

## Curiosity and the pleasures of learning: Wanting and liking new information

Jordan A. Litman

*University of South Florida, Tampa, FL, USA*

This paper proposes a new theoretical model of curiosity that incorporates the neuroscience of “wanting” and “liking”, which are two systems hypothesised to underlie motivation and affective experience for a broad class of appetites. In developing the new model, the paper discusses empirical and theoretical limitations inherent to drive and optimal arousal theories of curiosity, and evaluates these models in relation to Litman and Jimerson’s (2004) recently developed interest-deprivation (I/D) theory of curiosity. A detailed discussion of the I/D model and its relationship to the neuroscience of wanting and liking is provided, and an integrative I/D/wanting-liking model is proposed, with the aim of clarifying the complex nature of curiosity as an emotional-motivational state, and to shed light on the different ways in which acquiring knowledge can be pleasurable.

Curiosity is a gift, a capacity of pleasure in knowing. (Ruskin, 1819)

The gratification of curiosity rather frees us from uneasiness than confers pleasure; we are more pained by ignorance than delighted by instruction. (Johnson, 1751)

Curiosity may be defined as a desire to know, to see, or to experience that motivates exploratory behaviour directed towards the acquisition of new information (Berlyne, 1949, 1960; Collins, Litman, & Spielberger, 2004; Litman & Jimerson, 2004; Litman & Spielberger, 2003; Loewenstein, 1994). Like other appetitive desires (e.g., for food or sex), curiosity is associated with approach behaviour and experiences of reward (Berlyne, 1960, 1966; Loewenstein, 1994). As suggested by the first of the two quotes above, curiosity is often described in terms of positive affectivity, and acquiring knowledge when one’s curiosity has been aroused is considered intrinsically rewarding and highly pleasurable (Day,

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Correspondence should be addressed to Jordan A. Litman, Center for Research in Behavioral Medicine and Health Psychology, Department of Psychology, Tampa, Florida 33620-8200, USA; e-mail: jlitman@shell.cas.usf.edu

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1971; Kashdan, Rose, & Fincham, 2004; Peterson & Seligman, 2001). However, as noted in the second quote, discovering new information may also be rewarding because it dispels undesirable states of ignorance or uncertainty rather than stimulates one's interest (Berlyne, 1950, 1955; Litman & Jimerson, 2004; Loewenstein, 1994). These different views on the ways in which the attainment of knowledge can be pleasurable are reflected in two major theoretical accounts of curiosity: the *optimal arousal* model and *curiosity-drive* theory, respectively.

Curiosity-drive theory, which is the earlier of the two models, equates curiosity to relatively unpleasant experiences of "uncertainty", the reduction of which is rewarding.<sup>1</sup> In essence, curiosity-drive theorists assume that coherence, which is preferred in our cognitions and percepts, is disrupted by stimuli that are novel, complex, or ambiguous. By gathering new information about the relevant stimulus, cognitive and perceptual coherence is restored (Berlyne, 1950, 1955). In support of the curiosity-drive approach, numerous studies have demonstrated that the presentation of new or unusual stimuli (e.g., objects, pictures) elicits approach behaviour and sustained attention from humans and animals. After investigating such stimuli for a while, inspection is soon terminated, suggesting that uncertainty has been resolved once new information is obtained (Berlyne, 1950, 1955, 1957, 1958). Related studies on curiosity and memory have found that answers for general knowledge questions rated as more puzzling (presumably stimulating more uncertainty) were better remembered, indicating that learning was reinforced in proportion to the degree of curiosity that was reduced (Berlyne, 1954). However, organisms will often initiate exploratory behaviours well before any stimuli are presented to them (Brown, 1953; Butler, 1957; Harlow, 1953; Hebb, 1958), suggesting that in the absence of novel or complex stimulation, animals and humans may be motivated to seek it out. The fact that organisms appear to look for opportunities to have their curiosity aroused cannot be easily explained by drive reduction accounts of curiosity.

An alternate account of curiosity and exploratory behaviour was soon developed that argued animals and humans are motivated to maintain an optimal level of arousal, which is pleasurable, whereas being over- or underaroused is unpleasant (Berlyne, 1967; Hebb, 1955; Leuba, 1955). Such models are essentially extensions of the classic Yerkes-Dodson Law (1908) and Wundt's (1912/1924) related theories of hedonic tone. According to the optimal arousal model, when organisms encounter stimuli that are too intense (i.e., extremely new or unusual), very high levels of physiological arousal are experienced that motivate avoidance behaviour. On the other hand, if organisms are underaroused (i.e., bored) they will be motivated to increase their arousal to an optimal level, and

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<sup>1</sup> While the curiosity-drive model is steeped heavily in the behaviourist's methods and terminology, it also coincides closely with more cognitively oriented approaches (e.g., Hunt, 1963, 1965), which emphasise being motivated to eliminate intellectual or perceptual discrepancy.

will explore the environment in search of stimuli that may excite their curiosity (e.g., novel or complex sights, sounds, or events) and generate positive feelings of interest (Dember & Earl, 1957; Fowler, 1965; Harlow, 1954; Hebb, 1955). Of course, based on this view, after new information has been obtained, boredom is assumed to quickly return, motivating organisms to seek new stimulation once again. Thus, contrary to the drive account, optimal arousal theorists assume that curiosity *induction* is rewarding, and involves feelings of interest rather than uncertainty. While optimal arousal models elegantly explain why organisms would choose to seek out stimuli and situations to arouse their curiosity, they fail to explain why individuals would want to acquire new information if this ultimately leads to aversive states of boredom. If having one's curiosity perpetually aroused reflects an ideal state of affairs, why would anyone ever endeavour to learn anything new?

