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The Psychology of Curiosity: A Review and Reinterpretation

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Research on curiosity has undergone 2 waves of intense activity. The 1st, in the 1960s, focused mainly on curiosity's psychological underpinnings. The 2nd, in the 1970s and 1980s, was characterized by attempts to measure curiosity and assess its dimensionality. This article reviews these contributions with a concentration on the 1st wave. It is argued that theoretical accounts of curiosity proposed during the 1st period fell short in 2 areas: They did not offer an adequate explanation for why people voluntarily seek out curiosity, and they failed to delineate situational determinants of curiosity. Furthermore, these accounts did not draw attention to, and thus did not explain, certain salient characteristics of curiosity: its intensity, transience, association with impulsivity, and tendency to disappoint when satisfied. A new account of curiosity is offered that attempts to address these shortcomings. The new account interprets curiosity as a form of cognitively induced deprivation that arises from the perception of a gap in knowledge or understanding.

> Curiosity is the most superficial of all the affections; it changes its object perpetually; it has an appetite which is very sharp, but very easily satisfied; and it has always an appearance of giddiness, restlessness and anxiety. (Edmund Burke, 1757/1958, p. 31)

Curiosity has been consistently recognized as a critical motive that influences human behavior in both positive and negative ways at all stages of the life cycle. It has been identified as a driving force in child development (e.g., Stern, 1973, p. 33; Wohlwill, 1987) and as one of the most important spurs to educational attainment (Day, 1982). The pedagogical literature encourages teachers to stimulate curiosity (e.g., McNay, 1985), provides practical guidelines for doing so (e.g., Tomkins & Tway, 1985; Vidler, 1974), and decries the educational system's tendency to quell it (Torrance, 1965). Curiosity has also been cited as a major impetus behind scientific discovery, possibly eclipsing even the drive for economic gain (e.g., see Koestler, 1973; Simon, 1992). Furthermore, curiosity is seen as a significant response evoked by literature and art (H. Kreitler & Kreitler, 1972) and has recently been exploited in the commercial realm. Advertisers have begun to harness the power of curiosity in "mystery" ads that reveal the identity of the product only at the end of the advertisement (King, 1991).[1] Less happily, curiosity is associated with behavior disorders such as voyeurism and has been blamed for nonsanctioned behaviors such as drug and alcohol use (Green, 1990), early sexual experimentation (Cullari & Mikus, 1990), and certain types of crime such as arson (Kolko & Kazdin, 1989).

Yet our fascination with curiosity does not derive from its practical significance alone. Curiosity poses an anomaly for rational-choice analyses of behavior that assume that the value of information stems solely from its ability to promote goals more basic than the satisfaction of curiosity. Such analyses assume that "the utility of information to the agents . . . is indirect and not direct like the utility derived from consuming goods" (Laffont, 1989, p. 54). However, there is considerable research documenting situations in which people demand more information than would be predicted by "value of information analyses"—as if they value the information for its own sake. For example, managers "systematically gather more information than they use, yet continue to ask for more" (Feldman & March, 1981, p. 171). Patients want more information about their medical conditions than they typically receive but do not want more control over decisions (Strull, Lo, & Charles, 1984). Asch, Patton, and Hershey (1990) described this as a paradox because the decision-theoretic view is that patients should only want to know something if it helps them to make a more informed decision. The theoretical puzzle posed by curiosity is why people are so strongly attracted to information that, by the definition of curiosity, confers no extrinsic benefit.

This combination of practical importance and theoretical puzzle has stimulated psychologists' interest in various aspects of curiosity. Rather than producing an ever-growing mountain of research, however, the interest in curiosity has surged in two major "waves," divided from each other not only by an intervening trough of publications but by a focus on different issues.

The first wave, which crested in the early 1960s, focused on three basic issues. Foremost was the question of curiosity's underlying cause. Psychologists representing diverse intellectual perspectives speculated about the cause of curiosity and invariably concluded that curiosity could be explained in terms of their own preexisting theoretical frameworks. Secondarily, curiosity researchers pondered why people voluntarily seek out

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[1] Researchers have found that such advertisements produce greater subsequent brand recognition than matched nonmystery ads that reveal the product's identity from the start (Fazio, Herr, & Powell, 1992).

situations that they know will induce curiosity, such as mysteries and puzzles. Curiosity seeking posed a paradox for those early theorists who interpreted curiosity as a drive, because drive-based accounts viewed curiosity as aversive and, hence, seemed to predict that people would want to minimize curiosity rather than seek it out. Finally, a very limited body of research examined the situational determinants of curiosity, but the first wave of curiosity research subsided without experiencing the full influence of the situationalist revolution in psychology.

The second wave of curiosity research began in the mid-1970s and ebbed a decade later. It concentrated almost exclusively on the problem of measuring curiosity, a task that has proven to be extraordinarily difficult. Attempts to cross-validate curiosity scales have typically produced low intercorrelations, and efforts to correlate scales with behavior or with individual characteristics such as age, gender, and IQ have produced contradictory findings. Nevertheless, despite its failure to produce a reliable and valid curiosity scale, the measurement research has shed light on the important question of curiosity's definition and dimensionality.

This article reviews the literature on curiosity with a focus on the four central issues that were investigated in the two waves of research: curiosity's *definition and dimensionality*, its underlying *cause*, the explanation for *voluntary exposure to curiosity*, and curiosity's *situational determinants*. In addition to reviewing past efforts to address these issues, I offer some ideas of my own. In the second part of the article, I propose a new theoretical account of curiosity that integrates insights from existing perspectives with ideas from Gestalt psychology, behavioral decision theory, and social psychology. The new account views curiosity as a form of cognitively induced deprivation that results from the perception of a gap in one's knowledge. It points to a number of situational variables that stimulate curiosity and offers a new explanation for voluntary exposure to curiosity.

In addition to discussing the four issues that have occupied previous research, I raise a fifth that has not been discussed by psychologists but finds ample expression in fiction, philosophy, and theology. It is the question of what causes curiosity's peculiar combination of *superficiality* and *intensity* so eloquently described by Burke in the quote opening the article. Curiosity is superficial in the sense that it can arise, change focus, or end abruptly. For example, at the supermarket, the intense desire to learn the latest news of a movie star's marital woes typically vanishes immediately after one leaves the tabloids behind. Despite its transience, however, curiosity can exert a powerful motivational force. Like sexual attraction, curiosity often produces impulsive behavior and attempts at self-control. The stories of Pandora, Eve, and Lot's wife, in which curiosity causes people (frequently young women) to expose themselves knowingly to terrible consequences, pay tribute to curiosity's motivational power. These characteristics of curiosity have not been discussed in the psychological literature, although they are prominent in religious writing and fiction. To ignore these characteristics, however, is to lose sight of the very features that induce "curiosity about curiosity."

