no sense to loss sensitivity to cold after living a couple of months in Siberia: the individual would be able to "ignore" the weather and would eventually die from hypothermia.

It is a fact that fever, pain, and the main defense systems do not adapt: they would stop being defenses if they were to adapt. And the same is true for warning systems: an alarm that can be ignored is no longer an alarm. Since this is too obvious, scientists have not tried to test this. However, we did find some related studies.

Firstly, sound perception plays an important warning role: in our evolutionary history sounds may alert either the presence of a predator or the presence of a pray. Weinstein (1982) interviewed a panel of residents for four months and sixteen months after a highway was opened, and found that there is no adaptation whatsoever to noise. Moreover, the conclusions are supported by subsequent studies (see Weinstein, 1982).

The second example is about the human irritant sense, which is the chemical sensitivity of the mucosae (e.g. ocular, nasal). For instance, people who lack the sense of smell (anosmic) can detect airborne chemicals only through the irritant sense. This sense makes it impossible

\(^{21}\)A standard counter-argument would say that people could simply anticipate adaptation at an unconscious level, or through adaptive behavior.
for the individual to remain in toxic environments, which is a clear defense role. As expected, Cometto-Muniz et al. (1992) found very little adaptation to pungent, harmful chemicals.

Finally, we must mention that there are some studies arguing that chronic pain patients exhibit higher than normal thresholds for various types of experimental pain (e.g. Meskey et al., 1975). It is perfectly reasonable to expect mild adaptation to pain, since we were ultimately built to adapt. Especially given that the injuries in those studies are chronic: intense sensations are meant to elicit behavior (e.g. step out of the fire), and if the situation is chronic that may not be useful anymore.

However, the validity of the findings is weak. As Dar et al. (1995) suggest, painful experiences do not change the intensity of pain but the internal anchor points for the subjective evaluation of pain. Peters et al. (1992) shows that even though chronic pain patients reported higher tolerance to pain, they did not differ in objective measures such as nociceptive flexion reflex (a measure of spinal nociceptive processes). Finally, the estimates are not reduced-form estimates but simple mean comparisons, which can simply reflect the mere fact that those who are less afraid from injuries have on average more tolerance to pain.

Finally, our model provides a potential valuable tool for the measurement of hedonic adaptation. Consider the case of inter-temporal comparisons (the same argument can be made about inter-personal comparisons): i.e. we want to measure how subject $A$ adapts to stimulus $s$ from $t$ to $t+1$. Suppose an experimental design: you measure how much incremental pleasure the subject gets from a low stimulus $s$ at $t$, then you increase the stimulus for some time and measure the incremental pleasure at $t+1$.

Up to know there were two ways of measuring incremental pleasure: either varying the price of the good, or self-reports (e.g. "how much did you like the stimulus?"). The problem with the first approach is that either income, income expectations, expenditure or planned expenditure may change between $t$ and $t+1$. The second approach has a number of problems related to self-reports, such as how people’s interpretation of the question may vary considerably over time.

According to our model, the sensations related to defense and warning systems are the ones that should adapt the least. Then we can make people face trade-offs between the stimuli $s$ and some of the latter sensations (e.g. pain) to get a more consistent measure of incremental pleasure. We can use the literature on adaptation to get the best candidates: e.g. nociceptive flexion reflex or the irritant sense.

3. An Application: Psychological Defenses

Each sensation has its own (relatively) independent adaptation mechanism, and habituation may change dramatically from one sensation to another. For instance, we have not yet discussed the timing of the hedonic adjustments: they could be gradual or prompt, partially or completely automatic, and so on.

To illustrate the kind of characteristics that shape the dynamics of adaptation, in this section we will provide an application to a particular class of sensations: psychological states (e.g. anger, sadness). Psychologists have long recognized that hedonic states trigger processes to attenuate
the physiological impact (e.g. Taylor, 1991), ranging from homeostatic processes (e.g. Sandvik et al., 1985) to what they call defensive processes (e.g. Freud, 1937).

We have already noticed that the costs associated to sensations (stress, lack of concentration, etc.) are convex. The other building block of the model is the fact that psychological processes that attenuate distress may have costs (Lazarus, 1985; Richards et al., 2000; Wegner et al., 1993), and thus they tend to be triggered only when distress passes a critical threshold. This is known as the Region-β Paradox (Gilbert et al., 2004). Intuitively, people trigger psychological defenses when they face the death of a relative, but they do not trigger such defenses when their favorite shirt gets stained. You can find three experiments that illustrate this idea in Gilbert et al. (2004).