### Underlying mechanisms of reward in reduction and induction models of curiosity

Both drive (reduction) and arousal (induction) are explicitly connected to physiological processes that are theorised to underlie the emotional states, motivated behaviours, and experiences of subsequent reward associated with these constructs. Drive is assumed to stem from imbalances in various homeostatic systems that cause increasing discomfort until such systems are restored to equilibrium (e.g., replenishing depleted nutrients) (Reeve, 2001). Arousal is thought to reflect cortical and autonomic nervous system activation, which can range in intensity from low to high, with extremes producing discomfort and moderate levels being highly desirable (Petri & Govern, 2004). By extension, both reduction and induction models of curiosity presume that similar drive or arousal mechanisms, respectively, give rise to the emotional states, exploratory behaviours, and experiences of reward associated with curiosity, as described in the previous section.

However, it should be noted that improvements in our understanding of the biological systems involved in affect, motivation, and reward-learning have led to a general *abandonment* of both the drive and optimal arousal theories from which reduction and induction models of curiosity are derived. Drive reduction theory began to lose ground as a satisfactory explanation for reward-motivated behaviour based on a number of empirical findings, such as evidence that animals and humans are motivated to engage in behaviours that induce rather than reduce stimulation, and that stimuli which cannot reduce drive (e.g., non-nutritive sweet foods) are nevertheless rewarding (Reeve, 2001).<sup>2</sup> The optimal

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<sup>2</sup> See Berridge (2001) for further discussion of the limitations of drive reduction as an explanatory construct.

arousal model, which is based on the concept of “general arousal”, has also been found to lack explanatory power. Physiological indices of arousal turn out to be only weakly correlated with emotion and behaviour, and changes in arousal do not always demonstrate the expected curvilinear relationship with efficiency or accuracy in task performance, suggesting that what defines an “optimal” level of arousal may depend primarily on the situation (Petri & Govern, 2004).<sup>3</sup>

### Contemporary models of curiosity

Despite inherent limitations of drive and optimal arousal as theoretical models, contemporary curiosity theorists have continued to explain information-seeking behaviour in terms of either the reduction (drive) or induction (optimal arousal) of curiosity states. For example, Loewenstein (1994) posited that curiosity may be equated with unpleasant feelings of “deprivation” that result from lacking desired knowledge (i.e., “uncertainty”). Loewenstein (1994) theorises that the reduction of these aversive curiosity states through knowledge acquisition is the primary goal of information-seeking behaviour. Although Loewenstein (1994) recognises that information seeking may also be motivated by pure interest, he implies that such a motive would not be labelled as curiosity.

Loewenstein (1994) suggests that when individuals encounter novel, complex, or ambiguous stimuli, they may find there are discrepancies between information that is known and unknown—indicative of a “knowledge gap”. The perceived magnitude of such gaps are based on *feeling-of-knowing* (FOK) judgements, which are metacognitive estimates of one’s available (i.e., retrievable) knowledge (Brown & McNeill, 1966; Eysenck, 1979; Hart, 1965). According to Loewenstein (1994), stronger FOKs correspond with smaller perceived knowledge gaps, and result in feeling closer to figuring or finding out the desired knowledge (Loewenstein, 1994; Loewenstein, Adler, Behrens, & Gillis, 1992). Based on Miller’s (1959) approach-gradient theory, which predicts that the intensity of motives increase as one approaches goal achievement, Loewenstein (1994) hypothesises that as FOKs become stronger, knowledge gaps will seem smaller, and states of curiosity will intensify as individuals perceive themselves close to eliminating their knowledge discrepancy and the associated feelings of tension. In one study, Loewenstein et al. (1992) asked participants to indicate whether or not they knew the words that corresponded with a series of definitions (e.g., “The science of coins = Numismatics”). If the correct word was not known, participants were then asked if they had a “tip-of-the-tongue” FOK, and if so to rate its intensity. However, if they claimed to know the answer, participants were asked to report how certain they were of its

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<sup>3</sup> See Neiss (1988), Winton (1987), and also Woodman and Hardy (2001) for further commentary on the limitations of general arousal and optimal arousal models.

accuracy (a “reverse” FOK measure). To measure curiosity states, participants indicated how curious they were by ranking the definitions in order of their preference to learn the correct words. Consistent with expectations, FOK intensity ratings for “tip-of-the-tongue” states correlated positively with curiosity rankings whereas “I know” ratings of certainty were negatively related to curiosity.

Loewenstein’s (1994) “knowledge gap/approach gradient” theory of curiosity shares much in common with earlier drive models in that the reduction of aversive curiosity states is identified as the primary motive for exploration. Of course, given that Loewenstein did not assess the emotional reactions associated with self-reports of curiosity (nor for that matter measure any actual exploratory behaviour), he did not evaluate whether curiosity reduction or induction might have been the aim of subsequent information seeking. However, despite this limitation, Loewenstein’s (1994) unique emphasis on the magnitude of knowledge gaps as stimulators of curiosity provides a valuable and meaningful reconceptualisation of novelty, complexity, and ambiguity in terms of cognitive-perceptual processes, such as stimulus identification and metamemory.