Curiosity's Definition and Dimensionality

The earliest discussions of curiosity, predating the emergence of the field of psychology, were conducted by philosophers and religious thinkers and centered on the question of curiosity's moral status rather than on its psychological underpinnings. These discussions gave expression to epochal attitude swings when the assumption that curiosity is a virtue was periodically superseded by the tendency to condemn it as a vice.[2] Although there was little explicit discussion of curiosity's definition, it is evident that a common understanding of curiosity remained remarkably uniform across writers and over many centuries.

First, curiosity was seen as an intrinsically motivated desire for information. Aristotle, for example, commented that men study science for intrinsic reasons and "not for any utilitarian end" (Posnock, 1991, p. 40), and Cicero referred to curiosity as an "innate love of learning and of knowledge . . . *without the lure of any profit* [italics added]" (1914, p. 48). Although they acknowledged that information was also desired for extrinsic reasons, these early thinkers drew a sharp distinction between such an extrinsically motivated desire for information and curiosity.[3]

Second, curiosity was viewed as a passion, with the motivational intensity implied by the term. Cicero referred to curiosity as a "passion for learning" and argued that the story of Ulysses and the Sirens was really a parable about curiosity: "It was the passion for learning that kept men rooted to the Siren's rocky shores" (1914, p. 48). St. Augustine described curiosity as a "certain vain and curious longing for knowledge" (1943, p. 54) that he referred to as "ocular lust" to emphasize its frequent although not exclusive connection to visual perception. Hume (1777/1888) expressed an ambivalent attitude toward curiosity, but one respectful of its power, by subdividing it into two distinct motives: a good variety, which he called "love of knowledge," (p. 453) and a bad type, which he saw as a "passion de-

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[2] Harold Blumenberg (1966/1983) traced shifts in an ongoing "trial of curiosity," beginning with the ancient Greeks' embracing of curiosity as a virtue to be nurtured, a subsequent indictment of curiosity as a vice during the Middle Ages, and a somewhat ambivalent "rehabilitation" of curiosity during the Enlightenment. Blumenberg argued that such shifts resulted from the actions of identifiable historical events and personalities. He attributed the initial reaction against curiosity to the influence of St. Augustine and specifically to the diatribe against curiosity in his influential *Confessions*. Curiosity's rehabilitation in the 17th century was traced to the dissemination of Galileo's discoveries. According to Blumenberg (1966/1983), Galileo's discoveries with the telescope produced an appreciation of the knowledge-enhancing potential of scientific exploration, an awareness that " 'curiosity is rewarded'—the weighty significance of what had hitherto been withheld from man is confirmed, and thus the morality of self-restriction is disabused and put in the wrong" (p. 369).

Other writers have identified more recent fluctuations in the regard for curiosity. For example, Berlyne (1978) reported that "since about 1950, there has been a reversal. Curiosity has been lauded as a virtue and as one of the prime aims of education" (p. 99). He held this upsurge in regard for curiosity responsible for the coincident increase in interest in the topic. Holmes and Holmes (1991) found that the proportion of negative portrayals of curiosity in children's literature, which had always been higher than that of positive portrayals, showed, after 1969, a clear shift toward portraying curiosity in a negative light.

[3] Such a division is clearly evident in the assertion of an 18th-century physics handbook that "necessity and curiosity have perhaps made equal contributions to the discovery and further elaboration of the science of nature" (Blumenberg, 1966/1983, p. 233).

riv'd from a quite different principle" (p. 453). Good curiosity was exemplified by scientific inquiry; bad curiosity was exemplified by "an insatiable desire for knowing the actions and circumstances of [one's] neighbors" (p. 453).

Third, curiosity was seen as appetitive. Bentham (1789/1948, p. 34) referred to the "appetite of curiosity," Burke (1757/1958, p. 31) observed that curiosity "has an appetite which is very sharp," Kant referred to an "appetite for knowledge" (Blumenberg, 1966/1983, p. 430), and St. Augustine used the term *appetite for knowledge* interchangeably with *ocular lust*. As late as the 19th century, Feuerbach referred to the "pains [resulting from an] unsatisfied knowledge drive" (Blumenberg, 1966/1983, p. 445), suggesting that, analogous to physiological appetites, he viewed curiosity as producing painful feelings of deprivation if not satisfied. In sum, curiosity was viewed by premodern writers as an intense, intrinsically motivated appetite for information.

Early discussions by psychologists adhered to the premodern view of curiosity. For example, Freud referred to curiosity as a "thirst for knowledge" (1915, p. 153) or as "Schaulust," which, translated, approximates St. Augustine's ocular lust. James distinguished between two varieties of curiosity: a more common but unnamed type that was characterized by a "susceptibility for being excited and irritated by the mere novelty of . . . the environment" (James, 1890/1950, p. 430) and a second category referred to as "scientific curiosity" that was directed toward specific items of information. Although the exact distinction between the two types was described cursorily, both appear to be roughly consistent with the historically prevailing definition of curiosity.

The consensus definition of curiosity disintegrated early in the century when behavioristically oriented psychologists began to examine a wide range of behaviors that they referred to collectively as "curiosity" or "exploratory behavior." For example, Pavlov (1927), in the course of his research on conditioned responses, found that dogs would turn toward any unusual sight or sound and attributed the phenomenon to an investigatory reflex. Bühler and her colleagues (Bühler, Hetzer, & Mabel, 1928) referred to the same tendency observed in babies as curiosity. Such orienting reflexes have more in common with the modern term *attention* than with curiosity as defined in the premodern period. They are not necessarily intrinsically motivated, are unemotional in character, and lack the drive properties associated with a cognitive appetite.

Other researchers found that animals and humans seek out environmental variability. For example, a large number of studies showed that rats would explore the less familiar of two arms of a maze (e.g., Dember, 1956; Kivy, Earl, & Walker, 1956; Williams & Kuchta, 1957) or that they would learn a bar-press response when it was followed by either weak light onset or offset, as if they found any change in illumination reinforcing (for a summary, see Fowler, 1965, p. 36). Parallel findings were obtained with human subjects, who, when kept in darkness, repeatedly pressed a button to produce a quasi-random pattern of illumination (A. Jones, Wilkinson, & Braden, 1961). Although these studies differed in terms of subjects and specific research questions, there was a consensus that the observed behavior could be labeled curiosity.

