The Psychology of Economic Decisions

VOLUME I

Edited by
ISABELLE BROCAS
and
JUAN D. CARRILLO

OXFORD
UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS

Great Clarendon Street, Oxford OX2 6DP

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship,
and education by publishing worldwide in

Oxford New York

Auckland Bangkok Buenos Aires Cape Town Chennai
Dar es Salaam Delhi Hong Kong Istanbul Karachi Kolkata
Kuala Lumpur Madrid Melbourne Mexico City Mumbai Nairobi
São Paulo Shanghai Taipei Tokyo Toronto

with an associated company in Berlin

Published in the United States
by Oxford University Press Inc., New York

First published 2002

British Library Cataloguing in Publication Data
Data available

Library of Congress Cataloging in Publication Data
Data available

ISBN 0-19-925106-1 (hbk.)
ISBN 0-19-925108-8 (pbk.)

1 3 5 7 9 10 8 6 4 2

Typeset by Newgen Imaging Systems (P) Ltd., Chennai, India
Printed in Great Britain
on acid-free paper by

Contents

2

Irrational Pursuit: Hyper-Incentives from a Visceral Brain

KENT C. BERRIDGE

The purpose of this chapter is to consider the possibility that people make choices that are *irrational*—in a strong sense of the term. I acknowledge at the outset that many readers might object to a strong notion of irrational choice, either on the grounds that it is a contradiction in terms, or because it seems a mere admission of ignorance about someone else's private hedonic world. Yet, I will argue that irrational choice may be both plausible and in some cases demonstrable.

The notion of irrational choice may seem to be self-contradictory when viewed from the perspective that people always choose what has the most value or decision utility to them. If one defines 'having the most value' as 'what one chooses', then by definition one always chooses the most valued outcome. However, as documented by a number of authors in this volume, people may sometimes choose an outcome whose eventual *hedonic value* does not *justify* their choice (see Chapters 1, 3, 10, and 11).

Or a pronouncement of irrational choice might seem to imply nothing more than our ignorance about another's private hedonic priorities. After all, if *de gustibus non disputandum est*, then individual tastes are not a matter for dispute, nor can they be deemed either rational or irrational. What you like is the legitimate basis for your own choice. An outsider may not share or understand the basis of a particular choice, but it is presumptuous for that reason alone to call it irrational (it is an interesting and legitimate question for psychology to ask why one likes the things one does, and to identify causes of liking—but that is a separate issue).

Still, irrational choices may yet be possible, even when private expectations and likings are known, and even from the point of view of the individual who has them. What I want to consider here is whether there are degrees of irrationality regarding choice, and whether there are real-life examples of irrational choice.

I thank Richard D. Gonzalez for for suggesting the Latin quotation about tastes. I also thank Juan Carrillo, Richard Gonzalez and Cindy Wyvell for their thoughtful comments on an earlier version of the manuscript. Finally, I thank Andrew Caplin (who suggested the home-shopping scenario) and Daniel Kahneman for helpful conversations at the Brussels conference in June 2000.

Let's grant at the outset that the rationality or irrationality of your choice has nothing to do with why you like it, or with whether anyone else likes it too. The question of rationality hinges only on whether your choice consistently follows your expectations of hedonic likes. A truly *irrational choice* would be to choose what you *expect not to like*.

If an outcome is much liked, then by the rational criteria of hedonic decision making, it should also be much wanted (Gilbert and Wilson, 2000). The outcome should be wanted exactly to the degree that it is expected to be liked. *Expected* to be liked is the crucial phrase here. Human expectations of what will be liked can often be in error, but being wrong has nothing to do with rationality. Expectations may be wrong because of ignorance of the outcome or because of cognitive distortions. For example, Gilbert and Wilson and colleagues have shown that when people predict their future hedonic well being in the face of an adverse future outcome they tend to underestimate their emotional resiliency, and to underestimate also the compensating influence of other positive future outcomes (Gilbert and Wilson, 2000; Gilbert et al., 1998; Wilson et al., 2000).

Perhaps, a closer approach to irrationality comes from demonstrations by Kahneman and colleagues of the systematic 'violations of logic' in people's choices that are based upon the systematic distortions of hedonic memory (Kahneman, in press). A person's prediction of hedonic impact can be wrong even for the next occurrence of an already familiar outcome (Kahneman et al., 1993; Kahneman and Snell, 1992; Redelmeier and Kahneman, 1996). Kahneman argues that people base their memory of a hedonic event on a few prototype moments that occurred during that event, even when those moments do not reflect the full hedonic impact of the event as a whole (Kahneman, in press). For example, people may thus be induced to choose a longer pain over a shorter one that gives less total pain, due to an end-decrement that creates the memory illusion that the longer pain was less intense (Kahneman et al., 1990, 1993; Redelmeier and Kahneman, 1996). These cases distort choice by distorting the cognitive expectations of future hedonic impact. To the degree that wanting for an outcome is based on expected liking, any distortion of hedonic expectations will rationally result in a misguided choice. The wrong choice will be based on a false expectation.

Making the wrong choice on the basis of false hedonic expectations is misguided but not strictly irrational. A misguided choice remains rational as long as it corresponds to a maximized expectation of liking. If I believe that I will like an outcome very much, then I am rational to want it, to choose it over others, to work hard for it exactly to the degree that I expect to like it—even if I turn out not to like the outcome after all. Rationality cannot be held not responsible for the accuracy of my expectations, only for the consistency with which I act upon them. (One could argue that once one knows distortions of expectation may occur, then rationality demands the application of new strategies to avoid being fooled by distortions again. But such a high-level degree of rationality is beyond our current scope. Here we are interested, simply, in whether there are choices that fail to meet even the *ordinary* criteria for rationality.)

1. STRONG IRRATIONALITY

So what would be needed, in addition, to make a choice truly irrational? I wish to focus here on the *intrinsic rationality of a given decision*, rather than on properties such as transitivity that are assessed over a series of decisions. Irrational choice is something more than the mere mistaken belief about future liking. It is choice that diverges from the expectations of future liking (presuming the choice is not constrained by non-hedonic criteria). To aid the discussion, I will adopt here the utility terminology of Kahneman (Kahneman, 1999; Kahneman et al., 1997) to distinguish between *experienced utility* (actual liking for an outcome), *remembered utility* (memory of liking in the past), *predicted utility* (expected liking for the outcome in the future), and *decision utility* (manifest choice of the outcome).

For the purposes of this chapter, *I define a choice to be rational* so long as *Decision Utility = Predicted Utility*, and the choice maximizes both the decision and predicted utility (regardless of whether the prediction of future experienced utility proves to be correct). By contrast *irrational choice is defined to be possible only when Decision Utility > Predicted Utility*, such that a choice that maximizes the decision utility results in suboptimal predicted utility. In other words, an outcome is irrationally chosen only when it is wanted disproportionately to its expectation of being liked.

If truly irrational wanting is wanting what one does not like and does not expect to like, this may seem so bizarre and unlikely that economists and psychologists could safely dismiss the possibility. Why consider a phenomenon that cannot exist? But irrational wanting may indeed exist. There are several phenomena that approach irrational wanting, at least by incorporating increasing degrees of divergence of the decision utilities from the predicted utility. Further, there is evidence to suggest that, within strictly limited circumstances, irrational wanting may be quite a powerful control of choice and pursuit behavior. Irrational wanting may be a phenomenon that needs to be reckoned with.

2. EXPERIMENTAL APPROACHES: MANIPULATION OF DECISION UTILITY BY IRRELEVANT (UNCONSCIOUS) CAUSE

In some instances, a person may be entirely unaware of the occurrence of an event that influences their wanting for an outcome (Nisbett and Wilson, 1978; Wilson and Schooler, 1991; Winkielman et al., 2000; Zajonc, 1980). The most striking examples come from the work of Zajonc and colleagues on the subliminal (unconscious) presentation of a manipulation that changes preference for a later event (Murphy and Zajonc, 1993; Winkielman et al., 1997; Zajonc, 1980, 1998). For instance, the subliminal presentation of a happy or angry emotional facial expression, even though not consciously perceived, nonetheless alters the preference ratings of aesthetic value for a subsequent item that is consciously evaluated, such as the aesthetic value of a Chinese ideogram (Kunst-Wilson and

Zajonc, 1980; Winkielman et al., 1997). It seems plausible to presume that, irrelevant causes do not act by changing explicit expectations about the utility of the ideogram because the causal manipulations work at an unconscious level.