At about the same time, Spielberger and Starr (1994) proposed an optimal stimulation model that, like other optimal arousal models, emphasises the impact of stimulus characteristics on the activation of positive and negative affective states. Also similar to other optimal level theories, exploration is assumed to be aimed at the induction and growth of pleasurable states of arousal associated with curiosity. In order to induce and maintain curious feelings, organisms are motivated to approach new and unusual stimuli. However, because such stimuli may also indicate potential danger, if some degree of threat is perceived, curiosity and exploration may be inhibited by unpleasant states of anxiety. Thus, Spielberger and Starr (1994) describe optimal arousal as a function of two processes: pleasant states of curiosity and aversive conditions of anxiety that are aroused in tandem by novel stimuli and situations.

In keeping with the state-trait theory of emotion and personality (Spielberger, 1972; Spielberger & Reheiser, 2003; Spielberger, Ritterband, Sydeman, Reheiser, & Unger, 1995), Spielberger and Starr (1994) theorise that individual differences in tendencies to experience and express curiosity and anxiety as personality traits influence the arousal of parallel emotional states, which in turn motivate approach or avoidance behaviour, respectively. Specifically, they predict that individuals characterised by high levels of trait curiosity and trait anxiety will experience the corresponding states at a greater intensity as compared to those who are low in these traits under similar conditions.

In a key study, the findings of which were interpreted by Spielberger and Starr (1994) as generally supportive of their model, Peters (1978) assessed question asking and question answering behaviour by students confronted with an instructor perceived as either “threatening” or “nonthreatening”. To measure individual differences in curiosity, Peters (1978) used the Trait

Curiosity Inventory (Spielberger, Peters, & Frain, 1976) which, consistent with curiosity induction theory, measures the frequency with which one experiences positive emotional states associated with curiosity (“I feel curious”; “I feel interested”) and heightened arousal (“I feel stimulated”; “I feel eager”). Trait anxiety was assessed with the Trait Anxiety scale (Spielberger, 1972), which enquires about feelings of nervousness, worry, and dread (“I feel nervous and restless”; “I worry too much over something that really does not matter”). As might be expected, Peters (1978) found that all students asked and responded to more questions when the instructor was considered nonthreatening as compared to when the teacher was viewed as threatening. Question-asking behaviour was not related to trait anxiety, although students with high Trait Anxiety scale scores responded to fewer of their instructor’s questions (i.e., question answering behaviour) when he was perceived as threatening. When the instructor was not perceived as a threat, students with high scores on the Trait Curiosity scale asked three times as many questions as those with low scores.

Although it is not quite clear from Peter’s (1978) study that “optimal levels” of stimulation (as compared to a minimal degree of threat) coincided with the greatest question asking behaviour, Peter’s (1978) findings do provide good evidence that individual differences in curiosity as a personality trait are associated with more information-seeking behaviour (in nonthreatening conditions), presumably due to the fact that those with higher levels of trait curiosity experienced correspondingly higher levels of state curiosity. Thus, the results of this study are consistent with the state-trait theory of emotion and personality.

Although most aspects of Spielberger and Starr’s (1994) “optimal stimulation/two process” theory breaks relatively little new ground as a predictive model over earlier optimal arousal models, one significant improvement is their taking into consideration the relationship between individual differences in curiosity as a personality trait and the subsequent activation of curiosity states. However, as with other optimal arousal models, it cannot explain why curious students would want to have their questions answered if it would only serve to reduce the positive arousal of curiosity to less than optimal levels. While Spielberger and Starr (1994) acknowledge that some aversive affective experiences may also be aroused along with curiosity, they discuss these aversive states in terms of anxiety and perceptions of potential threats, rather than a desire to reduce uncertainty.

In summary, both Loewenstein (1994) and Spielberger and Starr (1994) have extended beyond the drive and optimal arousal models on which their theories are based. However, both theorists have still failed to reconcile whether the reward of obtaining new knowledge is mediated through the reduction or induction of curiosity states. Put another way, it still remains unclear as to whether curiosity is most appropriately conceptualised as a feeling of “deprivation”, as defined by Loewenstein (1994), or as a feeling of “interest”, as suggested by Spielberger and Starr (1994).

## Reconciling reduction and induction theories of curiosity

*The “interest/deprivation” model of curiosity.* Litman and Jimerson (2004) noted that a fundamental limitation of reduction- and induction-oriented models of curiosity was a failure to consider the possibility that *both* the satiation and activation of curiosity could be rewarding. For example, hunger may be stimulated from nutritional deficits and also from the pleasing smell of food, but in both cases consummatory behaviour can be pleasurable (Cornell, Rodin, & Weingarten, 1989). Building on this rationale, and adapting aspects of Lowenstein’s (1994) “knowledge gap/approach gradient” model and Spielberger and Starr’s (1994) “optimal stimulation/two process” model, Litman and Jimerson (2004) proposed that curiosity could be aroused when individuals feel as though they are deprived of information, and wish to reduce or eliminate their ignorance, as well as when they do not feel particularly deficient of information, but would nevertheless enjoy learning something new. Litman and Jimerson (2004) interpret these differences as reflecting curiosity as a feeling-of-deprivation (CFD) and curiosity as a feeling-of-interest (CFI), respectively. The two aspects of curiosity identified by Litman and Jimerson’s (2004) “interest/deprivation” (I/D) model are hypothesised to reflect qualitative differences in both the affective experience and general nature of desired information, as well as quantitative differences in the degree of exploration that each type of curiosity motivates.