When D. E. Berlyne began his path-breaking research on curiosity in the early 1950s, he recognized that the concept had become fragmented and proposed a categorization of different types of curiosity. He located curiosity on two dimensions: one extending between perceptual and epistemic curiosity and the other spanning specific and diversive curiosity. Perceptual curiosity referred to "a drive which is aroused by novel stimuli and reduced by continued exposure to these stimuli" (Berlyne, 1954a, p. 180). It was intended to describe the exploratory behavior of the animals in the studies just cited. Epistemic curiosity referred to a desire for knowledge and applied mainly to humans. Specific curiosity referred to the desire for a particular piece of information, as epitomized by the attempt to solve a puzzle. Finally, diversive curiosity referred to a more general seeking of stimulation that is closely related to boredom. In the four-way categorization produced by these two dimensions, specific perceptual curiosity is exemplified by a monkey's efforts to solve a puzzle, diversive perceptual curiosity is exemplified by a rat's exploration of a maze (in both cases with no contingent rewards or punishments), specific epistemic curiosity is exemplified by the scientist's search for the solution to a problem, and diversive epistemic curiosity is exemplified by a bored teenager's flipping among television channels.

Berlyne sided with the premodern writers by excluding extrinsically motivated exploratory behavior from his concept of curiosity. Thus, "orienting reflexes" (Pavlov, 1927) for which the biological significance is obvious would not be classified in Berlyne's taxonomy as curiosity. However, by including diversive and perceptual curiosity in his fourfold classification, Berlyne effectively institutionalized the tendency to classify the desire for change and novelty as curiosity.[4]

Although Berlyne's distinction between perceptual and epistemic curiosity has not been investigated, perhaps because doing so would require an awkward comparison of human with animal data, his specific–diversive distinction became a central focus of the second wave of research. For example, Day's (1971) Ontario Test of Intrinsic Motivation (OTIM) consists of 110 trait-oriented true–false items that measure areas of interest such as "I try to think of answers to the problems of international social relationships" and includes both diversive and specific curiosity subscales. The validity of the diversive–specific division was supported by a factor analysis of the scale demonstrating that the two subscales loaded on separate quasi-independent factors. However, Day himself raised the question of whether diversive curiosity should be classified as curiosity, or

[4] In addition to the division proposed by Berlyne, numerous other classifications of curiosity have been proposed. For example, S. Kreitler, Zigler, and Kreitler (1984) distinguished among manipulated curiosity, conceptual curiosity, and curiosity about the complex or the ambiguous and proposed novel measurement methods for each that involve observing children playing with toys and interacting with the researcher. Langevin (1971) suggested a division of curiosity into breadth and depth dimensions. Breadth curiosity reflects the number of different interests a person has, whereas depth curiosity indicates the extent to which a person pursues a single area of interest. Although the breadth–depth distinction might appear similar to that between diversive and specific curiosity, it actually subdivides the category of specific curiosity. Pursuing an interest, whether there be one or many, reflects a desire for specific information rather than a desire for stimulation in general. High breadth curiosity therefore simply signifies a diversity of interests.

whether it was more closely related to boredom and to the sensation seeking and stimulus seeking that boredom evoked. Supporting Day's doubts, a subsequent factor analysis of the OTIM and a variety of other scales (Olson & Camp, 1984a) indicated that the Specific Curiosity subscale of the OTIM loaded on a factor labeled General Curiosity whereas the Diversive Curiousity subscale loaded on a separate factor, along with Zuckerman's (1971) sensation seeking scale.

Furthermore, in a factor analysis of two curiosity scales—the Melbourne Curiosity Inventory (MCI) and the State Epistemic Curiosity Scale (SECS)—conducted with 300 secondary school students in Australia, Boyle (1989) found that negatively worded items tend to load together in a common factor that is independent of positively worded items. The MCI, developed by Naylor (1981), includes 40 items, half positively worded (e.g., "I feel absorbed in things I do") and half negatively worded (e.g., "I am not interested in what I am doing"); the items are rated on a 4-point scale ranging from *almost never* to *almost always*. The SECS, developed by Leherissey-McCombs (1971; Leherissey, 1972), includes 14 positively worded self-report items (e.g., "When I read a sentence that puzzles me, I will keep reading it until I understand it") and 6 reversed items (e.g., "I will find myself getting bored when the material is redundant"). One plausible interpretation of Boyle's finding is that the negatively worded items measure boredom, which is largely independent of specific curiosity. In other words, people answer positively worded items affirmatively when they are curious and answer negatively worded questions affirmatively when they are bored, and each of these states is relatively independent of the other.

These findings suggest that researchers may have included behaviors under the heading of curiosity that are only distantly related to one another. The curiosity that produces a preference for changing levels of illumination and a distaste for sensory deprivation may have little in common with the curiosity that motivates educational attainment and scientific achievement. Diversive curiosity appears to be more closely related to sensation seeking or novelty seeking than to curiosity as the term has been used historically. Interestingly, the posthumously published fragments of a book by Berlyne (1974, p. 144) suggest that he eventually regretted having classified the diversive type as curiosity, referring to it as "the other, rather odd, technical sense that some psychologists give to the term."

Other than Berlyne's distinction between diversive and specific curiosity, the most commonly studied division of curiosity has been that between state and trait curiosity. State curiosity refers to curiosity in a particular situation, whereas trait curiosity refers to a general capacity or propensity to experience curiosity. For example, Naylor's MCI includes trait and state subscales that are very similar in the items they contain. The trait scale asks subjects to rate how they generally feel and includes items such as "I feel absorbed in things I do," whereas the state scale asks respondents whether they feel absorbed in what they are doing "at this particular moment." The state scale must be administered in the context of an activity such as a career seminar or math lesson. Naylor tested his scales on 10th-grade students through college graduates and found, supportive of a meaningful state–trait distinction, that the trait scale had high test–retest validity and the state scale varied across situations. The items from the two scales also clustered neatly into two separate factors. Similar results were obtained by Boyle (1983, 1989).

However, perhaps not too much should be made of these results. For almost any construct, one could generate trait and state measures that would load on quasi-independent factors. For example, illumination preference could be measured in its trait and state versions, respectively, by asking "Do you generally find the rooms you are in to be too bright?" and "Is the room you are in too bright?" Questions of these two types would probably also load on independent factors. The presence of quasi-independent trait and state factors seems to reflect, at best, the fact that curiosity is influenced by both situation and disposition.