The subliminal shifts of decision utility apply not only to verbal or pencil-&-paper ratings, but also to real consumption behavior. This was recently demonstrated in a study conducted by Piotr Winkielman at the University of Denver, his student Julie Wilbarger, and me (Winkielman et al., 2000). Winkielman and colleagues found that the subliminal emotional expressions altered people's actual consumption and their willingness to pay for a fruit drink in ways that diverged somewhat from rationality.

Relevant to the degree that such subliminal effects on consumption behavior might be regarded as operating outside the bounds of rationality, we wanted to clarify the degree to which subliminal affective priming is truly unconscious. Are people simply unaware of the causal facial expression that produces an emotional response in them, but able to consciously experience the hedonic emotion itself in an ordinary way? If so, a case could be made that a conscious hedonic shift in mood could operate in a rational manner, by changing the hedonic value of choices considered after the shift in mood. Or are people actually unconscious of their own emotional reaction (in addition to being unaware of the subliminal facial expression that caused it)? An unconscious emotional reaction is more difficult to construe in rational terms.

Winkielman et al. assessed the conscious emotional reactions by asking subjects to rate online their subjective mood immediately after subliminal exposure to emotional facial expressions, and then measured their actual consumption behavior, in the form of how much beverage they subsequently poured for themselves and how much they drank (Winkielman et al., 2000). The subliminal stimuli were happy, neutral, or angry facial expressions, which lasted for only 1/60th of a second, and were followed immediately by a second 'masking' photograph of a face with a neutral expression, which stayed on the screen long enough to be seen consciously. The subjective experience of this procedure is that one is aware only of the neutral face that follows the subliminal emotional expression. Participants were told that their task was to guess the gender of the neutral face they saw. All the participants later denied having seen any emotional expressions, and were unable to recognize them, confirming that the emotional stimuli were indeed subliminal.

In another experiment, other subjects were given a single sip of the beverage after seeing the faces, and asked to rate how much they liked the drink, how much they wanted to consume, and how much they would be willing to pay for a can of the beverage.

The results showed that a subliminal exposure to *happy* facial expressions caused thirsty participants to choose to take more of the fruit-flavored drink when they poured their own glass than if they had seen only neutral facial expressions (Winkielman et al., 2000). They also consumed or swallowed more of what they poured after seeing happy expressions than after neutral expressions.

Their consumption behavior was increased by the happy expression, even though they had no conscious awareness of the expression or of any change in their mood.

By contrast, participants who had been subliminally flashed *angry* facial expressions did exactly the opposite. They took less of the drink when pouring than after neutral expressions, and they swallowed less of the drink from their glass. Thus, the effect on the objective decision utility of the drink was bivalent. Consumption behavior could be driven either up or down by the subliminal stimuli. Again, subjects whose consumption behavior was decreased experienced no corresponding decrease in their intervening ratings of a subjective hedonic mood, which could have explained their behavior (Winkielman et al., 2000).

When ratings of the drink itself were assessed after a sip, the same subliminal stimuli altered the ratings of wanting for the drink and of monetary value (Winkielman et al., 2000). The thirsty participants gave higher ratings after subliminal happy expressions than after angry expressions in answer to the question 'How much would you pay for this drink in a store?'. *They were willing to pay more than twice as much* (over 40 cents per can, U.S.$) *after seeing subliminal happy expressions* compared to after seeing subliminal angry expressions (less than 20 cents per can). They also gave higher ratings to the question 'How much do you want this drink' after the happy versus angry subliminal stimulus. These changes in the subjective decision utility of the drink again were not accompanied by changes in the subjective hedonic mood (Winkielman et al., 2000).

Thus, happy subliminal faces did not make drinkers feel better in general, nor did subliminal angry faces make them feel worse. Instead the subliminal stimuli rather directly altered the decision utility of the next affectively-laden event they encountered: in this case, the flavored drink.

Given that we are presently interested in irrational pursuits, I want to focus on the *increases* in decision utility caused by the subliminal exposure to a happy facial expression. The decision utility of the fruit-drink was increased by several measures: thirsty subjects took more of the fruit-drink when they could control the amount poured into their glass, they drank more after taking it, rated their wanting for it higher after a sip, and increased their stated willingness to pay money for the fruit-drink. By all of these indices, the subliminal emotional expressions increased the subjects' wanting for the drink (Winkielman et al., 2000).

But is a subliminal want irrational? The answer is not entirely clear. Certainly, the cause of the increased pursuit is unrelated to the outcome pursued (for the sake of argument, let us count the pouring behavior as a pursuit). Further, there is no a priori reason to suspect that the subliminal presentations altered explicit beliefs about the hedonic value of the drink. The people have no reason to change their assessment of a drink's potential pleasure after a subliminal exposure a to an emotional expression they do not consciously see, which induces an implicit emotional reaction they do not consciously feel. However, Winkielman et al. did not explicitly ask subjects about their expectations so this remains only a conjecture. The question remains open.

Unconsciously magnified pursuit might well be called unreasonable—in the sense that no good reason could be given for the magnification. But the lack of a good reason is not quite enough to call it irrational by our definition of irrational given above—namely, acting in contradiction to the expectation of pleasure. An irrelevant cause is not necessarily an irrational pursuit, not even if the irrelevant cause is unconscious. Subliminal wants may not be the stuff of strongly irrational pursuits. Perhaps we should look elsewhere for a truly irrational pursuit.

3. THE BRAIN MECHANISMS OF EXPERIENCED UTILITY AND DECISION UTILITY

A better understanding of the irrational forms of pursuit may come from considering the brain mechanisms that underlie aspects of decision utility. Let us start by considering where in the brain the utility value of rewards might be mediated. The answer to this question depends on whether by utility of a reward we mean its instantaneous experienced utility (hedonic impact of a reward at the moment it is experienced, or reward liking), remembered utility (declarative memory of hedonic impact, or reward memory), predicted utility (declarative expectation of future hedonic impact, or reward expectation), or decision utility (choice value—corresponding to predicted utility but also involving other factors, or reward wanting).

There are quite a number of structures and neural systems in the brain that are activated by rewards and are candidates to mediate utility (Berridge, in press; LeDoux, 1996; Panksepp, 1998; Rolls, 1999; Shizgal, 1999). These include several regions of the neocortex, such as the prefrontal cortex at the front of the brain (especially the orbitofrontal part, which is closest to the eyes), the cingulate cortex (at the top of the brain, near the middle between the two hemispheres), and the two amygdala (nestled within the temporal lobes at either side of the brain). The brain reward systems also include several structures and neural circuits beneath the cortex, such as the mesolimbic dopamine system that projects from the midbrain up to the nucleus accumbens and other targets, the nucleus accumbens itself (immediately underneath the neocortex at the front of the brain), and the ventral pallidum and lateral hypothalamus (at the base of the forebrain), which receive outputs from the accumbens.

There is reason to think that the orbitofrontal and cingulate cortex may mediate the cognitive aspects of declarative predicted and declarative remembered utilities—conscious expectations and memories (Balleine and Dickinson, 1998*a*; Damasio, 1999; Rolls, 1999). The nucleus accumbens, ventral pallidum and lateral hypothalamus are likely to mediate the basic aspects of experienced utility or hedonic impact (Berridge, 1999; Panksepp, 1998; Peciña and Berridge, 2000; Shizgal, 1999). For a specific aspect of *decision utility*, however, especially relevant to the possibility of irrational pursuit of rewards, we should turn to the subcortical mesolimbic dopamine system that projects from the midbrain up to the accumbens (Figure 2.1) (Berridge and Robinson, 1998).