Qualitatively, the arousal of CFI involves very positive feelings of interest and joy brought on by the anticipation of learning new information, whereas the arousal of CFD is theorised to involve some degree of negative affectivity (e.g., tension, frustration, dissatisfaction) related to uncertainty. Litman and Jimerson (2004) suggest that CFD is activated when individuals feel they are lacking needed information; this perceived knowledge deficit produces the feeling of “deprivation” associated with curiosity. Information sought during CFD reactions is theorised to be substantive, meaningful, and capable of increasing subjective feelings of competence, such as the answer to a complex question, a valuable fact, or solution to a difficult problem. By contrast, CFI is stimulated when individuals do not feel as though they are suffering from a lack of knowledge, but rather feel that it would be enjoyable to discover something new.<sup>4</sup> Thus, CFI is related to the anticipated pleasure from finding out

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<sup>4</sup>Conceptually, the Big Five domain of openness to experience (McCrae & Costa, 1997), which involves (among other things) interest in new ideas, music, and art, encompasses the lower order construct of curiosity, particularly those aspects that are most similar to the concept of CFI. Congruent with this observation, a recent study by Kashdan et al. (2004) found that their Curiosity and Exploration Inventory, which is a CFI-type measure, correlated substantially and positively ( $r > .5$ ) with an openness scale. Interestingly, Peterson and Seligman (2004) recently even went so far as to equate curiosity (presumably, the CFI variant) with openness to experience.

information of a more casual, unessential, entertaining, or aesthetically pleasing nature, such as juicy gossip, an amusing anecdote, or an entertaining story. CFI is assumed to reflect a sort of “take it or leave it” approach to learning new information, whereas CFD is a “need to know” experience, for which somewhat unpleasant feelings of tension precede its pleasurable satisfaction. These qualitative differences between CFI and CFD are theorised to result in important quantitative differences in the expression of curiosity: Because CFD reflects an unsatisfied need-like state, it is hypothesised to correspond with more intense experiences of curiosity than CFI, and therefore motivate more exploration.

### Measurement of individual differences in CFI and CFD as personality traits

Building on Spielberger’s (1972; Spielberger & Reheiser, 2003; Spielberger, Ritterband, Sydeman, Reheiser, & Unger, 1995) state-trait theory of emotion and personality, which identifies curiosity as an important personality trait, Litman and Jimerson (2004) theorise that individuals differ not only in their predisposition to become curious, but also in their tendency experience curiosity as feelings of either “deprivation” (CFD) or “interest” (CFI). Regarding the measurement of individual differences in these aspects of trait curiosity, there are already a number of scales that have been developed to assess CFI, which enquire about tendencies to experience feelings of enjoyment and increased arousal from taking in new information (for a review and discussion see Litman & Jimerson, 2004). However, a scale designed for the expressed purpose of measuring individual differences in CFD was only recently developed by Litman and Jimerson (2004). Based on the theoretical definition of CFD, and its hypothesised qualitative and quantitative differences with CFI, the CFD scale is comprised of items that predominantly describe being highly motivated to obtain new information, and to reduce moderately aversive feelings associated with lacking desired knowledge (e.g., “I can spend hours on a single problem because I just can’t rest without knowing the answer”; “It bothers me if I come across a word that I don’t know, so I will look up its meaning in a dictionary”; “I feel frustrated if I can’t figure out the solution to a problem, so I work even harder to solve it”).

Although Litman and Jimerson (2004) found that trait measures of CFD and CFI are strongly correlated (median  $r = .44$ ), they also found that the two overlapping constructs can be differentiated psychometrically with confirmatory factor analysis, and on the basis of the relative magnitude of their correlations with other constructs. For example, Litman and Jimerson (2004) reported that modest but significant positive correlations (median  $r = .11$ ) were found between the CFD scale and the anxiety, anger, and depression trait scales of the State-Trait Personality Inventory (STPI; Spielberger, 1979). By contrast, the only significant correlations found between CFI and these STPI measures were negative in sign (median  $r = -.31$ ). The directions of these correlations were in



accordance with the assumption that CFI is related primarily to positive emotional experiences whereas CFD involves a mild amount of negative affectivity. Moreover, finding that correlations between CFD and the STPI measures were relatively small was also consistent with the assumption that CFD is associated with the anticipation of *relieving* tension, rather than an expectation of suffering increased discomfort. In ongoing research (Litman, 2005), preliminary findings suggest that CFD is somewhat more related to constructs that involve being motivated by tension, dissatisfaction, or anger, such as Elliot's (1999) failure-avoidant achievement scale, Goldberg's (1999) need for orderliness scale, and Rosenman's (1986) Type-A behaviour checklist (median *ps*: CFD = .29, CFI = .17). By contrast, CFI appears to be more highly related to scales that assess very positive emotions and pleasurable states of arousal such as the Appreciation of Beauty, (sense of) Humour, and Vitality scales of the Values in Action inventory (Peterson & Seligman, 2004), and Elliot's (1999) mastery-oriented achievement scale (median *ps*: CFI = .26, CFD = .09). These results are also generally consistent with Litman and Jimerson's (2004) I/D model of curiosity.