Besides the use of multi-item scales, other techniques have been used to estimate trait curiosity. Most significant, W. H. Maw, E. W. Maw, and occasional colleagues conducted a series of studies involving fifth-grade subjects (e.g., Maw & Magoon, 1971; Maw & Maw, 1964, 1968, 1972) in which they evaluated the reliability and validity of measures of curiosity derived from teacher evaluations, peer evaluations, and self-evaluations. Teacher ratings were obtained by having teachers rank their pupils in terms of relative curiosity on the basis of a four-part definition of curiosity.[5] To aid in the ranking process, teachers were also provided with specific examples of behavior exemplifying curiosity. Peer ratings were obtained by having children name classmates whose behavior most resembled that of the characters in eight written scenarios. Four of the scenarios described the behavior of children who displayed high levels of curiosity, and the remaining four described the behavior of children with low curiosity. The peer score was equal to the number of times a student was named in connection with the high-curiosity sketches minus the number of times the student was named in association with the low-curiosity sketches. The self-rating scale asked students to evaluate a series of items on a 4-point scale ranging from *never* to *always*. Items included "I like to explore strange places," "I ask questions in school," and "I keep my hands clean." (On the last item, for some reason, the two extreme responses *never* and *always* were considered indicative of low curiosity.) Although the correlations among all three measures were not reported, a later study reported that the self-rating scale correlated .25 with a composite measure based on peer and teacher ratings (Maw & Magoon, 1971). However, the same study found a correlation of .61 between the same composite curiosity index and measured intelligence, raising the possibility—corroborated by subsequent research (Coie, 1974)—that the observed correlation between the curiosity measures resulted from their common relationship to IQ. Maw and Magoon also examined the correlation of the composite measure of curiosity with 26 different individual characteristics and traits elicited from a battery of personality sub-

[5] The definition they used was as follows: An elementary school child demonstrates curiosity when "he (a) reacts positively to new, strange, incongruous, or mysterious elements in his environment by moving toward them, exploring them, or manipulating them; (b) exhibits a need or a desire to know more about himself and/or his environment; (c) scans his surroundings seeking new experiences; and/or (d) persists in examining and/or exploring stimuli in order to know more about them" (Maw & Maw, 1968, p. 462).

scales. They found that curiosity was significantly correlated with (in order of importance) effectiveness, loyalty, reliability, accountability, intelligence, creativity, degree of socialization, tolerance for ambiguity, sense of personal worth, and responsibility. In yet another study, Maw and Maw (1972) found that a composite measure of curiosity correlated significantly with students' ability to recognize verbal absurdities such as "Give me my glasses and turn out the light so I can read the newspaper," even after matching subjects by IQ. However, the authors failed to provide an adequate explanation for why they anticipated such an association.

One particularly innovative study of curiosity was conducted by Coie (1974), in part to test the validity of Maw and Maw's teacher-rating method of curiosity measurement. Coie presented 120 schoolchildren of varying ages with four situations designed to gauge their levels of curiosity. In each, children were placed in the presence of a powerfully curiosity-evoking stimulus item such as a box with windows, lights, and protruding knobs. For two of the stimulus items (the "sanctioned" items), the children were encouraged to explore the item, establishing a setting in which failure to explore was unlikely to result from a fear of disobeying authority. The children were neither encouraged nor discouraged from exploring the other two stimulus items. Coie also administered two tests of intellectual ability, obtained the students' grade point averages, and elicited teacher ratings of curiosity in the manner prescribed by Maw and Maw. He found that behavioral measures of curiosity (e.g., approach latencies) toward the two sanctioned stimulus items were intercorrelated, as were those for the two nonsanctioned items. However, measures of curiosity toward the sanctioned items were not significantly correlated with measures of curiosity toward the nonsanctioned items. The behavioral measures of curiosity were also correlated with teacher ratings of curiosity, but that relationship vanished once Coie controlled for intelligence. Coie concluded that teacher ratings of curiosity actually measure intelligence.

The main use of trait curiosity scales and other types of measures has been to compare the curiosity of individuals who differ demographically. However, such investigations have produced a highly contradictory pattern of findings. Although many studies have detected significant relationships between curiosity and variables such as age (Vidler, 1977), gender (Stoner & Spencer, 1986) and socioeconomic status (S. Kreitler, Zigler, & Kreitler, 1984), other studies have yielded null results for the same variables (e.g., Camp, Rodrigue, & Olson, 1984; Engelhard & Monsaas, 1988), and statistically significant findings often differ in sign.

The inconsistent results obtained in analyses of group differences in curiosity may reflect a fundamental problem associated with efforts to measure interpersonal differences in trait curiosity. Curiosity scales almost inevitably measure curiosity toward particular topics or objects. Thus, Engelhard and Monsaas's (1988) School Related Curiosity scale consists of 10 yes–no statements including "I get excited about topics discussed in my classroom," "I am always asking questions and trying to find out more about my classwork," and "Being curious about my classwork is important to me." Langevin's Experimental Curiosity Measure (1971) provides subjects with a list of 40 "things" they might like to experience, which they rate on a 3-point scale for "wanting to experience." Clearly, an individual's or group's measured level of curiosity on these scales depends on the match between their own areas of curiosity and those included in the scale. For example, if younger students are curious about different topics than older students, the group that is more curious about the specific items included in the scales will score higher in curiosity. Thus, Engelhard and Monsaas's finding, in one of the schools they investigated, that school-related curiosity declined with age is as likely to be due to differences in the curriculum for those age groups as to an actual decline in trait curiosity. Other than asking "Are you a curious person?" which many scales in fact do, it may be impossible to create curiosity items that are not vulnerable to this problem. However, asking people how curious they are (and most of the other items included in curiosity scales) makes the purpose of the scale obvious to subjects. This is a serious deficiency when one is measuring a trait that is widely recognized as socially desirable.

Researchers have also examined the correlation between curiosity and traits such as IQ and creativity. Such analyses reflect, in part, efforts to test the convergent validity of curiosity scales, because there are good reasons to expect a positive relationship between curiosity and these traits. As Voss and Keller noted, "exploratory behavior is a major determinant for the development of intelligence," and "exploration is a form of intelligent behavior" (1983, p. 122). The same argument can be made for curiosity and creativity. Therefore, it would be disturbing *not to* find a positive interrelationship among these three constructs. There are also empirical findings that should lead one to anticipate a positive interrelationship among curiosity, intelligence, and creativity. The response to novelty by infants has been found to be correlated with later intelligence (Berg & Sternberg, 1985), and the desire for novelty by adults has been consistently linked to creativity (see Voss & Keller, 1983, p. 123). Because, as I discuss later, novelty plays a central role in several theories of curiosity, such results also suggest a positive relationship between curiosity, on the one hand, and creativity and intelligence, on the other.