To model this phenomenon we will use a model of dynamic optimization in continuous time. Assume that the hedonic state \( H \) follows an Ito process with slope \( \mu \) and variance \( \sigma \): \( dH = \mu dt + \sigma dz \), where \( dz \) is a Wiener Process. The fitness cost of sensations is convex in the level of hedonic state: \( C - \frac{b}{2}H^2 \), where \( C \) represents the fitness of an individual with a completely neutral hedonic state, and \( b \) is a parameter that scales the fitness cost of sensations (and its convexity as well).

Nature can hard-wire an individual to make his hedonic state automatically jump up or down when some pre-determined thresholds are reached: if \( A_i \) is the size of the adjustment \( i \) and \( h_i \) is the corresponding threshold, happiness will jump from \( h_i \) to \( h_i + A_i \) (if the jump is upwards) or \( h_i - A_i \) (if it is downwards) as soon as the hedonic state reaches \( h_i \). There may be two fitness costs associated to such jumps: fixed costs \( (C_i) \) and variable costs \( (c_i) \), all of them non-negative, where the index \( i \in \{U,D\} \) indicates that the costs can be different for upwards and downwards jumps.

We already discussed that people tend to underestimate the power of affective adaptation, and thus they tend to overestimate the duration of their hedonic states (Gilbert et al., 1998). We are assuming that people do not predict the bounce back in happiness due to the psychological defenses: the path of happiness is independent from the design of the adjustment process.

Denote \( A \) to the set of all possible adjustments. For every \( a \in A \), denote \( \tau(n) \) to the date of the \( n \)'th adjustment, \( C(n) \) to the fitness cost of the \( n \)'th adjustment, and \( A(n) \) to the size of \( n \)'th adjustment. If \( a \in A \) is the path of adjustments, then the resulting path of hedonic states is \( H_t(a) \). The problem of Nature is the following:

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22 Widely used in economic modeling of, say, investment decisions by firms (Bertola et al., 1990).
23 We could write a more elaborate model. For instance, a risky asset may be following an Ito Process, and we can obtain the hedonic state as the result of the optimal inter-temporal consumption and asset allocation. Nonetheless, the results would be about the same.
24 This is known as Homeostasis: there are detectors that monitor when a system departs from “set-points”.
25 This could not happen if the model is well-specified. Suppose that people know that if happiness goes down to \( U \) then it automatically bounces back to \( u \). Therefore, if someone is between \( u \) and \( U \) he would have to “harm himself” as to fall down to \( U \) and bounce back to \( u \). To our knowledge nobody has suggested that individuals embrace such self-destructive enterprises to take advantage of the psychological defenses.
\[
V(H) = \max_{a \in A} \mathbb{E}_t \left\{ \int_{\tau=t}^{\infty} e^{-\rho(\tau-t)} \left( -\frac{b}{2} H_\tau(a)^2 \right) d\tau - \sum_{n=1}^{\infty} e^{-\rho(\tau(n)-t)} C(n) \right\}
\]

\[
C(n) = \begin{cases} 
C_U + c_U A(n) & \text{if } A(n) \geq 0 \\
C_D + c_D |A(n)| & \text{if } A(n) < 0 
\end{cases}
\]

Where \( \rho \) is the discount rate. The solution to the model (see Appendix 2) is that Nature hard-wires the following automatic adjustments: if the hedonic state goes down to \( U \), then it is adjusted up to \( u \geq U \); and if the hedonic state goes up to \( D \), it is adjusted down to \( d \leq D \).\(^{26}\)

We can study how the adjustment mechanism changes when we modify the underlying parameters of the model. To begin with, higher hedonic volatility (\( \sigma \)) makes it more likely that a random change moves the hedonic process closer to zero, thereby increasing Nature’s willingness to refrain from making an adjustment: \( U \) decreases and \( D \) increases. An increase in hedonic growth (\( \mu \)) makes all \( U \), \( u \), \( D \) and \( d \) go down: the probability of hitting the upper (lower) bound increases (decreases), and the thresholds change accordingly. If we increase the fitness costs of sensations (\( b \)) then more frequent and bigger adjustments will be desired, so \( U \) and \( u \) decreases while \( D \) and \( d \) increases.

If there are no variable costs of adjustment then, conditionally on making an adjustment, Nature would always seek to adjust to the same point: that is to say \( u = d = 0 \) if \( c_U = c_D = 0 \) (and particularly \( u = d = 0 \) if \( \mu = 0 \)). If there are no fixed costs for adjustments, then Nature will make an infinitesimal adjustment when the marginal cost of an adjustment falls just below the expected loss from a marginal change in \( H \): that is, \( u = U \) and \( d = D \) if \( C_U = C_D = 0 \).