### Individual differences in CFI and CFD as personality traits, curiosity as an emotional-motivational state, feeling-of-knowing, and information seeking behaviour

In a very recent study, Litman, Hutchins, and Russon (2005) found that scores on trait measures of CFI and CFD were associated with higher levels of reported state-curiosity for unknown answers to various general knowledge questions, and the intensity of curiosity states was positively related to the degree of information seeking behaviour that was exhibited. However, the nature of this relationship appeared to depend on the feeling-of-knowing (FOK) states participants experienced for the missing information. Path analyses indicated that CFD only significantly predicted the intensity of curiosity states when individuals reported strong FOKs for answers ("tip-of-the-tongue" states), whereas CFI was associated with state-curiosity only when individuals indicated weak FOKs ("Don't know" states). Moreover, state-curiosity and exploratory behaviour attributed to CFD was much greater in magnitude than curiosity and exploration associated with CFI, which is highly consistent with Litman and Jimerson's (2004) interest/deprivation (I/D) model of curiosity.

In summary, the newly developed I/D model integrates the seemingly incompatible reduction and induction theories of curiosity by positing that curiosity can involve both pleasurable feelings stimulated by opportunities for learning something interesting (CFI) as well as experiences of tension associated with feeling deprived of knowledge (CFD). As well as this presumed qualitative distinction, CFD is also hypothesised to correspond with quantitatively more intense expressions of curiosity and exploration than CFI. In recent research, trait measures of CFI and CFD have been found to load on meaningfully

different factors and have also been found to correlate somewhat differently with measures of positive or negative emotional experiences (Litman, 2005; Litman & Jimerson, 2004). Additionally, the CFD scale has been found to correspond with higher levels of state-curiosity and subsequent exploratory behaviour as compared to CFI (Litman et al., 2005). Although considerably more research will be required in order to clarify the qualitative and quantitative differences between CFI and CFD, including the nature of the emotional states with which they are most associated and the extent of the exploratory behaviours that they differentially motivate, the findings of previously conducted studies (Litman & Jimerson, 2004; Litman et al., 2005) and preliminary results from ongoing research (Litman, 2005) have been generally supportive of the I/D model of curiosity.

### Underlying mechanisms of curiosity revisited

Although the I/D model nicely reconciles the divergent perspectives of curiosity reduction and induction theories, the nature of the physiological systems that may underlie the impact of CFI and CFD on affect and behaviour were not addressed by Litman and Jimerson (2004). Given the theoretical and empirical limitations of the drive and optimal arousal concepts that were previously noted, neither of these models can provide a satisfactory theoretical account for the physiological underpinnings of curiosity. Consequently, the identification of an alternative model that can explain how both the reduction and induction of curiosity could be rewarding is still needed.

As previously discussed, the I/D model of curiosity hypothesises that the rewards associated with knowledge acquisition depend on whether curiosity manifests as feelings of tension attributed to uncertainty (CFD), or as the delighted expectation of discovering something entertaining or aesthetically pleasing (CFI). Therefore, an ideal model of the physiology that underlies curiosity would offer a logical explanation of how curiosity can feel like “interest” or like “deprivation” depending on the circumstances, and would also clarify how these qualitative differences might correspond with observed quantitative differences in information-seeking behaviour, as has been found in previous research (Litman et al., 2005). Moreover, such a model should be more consistent with our contemporary understanding of emotion and motivation, and not suffer from the same drawbacks inherent to the drive and optimal arousal models upon which curiosity theorists have previously relied.

### An integrative interest-deprivation/wanting-liking model of curiosity

The terms *wanting* and *liking* refer to two subcortical neurobiological systems that appear to underlie appetitive motivation and subsequent experiences of pleasure (Berridge, 1999; Berridge & Robinson, 1998). Wanting involves

mesolimbic dopamine activation, and is theorised to motivate approach behaviour and to attribute incentive value to stimuli associated with reward (Berridge, 1996; Berridge & Robinson, 1998, McClure, Daw, & Montague, 2003). Liking involves opioid activity in the nucleus accumbens, and handles the evaluation of stimuli in terms of immediate or anticipated hedonic impact and corresponding affective value. In both animals and humans, stimulation of the liking system has been shown to produce strikingly similar behavioural expressions of pleasure (e.g., licking the lips) (Berridge, 2001, 2003a; Berridge & Robinson, 1998). The wanting and liking systems have been implicated in reactions to food, water, drugs, and even sensory stimulation suggesting that their role in motivating behaviour and stimulating pleasure are not limited to a particular appetite or class of stimuli, but rather that the two systems mediate reward learning in general (Berridge, 2001; Berridge & Robinson, 1998; Berridge & Winkielman, 2003; Nader, Bechara, & van der Kooy, 1997; Winkielman & Berridge, 2003).

Wanting is influenced by a variation in deprivation states, the presence of learned incentives for rewards, and the anticipated potential for a given stimulus to satisfy one's desire based on past experience (Berridge, 1999; Berridge & Robinson, 1998). Liking is somewhat more complex, and may vary due to the strength of relevant wanting states (e.g., strong vs. weak desire) and specific characteristics of stimuli such as sweetness. In humans, the extent to which novel sensory stimuli are liked may be influenced by the degree of their cognitive and perceptual interpretability—a quality referred to as “processing ease” or “fluency” (Reber & Schwarz, 2002; Reber, Winkielman, & Schwarz, 1998). Presumably, fluent stimuli are better liked because fewer cognitive resources are required in order to arrive at meaningful representations of the stimulus (Bush, Luu, & Posner, 2000; Vallacher & Nowak, 1999; Whittlesea, 1993; Winkielman, Schwarz, Fazendeiro, & Reber, 2002). With repeated exposure, stimuli become progressively more interpretable, more easily understood, and therefore better liked.