However, studies that have examined the interrelationship among scales measuring curiosity, IQ, and creativity have not consistently observed the expected positive correlations. For example, Langevin (1971) found a range of correlations, from negative to small but significantly positive, between IQ (measured by the Otis Quick-Scoring Mental Abilities Test and the Ravens Progressive Matrix Test) and seven different measures of curiosity, and Penney and McCann (1964) found no relationship between IQ and curiosity. Similarly, mixed findings have been obtained for the relationship between measures of creativity and various curiosity scales (Voss & Keller, 1983). These mixed results may reflect the curiosity scales' lack of validity, but a more radical conclusion is also possible. As Coie (1974) speculated, perhaps curiosity simply does not exist as a stable, generalized trait.

In conclusion, the study of specific state curiosity seems to hold greater promise than a focus on either diversive curiosity or trait curiosity. Diversive curiosity is more closely related to boredom and sensation seeking than to curiosity as the term is conventionally understood, and the deficiencies of existing trait scales may point to fundamental problems associated with the measurement of trait curiosity or even with the existence of

such a trait. Even if trait curiosity were measurable, the practical benefits of such a scale are questionable. Although individuals with high trait curiosity probably make superior students and scientists, the ability to measure such differences would, at best, aid in sorting or tracking students or scientists on the basis of their curiosity. An improved understanding of state curiosity, in contrast, has the potential to suggest practical methods of stimulating curiosity in the broader population. Moreover, if trait differences reflect the cumulative effect of situational factors, effective situational interventions to stimulate state curiosity might ultimately serve to enhance trait curiosity.

The Underlying Cause of Curiosity

The most basic problem that has occupied curiosity researchers and theorists is the underlying cause of curiosity. Psychologists representing diverse intellectual perspectives have debated whether curiosity is a primary or secondary drive or motive and, if secondary, from what more basic drive or motive it derives.

Early Accounts

An early account of curiosity, articulated by William James and then extended slightly by McDougall, viewed curiosity as an emotion closely related to fear in the sense that it is produced by the same stimuli. To illustrate the close connection between curiosity and fear, James cited the behavior of an alligator he had observed swimming gradually toward a man seated on the beach, "gradually drawing near as long as he kept still, [but] frantically careering back as soon as he made a movement" (James, 1890/1950, p. 429). In keeping with his functionalist approach, James believed that curiosity had evolved to motivate organisms to explore their environments, whereas fear had evolved, in part, to temper the risks posed by such exploration. McDougall (1918) proposed an almost identical perspective, complete with a description of a horse displaying the same behavior as James's alligator. McDougall's innovation was to include curiosity in his list of basic instincts.

Drive Theories

In the first half of this century, the most common response to the question of curiosity's cause was to postulate the existence of a curiosity drive. The defining feature of such accounts is their assumption that curiosity produces an unpleasant sensation (usually labeled *arousal*) that is reduced by exploratory behavior. Drive-based accounts differ from each other in whether they view curiosity as primary or secondary (i.e., derivative of other more basic drives) and in whether they view curiosity as a homeostatic drive or one that is stimulus induced. Homeostatic drives, such as hunger and thirst, are internally stimulated and generally intensify over time if not satisfied, whereas stimulus-induced drives such as fear are triggered by environmental cues. However, it is generally acknowledged that no drive fits squarely into either of these categories; all drives are influenced by both external stimuli and internal states.[6]

Freud: Curiosity and sex. From passages scattered through several of his essays, one can piece together Freud's interpretation of curiosity. Freud viewed curiosity as derivative of the sex drive.[7] He believed that curiosity was the product of sublimated infantile sexual exploration that arises between 3 and 5 years of age when the child begins to associate the pleasure evoked by genital manipulation with the looking impulse. When, under social pressure, sexual exploration is later abandoned, it becomes sublimated in one of three ways. In neurotic inhibition, the individual's thought processes become generally blocked by the act of repression, one consequence of which is that curiosity is stymied. Alternatively, residual sexual curiosity can manifest itself as compulsive brooding, which is also antithetical to curiosity. Finally, sexual curiosity can be sublimated directly into a generalized curiosity about the world. Although Freud saw this last case as the "rarest and most perfect" type of sublimation, he noted that "the research becomes to some extent compulsive and a substitute for sexual activity" (Freud, cited in Posnock, 1991, p. 46). Thus, one implication of Freud's account is that curiosity, in those rare cases when it develops, should exhibit some of the characteristics typically ascribed to the sex drive.

Perhaps because it is virtually nonfalsifiable, Freud's interpretation of curiosity persists in the psychiatric literature, which remains largely unaware of psychological research on the topic. As recently as 1984, the president of the American Academy of Child Psychiatry wrote (without citing supporting evidence) that "puberty marks a period of enormous upsurge of curiosity" (Beiser, 1984, p. 519). Again without citing any relevant research, she then cautioned parents against stifling curiosity in their children: "Some may go too far, and satisfy sexual curiosity with direct knowledge of their own sexual life. This can interfere with the development of a broader curiosity" (Beiser, 1984, p. 518).

Behaviorist accounts. Freud's account was unusual among drive theories, in part because it viewed curiosity as a personality trait and in part because it saw curiosity as derivative of the sex drive rather than as primary. Other early drive theorists such as Thorndike (see Hunt, 1963, p. 41) and Dashiell (1925), as behaviorists, were uninterested in individual differences and viewed curiosity as a primary drive.

Although drive theorists have often been criticized for inventing a new drive for every type of behavior—a tendency pejoratively labeled *drive naming*—such a criticism is misplaced in the case of curiosity. Beyond postulating the existence of a curiosity drive, behaviorists conducted numerous experiments to test whether curiosity, in fact, possesses the basic characteristics of a primary drive.

To demonstrate curiosity's status as a primary drive, it is first necessary to show that curiosity is not derivative of other, more basic drives. However, like the proposition that all swans are white, such primacy is impossible to demonstrate. Just as it is always possible that a swan hidden in some backwater is black,

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[6] Another difference between drive theorists is largely semantic. Most drive theorists have referred to the aversive state that produces exploration as curiosity, but a small group of dissenters have substituted other terms, such as stimulus hunger (Glanzer, 1953) or boredom (Fowler, 1965; Myers & Miller, 1954), while retaining an otherwise virtually identical theoretical outlook.