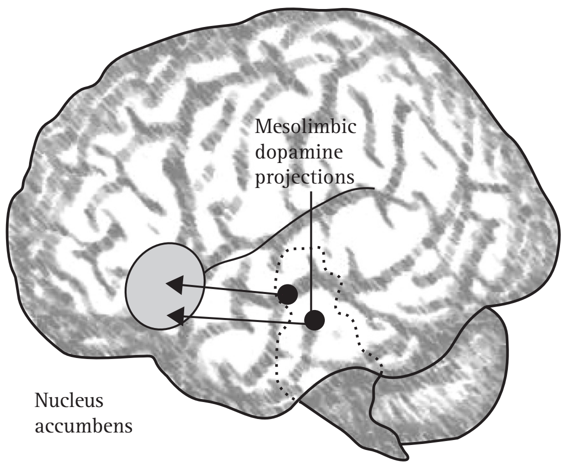

Figure 2.1. *The brain mesolimbic dopamine system. Dopamine neurons project from the midbrain up to the nucleus accumbens*

4. THE MESOLIMBIC DOPAMINE SYSTEM FOR REWARD UTILITY

The mesolimbic dopamine system is famous as a brain substrate of reward utility. There are ample reasons for that fame. The dopamine neurons are turned on by many naturally pleasurable events, at least under some circumstances, such as eating a delicious new food or encountering a sex partner (Ahn and Phillips, 1999; Fiorino et al., 1997; Mark et al., 1994). The dopamine neurons are also activated by most artificial rewards, such as drugs like cocaine, amphetamine, heroin, ecstasy, etc. (Wise, 1998). And many of the brain sites at which direct electrical stimulation is rewarding tend to activate the dopamine neurons or the targets of dopamine neurons (Flores et al., 1997; Hoebel et al., 1999; Panksepp, 1998; Shizgal, 1997, 1999; Yeomans, 1989). Finally, drugs that block the dopamine receptors, disrupting the system, cause animals to stop working in many situations—as though food, sex, cocaine, heroin, brain stimulation reward, etc., lose their reward properties after the suppression of dopamine neurotransmission (Wise, 1982).

Many hypotheses have been offered for the precise role of the mesolimbic dopamine systems in reward (Berridge and Robinson, 1998; Panksepp, 1998; Salamone et al., 1997; Schultz, 1998; Servan-Schreiber et al., 1998; Wise, 1982). Most famous has probably been the *hedonic hypothesis* that dopamine is the brain's 'pleasure neurotransmitter' that mediates hedonic impact at the moment of the actual reward (Gardner, 1997; Volkow et al., 1999; Wise, 1982; Wise and Bozarth, 1985).

Pleasure or hedonic impact is most closely related to instantaneous or experienced utility. Most neuroscientists have not used the utility terminology to describe the dopamine system, but one who has is Peter Shizgal, a leading affective neuroscientist. Shizgal has pondered which type of utility (among instantaneous and predicted decision utilities) might be activated by a rewarding brain electrode that stimulates the medial forebrain bundle, and so it is worth noting his opinion here. Shizgal explicitly chooses experienced or instantaneous utility as the type turned on by brain stimulation, positing that 'rewarding stimulation achieves its grip over ongoing behavior by simulating the real-time effect of a natural reward on the evaluative system, that is, *by driving instantaneous utility to positive values*' (Shizal, 1999, p. 503, italics added). Defining what he means by instantaneous utility, Shizgal writes, 'instant utility is experienced along an opponent hedonic dimension ('good/bad') while biasing the individual to continue or terminate the current course of action. States and stimuli that produce *positive values of instant utility are experienced as pleasurable . . .*' (Shizgal, 1999, p. 502, italics added). Thus, Shizgal essentially affirms the hedonic hypothesis that a neural basis for pleasure consists of high rates of firing of mesolimbic and related neurons, caused by a rewarding hypothalamic electrode.

The hypothesis that the mesolimbic dopamine mediates pleasure is based on hundreds of affective neuroscience experiments, all interpreted on the assumption that changes in the degree to which rewards are *wanted* by an animal reflects changes in the degree to which the rewards are *liked*. The assumption that wanting reflects liking is both plausible and no doubt often true—but perhaps not *always* true (Berridge and Robinson, 1998). The assumption may not be true in particular when applied to the brain mesolimbic dopamine systems (Berridge and Robinson, 1998; Robinson and Berridge, 2000).

5. THE BRAIN SYSTEMS FOR REWARD 'LIKING': MEASURING HEDONIC IMPACT OR INSTANTANEOUS EXPERIENCED UTILITY

I shared the belief that the mesolimbic dopamine neurotransmission was probably a mechanism for pleasurable reactions until about 10 years ago. But I no longer believe that dopamine mediates positive hedonic 'liking' for rewards, and this change of opinion is directly relevant to the possibility and mechanisms of irrational pursuit. My opinion changed as the result of surprising results in a series of experiments in our laboratory, which attempted to more directly expose the role of the mesolimbic dopamine systems (e.g., Berridge and Robinson, 1998). We asked simply whether dopamine mediates the *basic hedonic impact caused by a simple reward such as a sweet taste*. The experiments were part of our larger effort to identify the crucial brain mechanisms that cause positive affective reactions (i.e., that generate a positive affect) to pleasurable rewards. In a sense, we have sought to directly identify the neural bases of the instantaneous experienced utility.

Our search for pleasure in the brain has used an approach that, looks for brain manipulations able to cause changes in an immediate reflection of the degree of hedonic 'liking' impact produced by a reward—namely, changes in *natural affective reactions that are normally elicited by tasty food* (Berridge, 2000). Natural affective reactions are probably most familiar to readers in the form of facial expressions of pleasure and displeasure. To give the reader an idea of how we proceed, for example, a sweet taste elicits from a human infant a positive affective facial reaction: a pattern of tongue protrusions, lip sucking, facial relaxation, and the occasional smile (Steiner, 1979; Steiner et al., in press). A bitter taste, by contrast, elicits a completely different aversive pattern of gapes, nose wrinkling, head shaking, etc. Of course, we would never use a human infant in an affective neuroscience experiment. However, humans are not alone in their capacity for affective reactions to tasty food. Chimpanzees, orangutans or gorillas, our closest primate relatives, have facial positive and negative affective reactions to tastes that are highly similar to those of the human babies (Steiner et al., in press). Old world monkeys (primate relations that evolved in Africa and Asia), and New world monkeys (more distant relations that evolved in South America), also have behavioral affective reactions to sweet or bitter tastes, and even rodents such as rats show taste elicited affective reactions that are homologous to those of primates (Figure 2.2). Sweet tastes, for example, elicit tongue protrusions from all, whereas bitter tastes elicit gapes and headshakes. The measurement of these affective reactions by animals after neural manipulations allows us to make an affective neuroscience study of how brain systems mediate the basic hedonic impact of a tasty reward (Berridge, 2000).

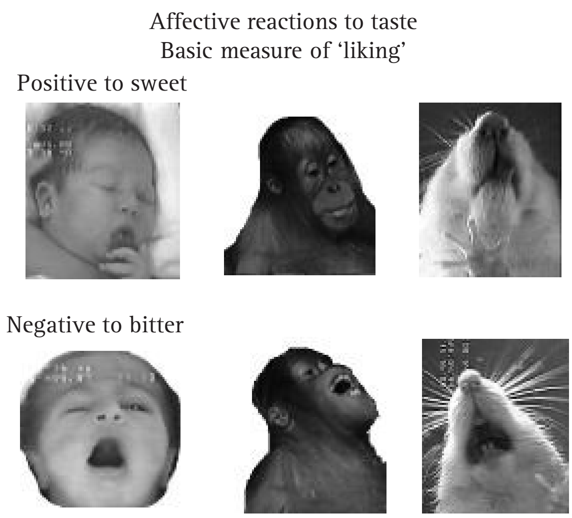

Figure 2.2. *The basic hedonic impact or experienced utility reflected in natural affective reactions. The affective reactions of a human infant, a young orangutan, and a rat, elicited by sweet and bitter tastes (Berridge, 2000a)*

Using the technique of measuring affective reactions elicited directly by the hedonic impact of a sweet taste, we have identified several brain systems that mediate the hedonic 'liking' for tastes. For example, neural circuits in the nucleus accumbens that use morphine-like opioid neurotransmitters, circuits in the ventral pallidum and lateral hypothalamus, and GABA-receptor circuits in the brainstem's parabrachial nucleus, all appear crucial to mediate the positive hedonic impact of tasty rewards (Cromwell and Berridge, 1993; Peciña and Berridge, 2000; Söderpalm and Berridge, 2000). Activating these neural systems in the brain of rats causes increases in the positive hedonic reactions that reflect the hedonic impact of a sweet reward. These are brain mechanisms capable of causing increased positive values of experienced utility or 'liking' for such a reward.