Not surprisingly, stimuli that are wanted are also expected to be liked, and thus these two systems are activated contiguously (Berridge, 1999, 2003b). However, as wanting and liking exert their influences through separate neural circuits, the degree of activation in one system can be relatively weaker or greater in intensity than the other. For example, an addict might intensely crave a drug, (relatively high wanting), but not look forward to experiencing much pleasure to result from taking it (relatively low liking) (Robinson & Berridge, 2003; Wyvell & Berridge, 2001). Moreover, numerous animal studies have demonstrated that complete inhibition of one system with surgery or pharmacological antagonism does not have an effect on normal activation in the other. Thus, wanting and liking appear to be cooperative but dissociated processes (Berridge, 2001; Berridge & Robinson, 1998).

Although the neural activity of wanting and liking is subcortical, and therefore beneath our immediate awareness, these two processes are considered to reflect the core components of subjectively felt desires and pleasures that we experience as on-line emotional states<sup>5</sup> (Berridge, 1996; Berridge & Winkielman, 2003; Winkielman & Berridge, 2003). The mesolimbic area (wanting) and nucleus accumbens (liking) are constantly engaged in a complex loop of neural crosstalk with higher cortical functions, which is consistent with this supposition (Berridge, 1996, 2001, 2003a; Berridge & Winkielman, 2003). Accordingly, pharmacological manipulations of dopaminergic systems have been found to influence subjective experiences of desire (wanting), while similar manipulations of opioid systems have been found to impact self-reports of pleasure (liking) (Berridge, 1999; Winkielman & Berridge, 2003). Drawing on these theoretical views and relevant empirical findings, examples of feeling states that may emerge due to varying degrees of wanting and liking are summarised in Table 1.

If we assume that subjective states of intense desire accompany high levels of wanting, whereas high liking underlies feelings of extreme pleasure, a combination of strong wanting and liking activation would presumably correspond with a ravenous (i.e., uncomfortably strong) appetite and the anticipated pleasure derived from satiating it.<sup>6</sup> Experiences of high wanting that involve relatively little anticipated liking have been described as “irrational” and may motivate impulsive approach-oriented behaviour, even though little positive affect is expected to follow (Berridge, 2004; Berridge & Winkielman, 2003; Winkielman & Berridge, 2003). Drug addiction, as briefly mentioned earlier, is considered to reflect irrational wanting (Robinson & Berridge, 2003; Wyvell & Berridge, 2001), as well as so-called “behavioural addictions” like gambling (Holden, 2001) and compulsive shopping (Berridge, 2004). States of high liking accompanied by little wanting have been referred to as “subrational”, and are evoked by the pleasurable affective experiences that are associated with an enjoyed (but not particularly craved for) stimulus (Berridge & Winkielman, 2003; Winkielman & Berridge, 2003). Along these lines, it has been suggested that states of high liking and little wanting, may reflect experiences of *aesthetic*

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<sup>5</sup> However, it should be noted that subcortical wanting and liking can also influence behaviour without any conscious awareness. For detailed discussions of these “unconscious emotions” see Berridge (1999, 2003b), Berridge and Winkielman (2003), and Winkielman and Berridge (2003).

<sup>6</sup> Berridge (1999) observes that in situations of very high wanting, the amygdala, which is primarily implicated in negative affectivity, is also activated, presumably manifesting as uncomfortable states due to deprivation. Consistent with this view, Berridge (1999) notes that sodium-deprived animals with amygdala lesions fail to give preference to ingesting salt over other foods, suggesting that these animals have an impaired ability to assign special value to the salt as capable of reducing their unpleasant sodium-deprived cravings. The involvement of amygdala activation during conditions of high wanting is generally consistent with subjective experiences of “hunger pangs”, and may, as Berridge (1999) suggests, also reflect an animal’s “want” to escape these aversive states.

TABLE 1  
 Classification of hypothesised experiences associated with  
 high and low levels of wanting and liking

<i>Liking</i>	<i>Wanting</i>	
	<i>Low</i>	<i>High</i>
High level	Subrational liking	Intense craving
Low level	General indifference	Irrational wanting

*appreciation*, in which the liked stimulus ‘‘gives pleasure, but not for utilitarian reasons’’ (Chatterjee, 2004, p. 56). Finally, a combination of low levels of activation in both the wanting and liking systems would presumably reflect a general lack of motivation, and manifest as a feeling of indifference.

Although specific investigations of wanting and liking in relation to curiosity have not yet been undertaken, numerous animal studies have shown that both dopaminergic (wanting) and opioid (liking) activation play a crucial role in approach to and inspection of novel stimuli (e.g., Bardo, Neisewander, & Pierce, 1989; Besheer, Jensen, & Bevins, 1999; Bevins, 2001; Bevins et al., 2002; Dulawa, Grandy, Low, Paulus, & Geyer, 1999; File & Clarke, 1981; Panksepp, 1982, 1986, 1998, Peciña, Cagniard, Berridge, Aldridge, & Zhuang, 2003; Lukaszewska & Klepaczewska, 1997; van Abeelen & van den Heuvel, 1982).<sup>7</sup> Accordingly, Panksepp (Ikemoto & Panksepp, 1999; Panksepp, 1998), one of the foremost contributors to the area of affective neuroscience, has explicitly ascribed subjective feeling states of curiosity and acts of exploration to the activity of dopaminergic systems, while attributing consequent states of pleasure to opioid activation (Panksepp, Knutson, & Burgdorf, 2002). Thus, it is reasonable to at least tentatively propose that the wanting and liking systems play a central role in the stimulation of curiosity and the rewards of subsequent knowledge acquisition, as they do for other appetites and their associated pleasures (Berridge, 2001; Berridge & Robinson, 1998; Nader et al., 1997).