[7] See Aronoff (1962) and Voss and Keller (1983) for detailed analyses of Freud's views on curiosity.

one can never rule out the possibility that curiosity derives from an as yet unidentified but more fundamental drive. Nevertheless, researchers attempted to exclude the possibility that curiosity depends on core drives such as hunger, thirst, and fear.

These efforts took two directions. In some cases (e.g., Harlow, Harlow, & Meyer, 1950), researchers sought to demonstrate that animals whose physiological needs were completely satisfied (they could eat and drink at will) nonetheless displayed exploratory behavior. However, such demonstrations are inconclusive because, as Brown (1953) pointed out, it is impossible to rule out the existence of very low levels of hunger, fear, thirst, and other drives. An alternative procedure induced different levels of biological drives in animals and monitored the effect on exploration. Although such studies produced a wide range of both negative and positive correlations between exploration and different forms of physiological deprivation, they, too, are inherently inconclusive. If animals search more when they are hungry, it suggests that hunger influences exploration but not that exploration is influenced only by hunger.

A second, more fruitful set of studies sought to demonstrate that curiosity, like drives such as hunger and fear, possesses motivational force. Early on, Dashiell (1925) and Nissen (1930) demonstrated that rats were willing to endure electrical shock to explore novel stimuli with no apparent connection to food or water. Later, Harlow and various coauthors (Harlow et al., 1950) showed that monkeys would attempt to solve a puzzle with no external incentive for doing so, and Butler (1953) found that monkeys kept in a shielded cage learned to discriminate the color of the window that would afford them a glimpse of the experimental room. Monkeys were placed in a bland covered cage with two opaque windows that looked out on the experimental laboratory. In each of a series of periods, one window would be covered with a panel of a specific color and then unlocked, and the other window would be covered with a different-colored panel and locked. Monkeys rapidly learned to discriminate the color that was associated with the unlocked window and would rush to open it and peer out, even though the only reward was a glimpse of the experimental laboratory. Subsequent experiments by Butler and Alexander (1955) introduced physical barriers to opening the windows. The fact that monkeys will hold a window open for long periods even though it requires physical dexterity and effort suggests that the animals are powerfully motivated to look out the window.

Similar results have been obtained with human subjects. Studies conducted mainly at McGill University in the 1950s and 1960s found that sensorially deprived human subjects will ask repeatedly to listen to numbingly boring material such as old stock market reports (Hebb, 1958). Although significant questions have been raised about the implementation and interpretation of the sensory deprivation studies (e.g., Zubek, 1973), it remains widely accepted that prolonged sensory deprivation is aversive.

A third line of research showed that unsatisfied curiosity tends to intensify over some interval, as do other drives such as hunger and thirst. For example, a second follow-up study by Butler (1957) found that the rate at which monkeys opened windows increased, at least initially, as a function of how long the monkeys spent in the box without visual stimulation. Other studies observed a similar pattern of behavior with subjects as varied as cockroaches (Darchen, 1957) and humans. For example, in the study by A. Jones et al. (1961), the frequency of button pushes to produce flashes of light first increased and then decreased as a function of the time that subjects spent in the darkened room (see also A. Jones, 1966). The authors noted that such an inverted U-shaped pattern of motivation is analogous to that observed with food deprivation and concluded that "information deprivation functions as a drive variable in the same sense as the well-studied homeostatic drives of hunger, pain, and thirst" (A. Jones et al., 1961, p. 135).

Still other research demonstrated that curiosity, like standard drives, could be seemingly "satisfied" by repeated exposure to stimulus materials (Glanzer, 1961; Montgomery, 1952). For example, Berlyne (1955) demonstrated that rats initially explored but later showed little interest in a novel stimulus item. As Woodworth noted, however, the decline of interest tends to be object specific in the case of curiosity, in contrast to other drives in which satiation is more generalized (cited in Fowler, 1965, p. 193). After one consumes a large restaurant meal, any additional food seems unappealing; however, even after a dinner companion has regaled one with the latest gossip about mutual friends, the muffled conversation at the next table retains its distractive potency.

Perhaps most telling, researchers have uncovered evidence of the link between curiosity and arousal that is the sine qua non of the drive perspective. Smith, Malmo, and Shagass (1954) had subjects listen to a recording of an article that was periodically made inaudible. They observed an initial increase in the tension of the arm muscles when the tape became inaudible. Wallerstein (1954) obtained a similar result with subjects who listened to a garbled reading of a philosophical essay: There was an initial rise in muscular tension followed by a fall after the first few minutes.

D. E. Berlyne. Whereas drive-theoretic accounts of curiosity generally assumed that curiosity is a homeostatic drive (i.e., internally stimulated), an alternative drive-based perspective advanced by D. E. Berlyne viewed curiosity as externally stimulated. Berlyne's theory also differed from those proposed by other behaviorists in that it cast cognitive variables in a central role. According to Berlyne, the curiosity drive is aroused by external stimuli, specifically "stimulus conflict" or, "incongruity." This construct encompasses properties such as complexity, novelty, and surprisingness. Berlyne believed that stimuli embodying these properties activate the curiosity drive and raise the organism's level of arousal.

Berlyne's view of curiosity as stimulus evoked was attacked by Fowler (1965), whose boredom-based perspective interpreted curiosity as a homeostatic (i.e., internally stimulated) drive. Fowler noted the apparent contradiction inherent in the view that the curiosity drive was both evoked and satisfied by the same stimuli. He argued that theorists such as Berlyne who viewed curiosity as externally stimulated were "forced to ascribe both drive-eliciting and reinforcing properties to the *same* stimuli—namely the novel stimuli for which the animal responded" (Fowler, 1965, p. 38). In many experiments, Fowler noted, animals produced the exploration-initiating response *before*, rather than after, exposure to the stimulus. For example, in Butler's studies, apes would open the window to see outside the cage, not in response to a view of the outside of the cage. Exam-

ined superficially, the temporal pattern of events seemed inconsistent with Berlyne's notion that curiosity was evoked by novel stimuli.

As is often the case in such disputes, both positions have merit. On the one hand, novelty, or the awareness that novel stimuli are available for inspection, can induce curiosity, just as the sight of food or the awareness that it is available can stimulate hunger. On the other hand, studies that found that the degree of exploration increases with the duration of sensory deprivation (e.g., Darchen, 1957; Premack, Collier, & Roberts, 1957) are consistent with the idea that exploration is in part internally stimulated.