6. 'WANTING' REWARD VERSUS 'LIKING' REWARD: INCENTIVE SALIENCE HYPOTHESIS OF DOPAMINE FUNCTION

My colleagues and I expected the mesolimbic dopamine systems to mediate the taste pleasure too. We were wrong—and at first very surprised—to find in a series of studies that the dopamine manipulations had no effect on the positive affective reactions to natural taste pleasures. We tried drugs that suppressed the dopamine systems (Peciña et al., 1997; Treit and Berridge, 1990), drugs that activated the dopamine systems (Treit and Berridge, 1990; Wyvell and Berridge, 2000), an electrical stimulation similar to Shizgal's of the lateral hypothalamus and of the medial forebrain bundle (Berridge and Valenstein, 1991), and chemically-induced brain lesions that selectively destroyed virtually all the dopamine neurons while sparing other circuits (Berridge and Robinson, 1998; Berridge et al., 1989). None of those manipulations of the mesolimbic dopamine altered our measures of the basic hedonic impact or the experienced utility (although they dramatically altered other traditional aspects of food reward more related to decision utility, such as whether food was pursued or eaten).

What psychological process can masquerade as pleasure in so many psychological tests yet not be pleasure? What psychological process is normally activated when a reward is 'liked'—in addition to the 'liking' itself? Rewards are usually conceived as things that are both liked and wanted. They are wanted just to the degree that they are liked—and vice versa. After all, that is rational. Liking and wanting are often viewed as nearly synonymous (indeed, an element of wanting is found even in the definitions of experienced utility used by Kahneman (Kahneman et al., 1997) and Shizgal (1999), namely persistence in goal-directed action; however, it is possible to view this element instead as a part of the decision utility). The solution we found ourselves pushed to adopt was to split the usual notion of reward into two parts and to stress the difference between the erstwhile synonyms.

What if liking and wanting are separable psychological processes, mediated by separate brain systems? And what if the mesolimbic dopamine systems mediate wanting for rewards specifically—and not a liking for rewards at all? A version of that hypothesis has helped resolve our paradox of brain manipulations that changed so many measures of how much a reward was wanted, without changing a measure of how much it was liked.

My colleagues and I have coined the phrase *incentive salience* for the form of 'wanting' we think is mediated by the brain dopamine systems. We believe that the brain dopamine systems attribute the representations of rewards with incentive salience whenever a cue for the reward is encountered. The incentive salience causes the cue and its reward, in our view, to become momentarily more intensely attractive and sought. We often use the term 'wanting' to refer to incentive salience—putting the words in quotation marks as a caveat to denote that this particular type of decision utility is somewhat different from what is meant ordinarily by the word wanting. For one thing, 'wanting' in the incentive salience sense is different in that it need not have a conscious goal or declarative target of predicted utility for it to control choice and pursuit—quite unlike the ordinary conscious wanting, which always has a declarative target (namely, an explicit expectation of predicted hedonic utility).

Wanting and 'wanting' thus differ, both psychologically and in their brain substrates (Berridge, 2001; Berridge and Robinson, 1998; Dickinson et al., 2000). Wanting is a conscious desire that depends on the cortical systems. 'Wanting' is cue-triggered incentive salience, leading to the pursuit of the cued reward, which need not be consciously experienced in order to control behavior, and which depends on the mesolimbic dopamine systems.

7. WANTING (CONSCIOUS DESIRE FOR A DECLARATIVE GOAL) VERSUS 'WANTING' (CUED ATTRACTION TO SALIENT INCENTIVE)

Wanting in the ordinary sense means a conscious desire for a cognitively-represented outcome, essentially a form of decision utility that corresponds directly to predicted utility. But the more basic incentive salience form of 'wanting' has actually been a topic of study for decades in animal studies, of the psychology and behavioral neuroscience of reward and conditioned incentive motivation (albeit not couched quite in the terms or concepts I will use) (Berridge, 2001; Bindra, 1978; Dickinson and Balleine, 1994; Dickinson et al., 2000; Rescorla, 1988; Toates, 1986, 1994). Conditioned incentive motivation is controlled by processes that have more in common with the associative learning mechanisms known as Pavlovian conditioning rather than with the declarative, consciously-accessible, and logical mechanisms of goal-directed cognition. The literature on conditioned incentive motivation is very large (for reviews see Berridge, 2001; Bindra, 1978; Dickinson and Balleine, 1994; Toates, 1986). Here, I will only mention the most relevant features.

Reward cues are logically valued for the pleasures they predict—that is, future states of experienced utility, which will occur after the cued reward is obtained.

A core of the incentive salience notion is that reward cues also often become 'wanted' themselves. This process is not strictly logical (and sometimes it has consequences that are downright illogical, costly, or even pathological—but nonetheless it is lawful and quite powerful). In traditional psychological parlance, the reward cues become conditioned incentive stimuli. There are many instances known in both human and animal psychology, but the process has probably been studied most in laboratories of animal learning theory and affective neuroscience. Animals quickly come to approach, seek out, and even attempt to consume conditioned incentives under certain circumstances. Conditioned incentive cues also have priming effects on the pursuit of their cued rewards—they have the power to evoke a strong 'wanting' for their associated hedonic rewards, and to potentiate behavior aimed at obtaining these rewards (Berridge, 2001; Bindra, 1978; Toates, 1986).

8. AFFECTIVE NEUROSCIENCE: ACTIVATING 'WANTING' AS A FORM OF DECISION UTILITY

A door may be opened to a truly irrational pursuit by considering the conditioned incentive salience or 'wanting' process that we believe are mediated by the brain mesolimbic dopamine systems. Recent experiments in our laboratory on this system appear to have produced a moderate but true form of irrational pursuit (Wyvell and Berridge, 2000), in which 'wanting' for a cued incentive outstrips both the actual hedonic impact and the expectations of future hedonic impact.

It is possible to tweak the brain rather selectively in affective neuroscience studies conducted in animals, by the use of experimental techniques such as the microinjection of drugs. If a microinjection of a tiny droplet of amphetamine is made directly into the nucleus accumbens, it causes the mesolimbic neurons to release their synaptic stores of dopamine and related neurotransmitters. This specifically activates the accumbens neuronal receptors. A microinjection is painless because it is made through a previously-implanted cannulae, placed into a selected brain structure weeks earlier when the animal was totally anesthetized. Brain tweaks of this sort are not limited to animal studies of course (major brain tweaks also happen to humans who suffer from certain pathological conditions, or who take many types of drugs). Much smaller brain tweaks happen to us all every minute of every day, as natural events cause the mesolimbic dopamine activity to rise or fall. The affective neuroscience studies of animals simply allow us to focus, intensify, and control such rises in neural activation to better identify their psychological consequences.

9. ARE ANIMALS CAPABLE OF IRRATIONAL PURSUIT?

We have defined irrational pursuit as the pursuit of an outcome that is not justified by the cognitive expectations of the hedonic value of that outcome. A shift to incorporate animal studies in this context may therefore strike the reader as problematic. Irrational pursuit requires, first, that animals be capable of cognitive expectations of an outcome's hedonic value (predictive utility or wanting in the ordinary sense), second that we be able to assess these expectations of hedonic value, and third that we be able to detect when pursuit deviates from those expectations. Before we can consider a possible instance of irrational pursuit from animal affective neuroscience studies, we had better make a brief detour into the psychology of animal learning to see if this is feasible.

How can one estimate an animal's expectation of hedonic value? A possible solution to this difficulty has been suggested by a leading psychologist of animal learning, Prof. Anthony Dickinson of Cambridge University in England (Dickinson and Balleine, 1994; Dickinson et al., 2000). Dickinson, together with Bernard Balleine and other colleagues, has developed a clever way to ask a mere rat about its cognitive expectations of reward value, and to detect changes in these expectations. Dickinson and colleagues ask rats about their expectations of the value of a food or drink reward, in part by testing their willingness to work for the rewards when they must be guided principally by these expectations alone. The rats are first trained to work for the real rewards, which come only every so often, so the rat has to persist in working if it wishes to earn its corresponding reward. Then the rats are tested for their willingness to work for these rewards later under so-called *extinction conditions*, when the rewards no longer come at all. Since there are no longer real rewards, the rats have only their expectations of reward to guide them (along with any non-expectational forms of learning that can support their learned response; for more discussion on these issues, see Berridge, 2001).