In keeping with Litman and Jimerson’s (2004) I/D model of curiosity, how might the wanting-liking system account for curiosity as an appetitive motive and knowledge attainment as a pleasurable reward? As previously described, the I/D model encompasses and extends contemporary curiosity reduction (Loewenstein, 1994) and induction models (Spielberger & Starr, 1994), and

<sup>7</sup>It should be noted that several other neural systems have been implicated in curiosity that appear to regulate novelty detection and orienting responses to novel stimuli, such as the hippocampus (for a review and discussion see Jellestad et al., 1994). However, these systems are of lesser relevance to the theories discussed in this paper.

TABLE 2  
 Classification of hypothesised experiences associated with high and low levels of wanting and liking for an integrative I-D model of curiosity

	<i>Wanting</i>	
	<i>Low level</i>	<i>High level</i>
<i>Liking</i>		
High level	Curiosity as a feeling of “interest” (Aesthetic appreciation)	Curiosity as a feeling of “deprivation” (Perceptual/conceptual/fluency)
Low level	Ambivalent disinterest or boredom (Spontaneous alternation or novelty seeking)	Need for uncertainty clarification (Need for cognitive closure; morbid or lurid curiosity)

I-D, interest-deprivation.

views curiosity as involving experiences of tension associated with knowledge deprivation that demand satisfaction (CFD), as well as the pleasurable expectation of finding out something that will be interesting, but not essential (CFI). Building on theory and research by Berridge and colleagues (Berridge, 2001, 2003a, 2003b; Berridge & Winkielman, 2003; Winkielman & Berridge, 2003), different emotional reactions that may be associated with wanting and liking activity in relation to the I/D model of curiosity are summarised in Table 2.

As discussed previously, wanting and liking are interactive but dissociated neurobiological systems; high levels of wanting may emerge as intense cravings that are implicated in need states, whereas low wanting is associated with a more modest appetite. Also as discussed earlier, high liking corresponds with the expectation of feeling intense pleasure, whereas low wanting occurs when only a mild amount of pleasure is anticipated. In the context of the I/D model of curiosity, a condition of relatively high wanting and high liking is quite similar to the concept of CFD. In this case, the absence of relevant information stimulates an intense desire for knowledge, the satisfaction of which requires the acquisition of substantive facts, in much the way that people may long for a nutrient-rich meal when their bodies are lacking essential vitamins and minerals.<sup>8</sup> Further, given that when CFD is experienced, the aim of information

<sup>8</sup> It is important to note that based on findings from Litman et al. (2005), curiosity seems to be unlike hunger or thirst, both of which increase in a relatively simple linear relation to the amount of time spent deprived of nutrients or fluid. Thus we might interpret the conditions likely to arouse CFD or CFI as *perceived deprivation* rather than *absolute deprivation*, suggesting that there is some selectivity in directing attention to that which is unknown rather than that which is known. In terms of CFD, it appears that the unknown becomes particularly salient. Of course, much more research is needed in order to identify the situations that are more likely to activate either CFD or CFI reactions.

seeking is the elimination of ignorance or uncertainty, the role of processing fluency in enhanced liking (e.g., Winkielman & Berridge, 2003) becomes more apparent. Perhaps, during CFD states, fluency is the central mechanism that mediates the experiences of reward associated with learning and understanding new information through increased investigation. By contrast, a combination of low wanting and high liking is consistent with the concept of CFI, in which curiosity may be induced by an interesting but unessential tidbit of knowledge. Here, information seeking is motivated purely by interest and anticipated enjoyment. The “hunger pangs” that may accompany higher wanting states are not a part of CFI experiences. Aesthetic appreciation,<sup>9</sup> which involves taking interest in and intrinsic pleasure from a novel and complex stimulation (Berlyne, 1971, 1974; Averill, Stanat, & More, 1998), shares much in common with the concept of CFI, and, as noted previously, has also been linked to states of high liking and low wanting (Chatterjee, 2004).

An integrative I/D/wanting-liking model views CFD as reflecting a higher degree of wanting than CFI, suggesting that CFD should involve more intense experiences of curiosity and motivate more exploratory behaviour than CFI, which has also been demonstrated in recent research (Litman et al., 2005). Moreover, given the conceptualisation that both CFI and CFD involve high liking while differing in the degree of associated wanting, one might predict that CFD and CFI would be positively correlated experiences, but should be discriminable on the basis of the different motives associated with their arousal. Findings from previous and ongoing research are generally supportive of these hypotheses (Litman, 2005; Litman & Jimerson, 2004). To further elucidate the qualitative differences between CFI and CFD, it will be especially worthwhile to examine whether these aspects of curiosity have distinctive physiological markers, as has been found for other emotions in previous research (e.g., Ekman, 1992; Izard, 1990; Tomkins, 1970). For example, expressions of “interest”, which are clearly relevant to the study of state-curiosity, may be identified by specific facial movements (Reeve, 1993; Reeve & Nix, 1997), changes in heart rate (Langsdorf, Izard, & Rayias, 1983) and patterns of neural activity (Tomkins, 1970).