Whether curiosity is or is not a drive is probably neither answerable nor particularly important. What is important is that curiosity possesses many of the features commonly associated with primary drives: It does not appear to be derivative of the other basic drives, it can be satisfied by an appropriate response, it does intensify if not satisfied (at least in some situations), and it seems to be aversive. Moreover, regardless of its status as a drive, it appears to be influenced by external and (to a lesser extent) internal factors.

Incongruity Theories

In the 1950s, a rather different account of curiosity was developed independently by Hebb, Piaget, and Hunt, who each reached the same conclusion from very different starting points. This account can be summarized by three basic propositions. First, curiosity reflects a natural human tendency to try to make sense of the world. Second, this need is not constant but is evoked by violated expectations. Third, there is an inverted U-shaped relationship between evoked curiosity and the extremity of such expectation violations. Like Berlyne, therefore, these theorists saw curiosity as evoked by incongruity. However, their focus was on only one of the categories of incongruities mentioned by Berlyne: violations of expectations. Also, most incongruity theories dropped Berlyne's assumption that curiosity is a drive.

Hebb (1955) arrived at this tripartite view of curiosity from his research on the connection between neurology and psychology. He noted that both neurological investigations and sensory deprivation studies contradicted the drive theorists' assumption that organisms seek to achieve a state of quiescence: "The nerve cell is not physiologically inert, does not have to be excited from outside in order to discharge. The nervous system is alive, and living things by their nature are active" (Hebb, 1955, p. 246).[8] Consistent with this perspective, Hebb saw curiosity as a manifestation of the organism's natural tendency toward cognitive processing.

He argued, further, that there is an optimal level of incongruity at which people function most effectively and that they find states of incongruity either above or below this point aversive: "Up to a certain point, lack of correspondence between expectancy and perception may simply have a stimulating (or 'pleasurable') effect; beyond this point, a disruptive (or unpleasant) effect" (Hebb, 1949, p. 149). Thus Hebb, like James, believed that minor violations of expectations induced curiousity but that major violations produced a fearlike aversive reaction.

Piaget arrived at a strikingly similar view of curiosity on the basis of his research on cognitive development. First, he saw curiosity as inextricably linked to the child's need to make sense of the world. According to Kakar (1976, p. 192), curiosity for Piaget "plays a part in the search for coherence and organization. It is a motive force in the need to order reality." Second, Piaget viewed curiosity as the product of cognitive disequilibrium evoked by the child's attempt to assimilate new information into existing cognitive structures. Such a need would naturally arise when reality diverged from expectations, pointing to the inadequacy of existing cognitive structures. Finally, Piaget also postulated an inverted U-shaped discrepancy–motivation relationship. At very low levels of discrepancy, he believed that new information would be assimilated effortlessly and automatically without requiring much attention or motivation. At very high levels of discrepancy, new information would be ignored because the infant would be unable to relate the new stimuli to existing cognitive structures (McCall & McGhee, 1977, p. 193).

Hunt arrived at a virtually identical position from his research on intrinsic motivation (1963, 1965). His theory of intrinsic motivation drew on diverse developments in psychology, each of which emphasized the importance of violated expectations as interrupters or motivators of behavior. These developments were McClelland's model of motivation (McClelland, Atkinson, Clark, & Lowell, 1953); G. A. Miller, Galanter, and Pribram's (1960) test–operate–test–exit (TOTE) analysis of behavior; and Helson's adaptation-level theory (Helson, 1947, 1948). On the basis of G. A. Miller et al. (1960), Hunt postulated that curiosity was triggered by violated expectations. On the basis of McClelland et al.'s theory of affect, he, too, postulated an inverted U-shaped function relating affect to the magnitude of such cognitive discrepancies. For Hunt, curiosity reflected a search for an intermediate level of cognitive incongruity that, in turn, was motivated by a desire for positive affect.

Hunt's incongruity account of curiosity was further refined by Kagan (1972) in a classic article on motivation. According to Kagan, there are four basic human motives: the motive to resolve uncertainty, sensory motives, anger and hostility, and the motive for mastery. The first, in his view, is synonymous with curiosity: "The motive to resolve uncertainty might be renamed the motive for cognitive harmony, consonance, equilibrium, or simply the motive to know, which Berlyne calls epistemic curiosity" (Kagan, 1972, p. 54). However, whereas Hebb, Piaget, and Hunt each believed that curiosity results from violations of expectations, Kagan (1972) argued that "Hunt ignored three other sources of uncertainty with motivational significance": incompatibility between ideas, incompatibility between ideas and behavior—both based on cognitive dissonance theory (Festinger, 1957)—and the inability to predict the future. Thus, Kagan, too, viewed curiosity as a response to incongruity

[8] This view was echoed in even more radical form by Nissen (1954), who believed that the brain and other organs carried with them their own source of motivation: "Among the requirements of all tissues is that they perform their normal functions. An unused muscle atrophies, and so does an unused gland. It is positively painful to deny any organ the exercise of its usual function. . . . The sense organs 'want to' see and hear and feel just as much as the mouth or stomach or blood-stream 'want to' eat or contract or maintain a certain nutrient balance. It is the function of the brain to perceive and to know" (p. 300).

but expanded the list of incongruities postulated to give rise to curiosity. In effect, Kagan's perspective can be viewed as a modern version of Berlyne's without the complicating baggage of behaviorism.

Incongruity theories express the intuition—supported by recent research—that people tend to be curious about events that are unexpected or that they cannot explain. Research examining the question of when people make causal attributions (when they ask "why" questions) demonstrates that violated expectations do, in fact, often stimulate a search for an explanation (Hastie, 1984; Psyszcynski & Greenberg, 1981; Wong & Weiner, 1981). The notion of an optimal level of incongruity also seems highly intuitive, although it has received less empirical support. Some researchers have obtained weak supportive evidence (e.g., Miyake & Norman, 1979), including one study particularly relevant to curiosity that found that frequency of question asking depends on the match between the difficulty of the question and the expertise of the respondent (McCall & McGhee, 1977). But one systematic review found, at best, mixed support for the hypothesis and discussed numerous difficulties inherent in measuring the relevant constructs and their relationship to one another (Wachs, 1977).

Finally, the incongruity theorists' notion that there is a natural human need for sense making has received broad support from diverse areas of research, although little of it was cited by incongruity theorists. As Gilovich (1991, p. 9) wrote, "We are predisposed to see order, pattern, and meaning in the world, and we find randomness, chaos, and meaninglessness unsatisfying. Human nature abhors a lack of predictability and the absence of meaning."