Naturally, without real rewards to sustain efforts, performance in the extinction test gradually falls off. But since the rats originally learned that perseverance pays off, they persist for quite some time in working based largely on their expectation of reward. Even a single experience of a new value of the reward is sufficient to shift this expectation-guided performance in extinction, if its experienced utility value is altered—but that single experience of a new experienced utility value is essential. Dickinson and Balleine conclude that a taste of the altered experienced utility of a reward, henceforth, essentially alters its remembered utility. The new hedonic memory in turn alters the reward's predicted utility, and thus its decision utility or degree to which it is cognitively wanted—all in a rational manner (Dickinson and Balleine, 1994; Dickinson et al., 2000). Alteration in cue-triggered 'wanting' based on incentive salience, by contrast, acts in a more direct manner that circumvents the rational chain of experience-remember-predict-and-choose, and needs no explicit new experience with the altered experienced utility in order to alter behavior (Balleine and Dickinson, 1998*a,b*; Dickinson and Balleine, 1994; Dickinson et al., 2000).

The issues involved in using a Dickinson-style approach to tease apart cognitive wanting from cue-triggered 'wanting' are rather complex. I have discussed them at greater length elsewhere (Berridge, 2001), and the interested reader is referred also to Dickinson's articles mentioned above. For our purpose it is enough to say that, these techniques of assessing animals' cognitive expectations of hedonic value can be of great use in detecting transient instances when the decision utility suddenly diverges from the predicted utility after the brain is viscerally tweaked. They allow an affective neuroscience of irrational pursuit.

10. IRRATIONAL PURSUIT: VISCERAL MESOLIMBIC ACTIVATION OF 'WANTING' FOR A CUED HYPER-INCENTIVE

We can now approach the possibility of observing an irrational level of a high decision utility for a hedonic outcome by combining brain tweaks in the form of amphetamine microinjections, which activate the mesolimbic dopamine systems, with Dickinson's techniques for assessing predicted utility and conditioned incentive motivation. Cindy Wyvell, a doctoral student in our laboratory at the University of Michigan, has done just that (Wyvell and Berridge, 2000). Wyvell has examined the effect of the mesolimbic activation, caused by the amphetamine microinjection in the nucleus accumbens, on decision utility grounded either in the predicted utility of a sugar reward or in its conditioned incentive salience. She found dopamine activation to cause a transient but intense form of irrational pursuit linked to incentive salience. The irrational level of pursuit has two sources that restrict its occurrence and duration: a visceral factor (mesolimbic activation) and a psychological factor (the presence of a reward cue). When both factors are present simultaneously, Wyvell finds that, reward pursuit is driven to an irrational level, which more than four times its normal value (Wyvell and Berridge, 2000).

In this experiment, Wyvell first trained rats to work on some days instrumentally for occasional sugar pellet rewards by pressing a lever (a second lever was also present, but pressing on the second earned nothing, and merely measured the rats' general tendency to move around and do things). On different days, the rats learned a reward cue (CS+) for the sugar pellets, by being exposed to Pavlovian pairings in which sugar was preceded by either the illumination of a small light in the lever (for some rats) or by a sound (for other rats). In these cue-learning sessions, the rats did not have to work for sugar rewards—instead rewards came automatically after each cue. All the rats were implanted with a microinjection cannulae so that a droplet of amphetamine or of a drug-free vehicle solution could be a infused into their nucleus accumbens. Finally, the rats were tested for work using the Dickinson extinction procedure after they had received either the amphetamine or vehicle microinjections. During this test, their performance could be guided only by the predicted utility of sugar because they received no real sugar rewards (no experienced utility or response reinforcement). And while they pursued their expected reward, their reward cue (light or sound for 30 s) was occasionally presented to them over the course of the half-hour session. In a related experiment, Wyvell tested the effect of amphetamine microinjections on the experienced utility or hedonic impact of real sugar, by measuring the positive hedonic patterns of the affective reactions of rats as they received an infusion of sugar solution directly into their mouths (Wyvell and Berridge, 2000). What would be enhanced by the mesolimbic dopamine activation: experienced utility, predicted utility, decision utility, or all three? The answer turns out to be *decision utility* alone, and *only a piece of it* at that.

Remember that in this experiment the experienced utility of a sugar reward is measured by the hedonic reactions to its taste, while the decision utility of sugar is measured by how hard the rat works for the expected sugar. But there are *two types* of decision utility to be assessed here. One type is *ordinary wanting*, when the rat works guided primarily by its expectation or the predicted utility of sugar (measured by the baseline performance on the lever). Another type of decision utility adds '*wanting*' (conditioned incentive salience attributed by the mesolimbic systems to the representation sugar reward that is activated by the cue) to ordinary wanting, during the brief 30 s presentations of the reward cue. Wyvell found that the activation of the dopamine neurotransmission in the accumbens, caused by the microinjections of amphetamine directly into that brain structure, did not substantially change the baseline lever pressing in the absence of the reward cue, indicating no effect of the amphetamine on the predicted utility of the sugar reward, or on the ordinary wanting or the decision utility of sugar based on the cognitive expectations of predicted utility (Wyvell and Berridge, 2000). Similarly, amphetamine did not increase the positive hedonic affective reactions elicited by the taste of real sugar, indicating that the amphetamine did not increase the hedonic impact or the experienced utility of the sugar reward. However, the amphetamine microinjection still enhanced decision utility of the sugar reward in the 'wanting' sense of cue-triggered pursuit.

The amphetamine in the accumbens caused the sugar cue to trigger a relative frenzy of pursuit for the reward, 400 percent higher than the normal level without mesolimbic activation, whenever the cue was presented (Wyvell and Berridge, 2000). This relatively intense level of work for the sugar reward was transient, and decayed within minutes—only to be triggered again by the next reward cue. It is unlikely that the mesolimbic activation altered any stable cognitive representation of the predicted utility of the sugar reward, because the amphetamine was present in the nucleus accumbens throughout the entire session, but the intense enhancement of pursuit lasted only while the cue stimulus was actually present. Thus, it seems implausible that the intensely high pursuit was rational (i.e., matched by an intense increase in the predicted utility). If the cue-triggered intense pursuit was not rationally matched by an elevated expectation of predicted utility, then we must conclude that the cue triggered a momentary divergence of the decision utility from the predicted utility. In other words, the mesolimbic activation caused the reward cue to become a hyper-incentive, triggering an irrationally high (albeit temporary) level of 'wanting' for the sugar reward. The high level of 'wanting' decision utility was irrational because it was not justified by a matching increase for the same reward in either the experienced utility (i.e., no increase in affective reactions to the taste of sugar) or predicted

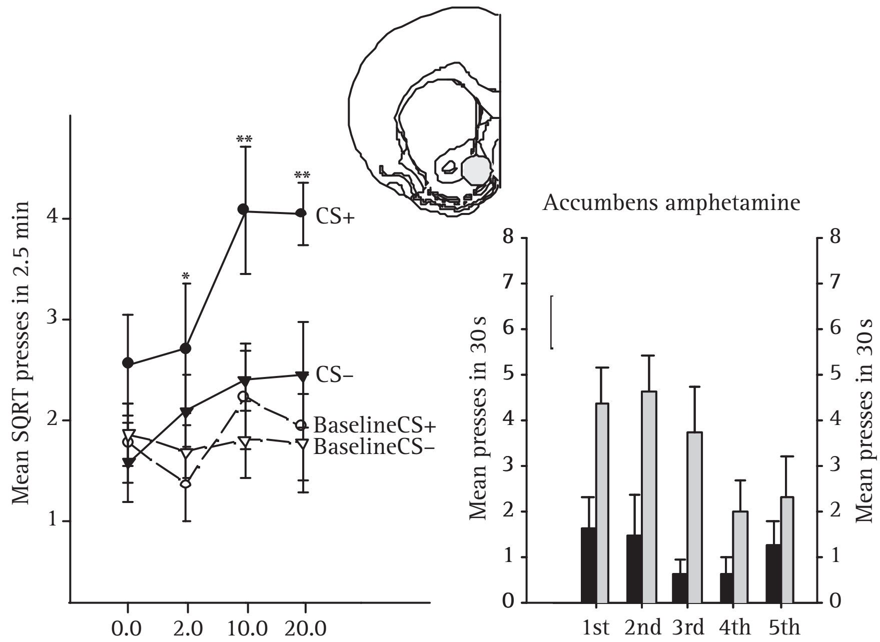

Figure 2.3. *The hyper-incentive effects of a reward cue gated by the visceral mesolimbic activation. The amphetamine microinjection in the nucleus accumbens magnifies the decision utility of the sugar reward in the presence of the reward cue (CS+), but has little effect on lever pressing for sugar in the absence of a cue (baseline, reflecting predicted utility) or during an irrelevant cue (CS−) (left). Decision utility amplification comes and goes with the cue during a single session after an amphetamine microinjection (right). The black bars denote work in the absence of the reward cue, the grey bars show the elevation when the cue was present. Modified from Wyvell and Berridge (2000)*

utility (i.e., no increase in the baseline effort for sugar in the absence of a reward cue) (Figure 2.3).