How might conditions of high wanting and low liking (“irrational wanting”) fit within the integrative I/D/wanting-liking model of curiosity? Loewenstein (1994) observed that curiosity has been historically associated with impulsive behaviour, that is, desiring new information simply for the sake of knowing, sometimes even if the information is expected to be disappointing (i.e., disliked).

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<sup>9</sup>Related to aesthetic appreciation is the study of *awe*, which involves intense emotional responses to stimuli that are perceived as vast in size or scope and that are difficult to comprehend fully (Keltner & Haidt, 2003). While Izard (1977) suggested that awe-inspiring stimuli could evoke curiosity, the nature of the complex relationships between awe, aesthetic experience, and curiosity are not well understood and will be an interesting topic for future study.

Such an impulse is similar in many respects to the concept of *need for cognitive closure* (Kruglanski, 1990; Webster & Kruglanski, 1994), which reflects a strong desire to have a clear answer—even a poor one—when faced with the unknown, rather than endure confusion or uncertainty. Another highly relevant example of irrational wanting in the context of curiosity and information-seeking behavior might be *morbid curiosity*, a woefully understudied construct. Morbid curiosity, which motivates investigation of dark or gruesome things such as scenes of violence or death (Zuckerman & Litle, 1986), compels people to seek information that may not only be disliked, but that may even evoke unpleasant experiences of fear. If we expand the definition of morbid curiosity to encompass a desire to examine that which is disgusting, vulgar or generally unpleasant,<sup>10</sup> then these exploratory behaviours may be also explained in terms of irrational wanting.

Finally, a combination of low wanting and low liking would logically correspond to experiences of amotivation in the face of novelty—surprisingly, such events are not given much, if any consideration, by the drive reduction, optimal arousal, or I/D theories in their present forms. Nevertheless, commonly observed behaviour suggests that there are countless occasions when individuals realise that they lack information, but their curiosity is not appreciably aroused—essentially, an “I don’t know, and I don’t care” reaction. Rather than desire to see or learn *everything* that is presently unknown, people seem to pick and choose which pieces of information they will pursue based on either anticipation of its interestingness (consistent with the concept of CFI), or expectations that the information will specifically “answer a question”, “solve a puzzle”, or otherwise close a knowledge gap (consistent with CFD). What behaviours might be correlated with such “ambivalent disinterest” if any? Possibly, low activation of both wanting and liking coincides with aimlessly seeking stimulus variety or change (Dember, 1960; Dember & Fowler, 1958; Glanzer, 1953), behaviours that are associated as much with *boredom* as curiosity.

## SUMMARY AND CONCLUSIONS

The interest-deprivation (I/D) model reconciles the reduction- and induction-oriented accounts of curiosity that have emerged over the past 50 years, by conceptualising curiosity as reflecting qualitatively and quantitatively distinct (but overlapping) experiences of interest in learning something new (CFI) and feelings of knowledge-deprivation due to uncertainty (CFD). Moreover, the I/D model maps reasonably well on to the neuroscience of wanting and liking, which

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<sup>10</sup>I might suggest that a more appropriate term for curiosity stimulated by information of a disgusting, vulgar or generally unpleasant nature be labelled “lurid curiosity”. However, while morbid curiosity as a psychological construct has been investigated (though understudied), the concept of lurid curiosity has not even been acknowledged hitherto this paper, at least to my knowledge.



are two neural systems that appear to underlie motivation and affective experience for a broad class of appetites. Importantly, applying wanting and liking as general explanatory concepts moves theoretical accounts of curiosity beyond the drive and optimal arousal models, both of which suffer from a number of empirical and theoretical limitations. A consideration of dissociated wanting and liking systems is especially well suited to the study of curiosity given that there may be a number of circumstances in which desire and anticipated pleasure are markedly disproportionate to one another, as in the case of morbid curiosity.

However, determining the meaningfulness of an integrative I/D/wanting-liking model will require a great deal of future research. First, it will be essential to assess changes in approach to and inspection of novel stimuli following the experimental isolation of wanting and liking circuits in animals. Second, in humans, it will be important to evaluate changes in markers of hedonic tone such as facial expressions that are indicative of pleasure and displeasure (i.e., smiling and gaping, respectively), which may change as states of CFD, CFI, need for cognitive closure, and disinterest are experienced in the course of information search and discovery.<sup>11</sup> Finally, more research is needed to clarify the situational and personality variables that stimulate either CFD or CFI reactions, as well as the different affective and behavioural consequences that are associated with these two aspects of curiosity. Thus, the integrative I/D/wanting-liking model proposed in this paper suggests a number of new research directions that may help elucidate the nature of curiosity as an emotional-motivational state, and reveal much about information seeking behavior and the pleasures associated with learning.

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<sup>11</sup> It will also be important to evaluate the extent to which these changes are consciously experienced, given that wanting and liking activation is subcortical, and may correspond with changes in motivation and behaviour that reflect “unfelt” or “unconscious” emotions as well as give rise to relevant subjective feeling states (Berridge, 2004; Berridge & Winkielman, 2003; Winkielman & Berridge, 2003).

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