It can be quite difficult to figure out the composition of the fitness costs of a particular psychological defense. Consider two usual examples: fantasy and denial. On the one hand, fantasy has a relatively larger fixed cost: the organism need time and energy to generate the fantasies in our mind, regardless of whether the illusion is meant to rationalize the death of a relative or the death of a pet.

Denial on the other hand doesn’t seem to have a fixed cost. Yet the variable cost is certainly nonzero: denying that raspberries are delicious is from a fitness point of view much less dangerous than, say, denying the law of gravity. Thus, in the case of negative experiences, we should expect fantasy (relatively to denial) to have a lower threshold but trigger greater jumps.\(^{27}\)

4. Conclusions

Many characteristics of our pleasure and pain systems can tell us a lot about our biological design once we see them as a result of evolution. For instance, we wondered why Nature did not give us a system of stochastic rewards, and the reason why we have a multiplicity of sensations.

\(^{26}\)Graham et al. (2006) proposed a model where people “smooth” bad life-shocks by the drawing down of what they call “hedonic capital”. This would be in some sense a supplement to what Nature tries to do automatically.

\(^{27}\)In fact the hedonic state is multidimensional, and then there are different psychological defenses with different adjustment costs and therefore Nature triggers different psychological defenses defined all over the “hedonic space.”
Nature is a principal much smarter than some of her agents tend to believe. After taking into consideration two simple biological facts, we showed that Nature must use utility functions with regulation mechanisms such as hedonic adaptation or expectation-based preferences. Far from being a novelty, both mechanisms are part of the mainstream in psychology and neuroscience. Incorporating them into economic models will increase the number of behavioral phenomena that we are able to explain, and furthermore it will provide more accurate welfare predictions.

Even though the theory of hedonic adaptation may seem nihilistic at first glance, there is a romantic interpretation: Nature gave us a life of constant challenges. And even if since times of the hunter-gatherer mankind has been running on the never-ending hedonic treadmill, we may possibly reach a status of enlightenment such as to perpetuate happiness, or even more, put the treadmill in reverse.

References


Appendix 1.

The question is whether Nature could have hard-wired us in such a way that it is difficult for us to outsmart the system. First notice that the greater $\delta$ the less the differences in behavior between naïve and sophisticate introduced by $\gamma > 0$. Nature could have used more complex adaptation rules. For example, current utility may be negatively affected by the mean utility during the last $N$ periods: $U(c_t) - \frac{1}{N} \sum_{s=1}^{N} U(c_{t-s})$. Starting at period $N$ we get the original problem with $\kappa^0 = 1$ and $\kappa = 1 - \frac{\delta}{1-\delta} \frac{1+N}{N}$. The distortion brought by sophisticate agents decreases rapidly as we increase $N$. Intuitively, the impact of current consumption on future adaptation is "smoothed" over $N$ periods. Notice that we would get the same result by using as a benchmark the utility from $N$ periods ago. However, in both cases the results are limited during the first $I < N$ periods (since we do not have enough "history").

Nature could have completely eliminated the distortions in a rather simple way: by multiplying the $U(\cdot)$ of the sophisticate by $1/\kappa^s$, in which case the problems of both types become the same. This solution is impossible if $\gamma \delta = 1$, but even if $\gamma \delta$ is not one but close to one it is still problematic: we would have a utility function for the sophisticate with asymptotic mean zero, but extremely "steep." Since sensations have convex fitness costs, Nature will face restrictions to take advantage of this particular solution.

To study this more deeply we need a richer lifetime model. If the individual’s consumption converges to a fixed number, then in the long run they will be no cost from scaling the utility function. But if consumption jumps a lot (e.g. there are credit constrains and stochastic income), then scaling is costly and we should solve a trade-off between mean and variance.

Finally, it would be interesting to consider a model where people “learn” about $\gamma$ over time, while they cognitively process past information on stimuli and hedonic responses. We should expect $\gamma_t$ to be increasing in $t$. But individuals would be naïve about future selves: at time $t$ people should act as if $\gamma_s = \gamma_t \forall s \geq t$. That is to say, this version of hedonic adaptation would bring dynamically inconsistent preferences.

There is vast evidence on imperfect affective forecasting beyond the particular case of hedonic adaptation (for an extensive review see Loewenstein et al., 1999, 2003). In the last three million years the human brain tripled in size, mainly because the growth of the frontal lobe and its prefrontal cortex. One of the core roles of this structure is the ability to make predictions (Banyas, 1999). If Nature gave us a "simulator" capable of predictions beyond the computational power of the most advanced super-computers, there must be a reason why we cannot forecast the simplest hedonic experiences. Hedonic adaptation may provide an explanation for this puzzle: thanks to imperfect affective forecasting, Nature can prevent us from "outsmarting" the system.

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