Cue-triggered 'hyper-wanting' is irrational and transient. It is repeatedly reversible, even over the short span of a 30 min test session, in which irrational 'wanting' was triggered and then decayed several times (Wyvell and Berridge, 2000). It is triggered by the encounter with reward cues, and at that moment it exerts its irrational effect, disproportionate to the cognitively expected hedonic value of the reward. One moment the dopamine-activated brain of the rat simply wants sugar in the ordinary sense. The next moment, when the cue comes, the dopamine-activated brain both wants sugar and 'wants' sugar to an exaggerated degree. A few moments later it has returned to its rational level of wanting appropriate to its expectation of reward. Moments later still, the cue is encountered again, and excessive and irrational 'wanting' again takes control.

For the brain in a state of mesolimbic activation, the conditioned reward cue becomes a hyper-incentive cue, able to trigger an irrational degree of pursuit for the sugar reward. During the mesolimbic brain excitation, the cue confers a momentary decision utility upon the outcome, beyond what its actual (or predicted) hedonic value can justify.

11. COMPARISON TO VISCERAL FACTORS

This view of hyper-incentive cue prompting irrational pursuit by a viscerally-activated brain, seems consistent with the theory of Loewenstein and colleagues regarding *visceral factors* as an influence on decision making (Loewenstein, 1996, 1999; Loewenstein and Schkade, 1999). Regarding irrational wanting in particular, cue-triggered hyper-incentive motivation caused during the brain mesolimbic activation dovetails with Loewenstein's suggestion that 'there are certain types of influences or incentives that operate independently of, and overwhelm, individual deliberation and volition' (Loewenstein, 1996, p. 276). For Loewenstein, the visceral factors include states of hunger, sexual arousal, and drug addiction. All of these states interact with the brain dopamine systems. For example, the mesolimbic dopamine systems are most highly activated by a taste of food when animals are hungry (Wilson et al., 1995). The visceral states can also be triggered by incentive cues (Loewenstein, 1996), and may be more highly aroused by freshly potent stimuli, such as a fresh course in a meal or a new sexual partner (Loewenstein, 1996). Accordingly, Phillips and colleagues have shown that the mesolimbic dopamine systems are most activated in animals when the palatable food is fresh (Ahn and Phillips, 1999), or when a fresh sexual partner is encountered (Fiorino et al., 1997).

Loewenstein views the visceral states as having a negative hedonic tone themselves (Loewenstein, 1996), which is slightly different from the view of incentive salience that I have presented here. Hunger states and other 'drives' may facilitate the mesolimbic activation, but their negative affective tone (if any) is not essential to the resulting increase in cue-triggered 'wanting' (Berridge, 2001; Toates, 1994). Positive motivational states may equally suffice, so long as they activate the brain mesolimbic systems. For example, in Wyvell's experiment on irrational cue-triggered 'wanting' for the sugar reward, the mesolimbic dopamine activation was caused directly by a microinjection of amphetamine into the brain's nucleus accumbens (Wyvell and Berridge, 2000). Similar brain amphetamine microinjections trigger the relapse of heroin pursuit in previously-addicted rats (Stewart and Vezina, 1988), relevant to the incentive-sensitization that may underlie addiction (Robinson and Berridge, 2000). But such microinjections are unlikely to induce an aversive drive state. The accumbens amphetamine microinjections are preferred and chosen by animals, rather than avoided. (Carr and White, 1986; Phillips et al., 1994). However, for many predictions the hedonic valence of the visceral states is not a source of serious difference between Loewenstein's view and incentive salience. In general, the incentive salience hypothesis and the relevant experimental results are fully supportive of Loewenstein's visceral factors theory (Loewenstein, 1996, 1999), and provide one specific mechanism by which visceral factors might actually overwhelm volition to produce irrational choices.

12. RELEVANCE OF HUMAN DECISION MAKING TO PSYCHOLOGISTS AND BEHAVIORAL ECONOMISTS

I am not so rash as to propose that the type of irrational choice sketched here is a model to be simply applied to human decision making. Rats are not humans; associatively-established conditioned stimuli for rewards do not replicate the full range of imagery and representation cues that impinge on human choices; a lever box with one reward is not an adequate model of human choice; and the brain microinjections are an artificial manipulation of the decision utility. My purpose here is simply to suggest truly irrational pursuit as a phenomenon for consideration, and to raise some relevant issues regarding the affective neuroscience of goal pursuit and human choice that may prove useful to psychologists and behavioral economists.

13. HYPER-INCENTIVES FOR NORMAL HUMANS

What are the human implications if this interpretation of irrational 'wanting' is correct? While admittedly humans are not rats, humans have brain dopamine systems that can be expected to respond similarly to reward cues and to influence the decision utility of associated rewards (Childress et al., 1999; Sell et al., 1999; Servan-Schreiber et al., 1998). Beyond this, it is possible that for human minds the cognitive representations of rewards might serve to interact with dopamine systems in some circumstances, instead of the associative cues that are useful in animal studies. Could the vivid imagery of an outcome, evoked or spontaneous, interact with the human brain in a state of high-but-normal mesolimbic activation to create an irrational hyper-incentive for a human? This is an open question for the future.

14. HYPER-INCENTIVES IN ADDICTION

Humans do not have microinjection cannulae in their brains, but human drug addicts routinely activate their brain dopamine systems in pharmacological ways. Further, there is considerable evidence to suggest that drug addicts may undergo potentially permanent incremental changes in their brain dopamine systems, known as neural sensitization (Robinson et al., 1998). Neural sensitization may increase the cue-triggered activity of mesolimbic systems in a way that parallels the effect of the amphetamine microinjection, creating hyper-incentive drug cues that trigger the compulsive pursuit of drug rewards (Robinson and Berridge, 1993, 2000). Incentive-sensitization is an explanation of addiction based on irrational choice.

Neural sensitization means that the dopamine neurons become hyper-excitable and physically altered (Badiani et al., 1997; Robinson et al., 1998; Robinson and

Kolb, 1999). The sensitized neural systems are not always in a hyper-excited state, but once sensitized they can be triggered into a hyper-excited state if the drug is taken again and their triggering into hyper-excitation is strongly gated by reward cues. My colleague Terry Robinson and I have suggested that neural sensitization in the brains of human drug addicts may be responsible for the development of addictive and compulsive drug taking (Robinson and Berridge, 1993, 2000). This explanation for addiction is especially useful for understanding relapse (often triggered by the encounter with drug cues) in addicts who have been abstinent for some time. Relapse by abstinent addicts is one of the most powerful aspects of addiction, and one of the most difficult features to explain rationally. After all, first time users may over-estimate their ability to resist addiction, or over-estimate the pleasure they will continue to take for the drug, or under-estimate the costs they will pay if they become addicts (Herrnstein and Prelec, 1991). All of those expectations may be wrong, but if the novice user holds them, then drug use is not irrational. But for the experienced addict, who knows these beliefs to be incorrect, to take the drug means the predictable loss of control. If the addict wishes to quit, and has decided that drug pleasures are not worth the costs, then to take the drug again is irrational. Yet, addicts do frequently relapse and do take the drug again, especially when they encounter drug cues. And they do so even when they do not feel the specific symptoms of withdrawal. Hyper-incentive cues, able to provoke the irrational decision utility from a sensitized brain, may be a mechanism for the irrational pursuit of drugs. If drug cues trigger the activation of sensitized mesolimbic dopamine systems, then an addict may be moved to take drugs again by hyper-incentive 'wanting'. Such an excessive 'wanting' may sometimes be irrational, but need be no less potent for that.

15. APPLICATIONS TO ORDINARY LIFE

Are the choices of ordinary humans ever tipped by cues and imagery in an irrational sense? Does the decision utility of outcomes we consider in our lives ever fluctuate independent of the predicted utility under the influence of vivid cues?

Consider one final scenario. Imagine that a consumer watching a television home shopping channel is more likely to choose to buy an item shown at a particular moment, than to get in the car later that day and drive to the store for the physical purchase of the same item. If so, the image on television is a cue-like influence on choice. Immediacy of arrival of the actually-bought item itself seems not very relevant to this choice. The item itself is delayed, whether one buys through the shopping channel and waits days for delivery or one waits to go to the store oneself. It may even be faster to drive to the store for the item than to wait days for delivery. The power of the shopping channel may come from the immediacy of the image and its influence on the momentary decision to buy—not from any home shopping advantage regarding the item itself (let us assume the home shopper drives to pickup the item, which equalizes transaction efforts).

But although the item itself arrives no sooner for the home shopper, the cue and image of the item are immediate and prompt a decision to buy.

To the degree that vivid imagery and cues induce shoppers to choose what they would not have chosen in the absence of those cues, the mesolimbic dopamine and incentive salience 'wanting' may play a role, and sometimes operate outside the bounds of declarative conscious awareness. To the degree that choices based on 'wanting' diverge from the expectations of future hedonic consequences, an irrational choice has been made.

If an irrational choice occurs at all in normal human life, the situations that will produce it will be relatively rare. By the mechanism considered here, it would require a high excitability in the mesolimbic brain 'wanting' systems and a simultaneous immediate encounter with the reward cues. Whether these situations occur at all, and if so, how frequently, are questions for the future. But the evidence discussed above suggests that, under the right conditions, irrational choice may be a powerful phenomenon.

One may 'want' more than one wants. Decision utility may transiently detach and soar above predicted utility, as well as above eventual experienced utility. If so, the outcomes will be pursued to a degree disproportionate both to their actual liking and to their current expectation of being liked. That is just irrational.

REFERENCES

Ahn, S. and Phillips, A.G. (1999). Dopaminergic correlates of sensory-specific satiety in the medial prefrontal cortex and nucleus accumbens of the rat. *Journal of Neuroscience, 19*(19), B1–6.

Badiani, A., Camp, D.M., and Robinson, T.E. (1997). Enduring enhancement of amphetamine sensitization by drug-associated environmental stimuli. *Journal of Pharmacology and Experimental Therapeutics, 282*(2), 787–94.

Balleine, B.W. and Dickinson, A. (1998*a*). Goal-directed instrumental action: contingency and incentive learning and their cortical substrates. *Neuropharmacology, 37*(4–5), 407–19.

—— and ——(1998*b*). The role of incentive learning in instrumental outcome revaluation by sensory-specific satiety. *Animal Learning and Behavior, 26*(1), 46–59.

Berridge, K.C. (1999). Pleasure, pain, desire, and dread: Hidden core processes of emotion. In D. Kahneman, E. Diener, and N. Schwarz (Eds.), *Well-being: The foundations of hedonic psychology* (pp. 525–57). New York, NY: Russell Sage Foundation.

—— (2000). Measuring hedonic impact in animals and infants: microstructure of affective taste reactivity patterns. *Neuroscience and Biobehavioral Reviews, 24*(2), 173–98.

—— (2001). Reward learning: Reinforcement, incentives, and expectations. In D. L. Medin (Ed.), *The Psychology of Learning and Motivation* (Vol. 40, pp. 223–78). New York: Academic Press.

—— (in press). Comparing the emotional brain of humans to other animals. In R. J. Davidson, H.H. Goldsmith, and K. Scherer (Eds.), *Handbook of Affective Sciences*. Oxford: Oxford University Press.

—— and Robinson, T.E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Research—Brain Research Reviews, 28*(3), 309–69.

—— and Valenstein, E.S. (1991). What psychological process mediates feeding evoked by electrical stimulation of the lateral hypothalamus? *Behavioral Neuroscience, 105*(1), 3–14.

—— Venier, I.L., and Robinson, T.E. (1989). Taste reactivity analysis of 6-hydroxydopamine-induced aphagia: Implications for arousal and anhedonia hypotheses of dopamine function. *Behavioral Neuroscience, 103*(1), 36–45.

Bindra, D. (1978). How adaptive behavior is produced: a perceptual-motivation alternative to response reinforcement. *Behavioral and Brain Sciences, 1*, 41–91.

Carr, G.D. and White, N.M. (1986). Anatomical disassociation of amphetamine's rewarding and aversive effects: an intracranial microinjection study. *Psychopharmacology (Berl), 89*(3), 340–6.

Childress, A.R., Mozley, P.D., McElgin, W., Fitzgerald, J., Reivich, M., and O'Brien, C.P. (1999). Limbic activation during cue-induced cocaine craving. *American Journal of Psychiatry, 156*(1), 11–8.

Cromwell, H.C. and Berridge, K.C. (1993). Where does damage lead to enhanced food aversion: the ventral pallidum/substantia innominata or lateral hypothalamus? *Brain Research, 624*(1–2), 1–10.

Damasio, A.R. (1999). *The feeling of what happens: body and emotion in the making of consciousness.* (1st ed.). New York: Harcourt Brace.

Dickinson, A. and Balleine, B. (1994). Motivational control of goal-directed action. *Animal Learning and Behavior, 22*, 1–18.

—— Smith, J., and Mirenowicz, J. (2000). Dissociation of Pavlovian and instrumental incentive learning under dopamine antagonists. *Behavioral Neuroscience, 114*, 468–83.

Fiorino, D.F., Coury, A., and Phillips, A.G. (1997). Dynamic changes in nucleus accumbens dopamine efflux during the Coolidge effect in male rats. *Journal of Neuroscience, 17*(12), 4849–55.

Flores, C., Arvanitogiannis, A., and Shizgal, P. (1997). Fos-like immunoreactivity in forebrain regions following self-stimulation of the lateral hypothalamus and the ventral tegmental area. *Behavioural Brain Research, 87*(2), 239–51.

Gardner, E.L. (1997). Brain reward mechanisms. In J.H. Lowinson, P. Ruiz, R.B. Millman, and J.G. Langrod (Eds.), *Substance Abuse: A Comprehensive Textbook* (3rd ed., pp. 51–85). Baltimore: Williams and Wilkin.

Gilbert, D.G. and Wilson, T.D. (2000). Miswanting: Some problems in forecasting future affective states. In Forgas (Ed.), *Feeling and thinking: the role of affect in social cognition.* Cambridge: Cambridge University Press.

Gilbert, D.T., Pinel, E.C., Wilson, T.D., Blumberg, S.J., and Wheatley, T.P. (1998). Immune neglect: A source of durability bias in affective forecasting. *Journal of Personality and Social Psychology, 75*(3), 617–38.

Herrnstein, R.J. and Prelec, D. (1991). Melioration—a Theory of Distributed Choice. *Journal of Economic Perspectives*, 5(3), 137–56.

Hoebel, B.G., Rada, P.V., Mark, G.P., and Pothos, E.N. (1999). Neural systems for reinforcement and inhibition of behavior: Relevance to eating, addiction, and depression. In *Well-being: The foundations of hedonic psychology* (pp. 558–572). New York, NY: Russell Sage Foundation.

Kahneman, D. (1999). Objective happiness. In *Well-being: The foundations of hedonic psychology* (pp. 3–25). New York, NY: Russell Sage Foundation.

—— (in press). Evaluation by moments: past and future. In D. Kahneman and A. Tversky (Eds.), *Choices, values, and frames.*

—— Fredrickson, B.L., Schreiber, C.A., and Redelmeier, D.A. (1993). When more pain is preferred to less: adding a better end. *Psychological Science, 4*, 401–5.

—— Knetsch, J., and Thaler, R. (1990). Experimental tests of the endowment effect and the Coase theorem. *Journal of Political Economy, 98*, 1325–48.

—— and Snell, J. (1992). Predicting a changing taste. *Journal of Behavioral Decision Making, 5*, 187–200.

—— Wakker, P.P., and Sarin, R. (1997). Back to Bentham? Explorations of experienced utility. *The Quarterly Journal of Economics, 112*, 375–405.

Kunst-Wilson, W.R. and Zajonc, R.B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, 207*(4430), 557–8.

LeDoux, J. (1996). *The Emotional Brain: The Mysterious Underpinnings of Emotional Life.* New York: Simon and Schuster.

Loewenstein, G. (1996). Out of control: Visceral influences on behavior. *Organizational Behavior and Human Decision Processes, 65*(3), 272–92.

—— (1999). A visceral account of addiction. In J. Elster and O.J. Skog (Eds.), *Getting hooked: Rationality and addiction* (pp. 235–64). Cambridge: Cambridge University Press.

—— and Schkade, D. (1999). Wouldn't it be nice? Predicting future feelings. In *Well-being: The foundations of hedonic psychology* (pp. 85–105). New York, NY: Russell Sage Foundation.

Mark, G.P., Smith, S.E., Rada, P.V., and Hoebel, B.G. (1994). An appetitively conditioned taste elicits a preferential increase in mesolimbic dopamine release. *Pharmacology Biochemistry and Behavior, 48*(3), 651–60.

Murphy, S.T. and Zajonc, R.B. (1993). Affect, cognition, and awareness: affective priming with optimal and suboptimal stimulus exposures. *Journal of Personality and Social Psychology, 64*(5), 723–39.

Nisbett, R.W. and Wilson, T.D. (1978). Telling more than we can know: verbal reports on mental processes. *Psychological Review, 84*, 231–59.

Panksepp, J. (1998). *Affective Neuroscience: the Foundations of Human and Animal Emotions.* Oxford: Oxford University Press.

Peciña, S. and Berridge, K.C. (2000). Opioid eating site in accumbens shell mediates food intake and hedonic liking: map based on microinjection Fos plumes. *Brain Research, 863*, 71–86.

Peciña, S., Berridge, K.C., and Parker, L.A. (1997). Pimozide does not shift palatability: Separation of anhedonia from sensorimotor suppression by taste reactivity. *Pharmacology Biochemistry and Behavior, 58*(3), 801–11.

Phillips, G.D., Robbins, T.W., and Everitt, B.J. (1994). Bilateral intra-accumbens self-administration of d-amphetamine: antagonism with intra-accumbens SCH-23390 and sulpiride. *Psychopharmacology (Berl), 114*(3), 477–85.

Redelmeier, D.A. and Kahneman, D. (1996). Patients memories of painful medical treatments: real-time and retrospective evaluations of two minimally invasive procedures. *Pain, 66*(1), 3–8.

Rescorla, R.A. (1988). Pavlovian conditioning. It's not what you think it is. *American Psychology, 43*(3), 151–60.

Robinson, T.E. and Berridge, K.C. (1993). The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Research Reviews, 18*(3), 247–91.

—— and Berridge, K.C. (2000). The psychology and neurobiology of addiction: an incentive-sensitization view. *Addiction, 95*(8 (Suppl. 2)), S91–S117.

—— Browman, K.E., Crombag, H.S., and Badiani, A. (1998). Modulation of the induction or expression of psychostimulant sensitization by the circumstances surrounding drug administration. *Neuroscience and Biobehavioral Reviews, 22*(2), 347–54.

—— and Kolb, B. (1999). Alterations in the morphology of dendrites and dendritic spines in the nucleus accumbens and prefrontal cortex following repeated treatment with amphetamine or cocaine. *European Journal of Neuroscience, 11*(5), 1598–1604.

Rolls, E.T. (1999). *The Brain and Emotion*. Oxford: Oxford University Press.

Salamone, J.D., Cousins, M.S., and Snyder, B.J. (1997). Behavioral functions of nucleus accumbens dopamine: empirical and conceptual problems with the anhedonia hypothesis. *Neuroscience and Biobehavioral Review, 21*(3), 341–59.

Schultz, W. (1998). Predictive reward signal of dopamine neurons. *Journal of Neurophysiology, 80*(1), 1–27.

Sell, L.A., Morris, J., Bearn, J., Frackowiak, R.S. J., Friston, K.J., and Dolan, R.J. (1999). Activation of reward circuitry in human opiate addicts. *European Journal of Neuroscience, 11*(3), 1042–8.

Servan-Schreiber, D., Bruno, R.M., Carter, C.S., and Cohen, J.D. (1998). Dopamine and the mechanisms of cognition: Part I. A neural network model predicting dopamine effects on selective attention. *Biological Psychiatry, 43*(10), 713–22.

Shizgal, P. (1997). Neural basis of utility estimation. *Current Opinion in Neurobiology, 7*, 198–208.

—— (1999). On the neural computation of utility: Implications from studies of brain stimulation reward. In *Well-being: The foundations of hedonic psychology* (pp. 500–24). New York, NY: Russell Sage Foundation.

Söderpalm, A.H. V. and Berridge, K.C. (2000). The hedonic impact and intake of food are increased by midazolam microinjection in the parabrachial nucleus. *Brain Research, 877*(2), 288–97.

Steiner, J.E. (1979). Human facial expressions in response to taste and smell stimulation. *Advances in Child Development and Behavior, 13*, 257–95.

—— Glaser, D., Hawilo, M.E., and Berridge, K.C. (in press). Comparative expression of hedonic impact: Affective reactions to taste by human infants and other primates. *Neuroscience and Biobehavioral Reviews.*

Stewart, J. and Vezina, P. (1988). A comparison of the effects of intra-accumbens injections of amphetamine and morphine on reinstatement of heroin intravenous self-administration behavior. *Brain Research, 457*(2), 287–94.

Toates, F. (1986). *Motivational Systems*. Cambridge: Cambridge University Press.

Toates, F.M. (1994). Comparing motivational systems—an incentive motivation perspective. In C.R. Legg and D.A. Booth (Eds.), *Appetite: Neural and Behavioural Bases* (pp. 305–27). New York: Oxford University Press.

Treit, D. and Berridge, K.C. (1990). A comparison of benzodiazepine, serotonin, and dopamine agents in the taste-reactivity paradigm. *Pharmacology Biochemistry and Behavior, 37*(3), 451–6.

Volkow, N.D., Wang, G.J., Fowler, J.S., Logan, J., Gatley, S.J., Wong, C., Hitzemann, R., and Pappas, N.R. (1999). Reinforcing effects of psychostimulants in humans are associated with increases in brain dopamine and occupancy of D-2 receptors. *Journal of Pharmacology and Experimental Therapeutics, 291*(1), 409–15.

Wilson, C., Nomikos, G.G., Collu, M., and Fibiger, H.C. (1995). Dopaminergic correlates of motivated behavior: importance of drive. *Journal of Neuroscience, 15*(7), 5169–78.

Wilson, T.D. and Schooler, J.W. (1991). Thinking too much: introspection can reduce the quality of preferences and decisions. *Journal of Personality and Social Psychology, 60*(2), 181–92.

—— Wheatley, T., Meyers, J.M., Gilbert, D.T., and Axsom, D. (2000). Focalism: A source of durability bias in affective forecasting. *Journal of Personality and Social Psychology, 78*(5), 821–36.

Winkielman, P., Berridge, K.C., and Wilbarger, J. (2000). Unconscious affect for doing without feeling: Subliminal facial expressions alter human consumption. *Unpublished manuscript.*

—— Zajonc, R.B., and Schwarz, N. (1997). Subliminal affective priming resists attributional interventions. *Cognition and Emotion, 11*, 433–65.

Wise, R.A. (1982). Neuroleptics and operant behavior: the anhedonia hypothesis. *Behavioral and Brain Sciences, 5*, 39–87.

—— (1998). Drug-activation of brain reward pathways. *Drug & Alcohol Dependence, 51*(1–2), 13–22.

—— and Bozarth, M.A. (1985). Brain mechanisms of drug reward and euphoria. *Psychiatric Medicine, 3*(4), 445–60.

Wyvell, C.L. and Berridge, K.C. (2000). Intra-accumbens amphetamine increases the pure incentive salience of sucrose reward: Enhancement of reward 'wanting' without 'liking' or response reinforcement. *Journal of Neuroscience, 20*(20), 8122–30.

Yeomans, J.S. (1989). Two substrates for medial forebrain bundle self-stimulation: myelinated axons and dopamine axons. *Neuroscience and Biobehavioral Review, 13*(2–3), 91–8.

Zajonc, R.B. (1980). Feeling and thinking: preferences need no inferences. *American Psychologist, 35*, 151–75.

—— (1998). Emotions. In D.T. Gilbert, S.T. Fiske, and G. Lindzey (Eds.), *The handbook of social psychology* (4th ed., Vol. 2, pp. 591–632). Boston: McGraw-Hill.