Gestalt psychologists have been some of the most persistent advocates of the view that there is a human need for sense making. Indeed, the very notion of a gestalt reflects the fundamental human tendency to make sense of information by organizing it into coherent "wholes." More important, Gestalt psychologists have argued that the drive toward gestalt creation has motivational force (Heider, 1960; see also Suchman, 1971). As H. Kreitler and Kreitler (1972) wrote in their book on aesthetics, the "pressure to straighten out, to improve, or to perfect . . . perceived figures may be so potent that it can be neither disregarded nor withstood by the spectator and is accompanied by tension and discomfort until it is resolved by a proper perceptual act" (pp. 86–87).[9] An analogous observation in the epistemic realm was made by Reiser (1931, p. 361), who noted that "a problem presents itself as an open Gestalt which 'yearns' for a solution, and it is the function of thought to find the solution by transforming the open Gestalt into a closed one." Although Gestalt psychologists have not discussed curiosity explicitly, Malone (1981) proposed—but did not further develop—an account of "cognitive curiosity" based on gestalt concepts. Cognitive curiosity "is evoked by the prospect of modifying higher level cognitive structures . . . [and] can be thought of as a desire to bring better 'form' to one's knowledge structures" (Malone, 1981, p. 363).

A need for sense making is reflected in other diverse areas of research. For example, the need for cognition (Cohen, Stotland, & Wolfe, 1955, p. 291) is defined as "a need to structure relevant situations in meaningful, integrated ways . . . to understand and make reasonable the experiential world." The original article laying out the need for cognition hypothesis further proposed that "feelings of tension and deprivation arise from its [the need for cognition's] frustration (Cohen et al., 1955, p. 291), a proposition that is consistent with the idea that sense making has motivational force. Supportive of a link between need for cognition and curiosity is the high correlation between need for cognition and various specific curiosity scales (mean $r = .57$) found in one study (Olson & Camp, 1984b). Clearly, need for cognition is closely related to specific curiosity. However, as it has evolved, the research on the need for cognition provides few insights applicable to specific epistemic state curiosity because of its focus on trait differences and their consequences (e.g., Cacioppo & Petty, 1982). Need for cognition has become widely viewed as a personality trait rather than a psychological state subject to situational influences.

Also closely related to the need for sense making is the concept of ambiguity aversion (Ellsberg, 1961; Frenkel-Brunswik, 1949). Ambiguity refers to the absence of a single coherent interpretation of a situation or, obversely, the presence of more than one plausible interpretation. Recently, Frisch and Baron (1988) have characterized ambiguity aversion as the avoidance of situations in which one believes that there is a lack of information relevant to making a decision (Frisch & Baron, 1988). The main difference between the literature on ambiguity aversion and that on curiosity is their focus. The ambiguity literature examines how people avoid ambiguity by not making decisions when information is missing or by avoiding alternatives with ambiguous attributes, whereas curiosity research tends to focus on the desire for information itself.

Although the various components of the incongruity approach have generally been supported by empirical research, it is questionable whether incongruity provides a sufficiently comprehensive account of curiosity or even of its specific epistemic state variant. Although incongruity is an important instigator of curiosity, it is not the only instigator of curiosity, even using Kagan's broad definition of the concept. In many cases, such as in straining to overhear a conversation taking place at an adjoining table in a restaurant, in the desire to solve a puzzle, or in the compulsion to read another person's diary, curiosity does not seem to result from incongruity but from other factors such as the salience of specific missing information or understanding.

Competence and Intrinsic Motivation

Diametrically opposed to both the drive-based and incongruity-based accounts of curiosity is a theoretical perspective articulated by White (1959). According to White, curiosity results from a motivation to master one's environment that he called the "competence" or "effectance" motive. White denied the existence of a curiosity drive, arguing that curiosity has none of the characteristics usually associated with such physiological drives as hunger. First, he noted that unlike hunger, curiosity does not involve "a tissue need or deficit external to the nervous system" (White, 1959, p. 301), and he attacked Hebb's

[9] Kreitler and Kreitler also conducted extensive research on curiosity (e.g., S. Kreitler, Kreitler, & Zigler, 1974; S. Kreitler, Zigler, & Kreitler, 1984) but, surprisingly, failed to apply the insights from their work on aesthetics to that on curiosity.

contention that curiosity could originate spontaneously in the nervous system. Second, White (1959) asserted that curiosity "cannot be regarded as leading to any kind of consummatory response" (p. 301). Responding to the natural objection that obtaining information often leads to a sudden reduction in curiosity, White (1959) stated that "if the animal at some point turns away and leaves the once novel object we may say that its curiosity is 'satisfied,' but we do not mean by this that the equivalent of a consummatory response has just taken place" (p. 301). White argued that curiosity is derivative of the competence motive so that the former could be subsumed under the latter without causing great theoretical damage.

White's analysis was later extended by Deci (1975), who embraced White's competence notion and, like White, proposed to subsume curiosity into "the more general realm of all intrinsically motivated behaviors" (p. 53). In support of a link between curiosity and competence, Deci (1975) noted that competence, like curiosity, "is not intense and immediate in the sense that thirst, fear, etc. are, but rather it is an ongoing process which is periodically interrupted by tissue needs" (p. 55). In other words, Deci viewed curiosity as a mild motivational state that is easily overwhelmed by even weak physiological drives.

Just as the incongruity perspective was inspired by the observation that violated expectations trigger curiosity, the competence perspective reflects the well-established observation that people are curious about their own abilities (e.g., Festinger, 1954). The competence perspective has received some empirical support (although not intended as such) in research by Swann, Stephenson, and Pittman (1981). They found that the tendency to ask diagnostic questions during an interview (a measure of curiosity) was greater for subjects who had earlier been deprived of control (presumably undermining their feelings of mastery over their environment). However, the competence account suffers from the same deficiency as the incongruity perspective in that it fails to offer a comprehensive account of curiosity. *Competence* is not synonymous with *curiosity*. On the one hand, the effort to learn how to pitch a baseball is likely to be motivated by a desire for mastery but not by curiosity. On the other, the desire to overhear a conversation at the next table in a restaurant seems to reflect curiosity but not a desire to achieve competence, except in the most remote sense of the term. Furthermore, contrary to Deci's assumption that curiosity is overwhelmed by even weak physiological drives, most people can recall times in their lives when curiosity was extremely intense, even to the point of interfering with "tissue needs" such as hunger and thirst. Interestingly, although Kagan (1972) included mastery in his list of four fundamental motives, he explicitly disavowed a connection between mastery and curiosity.

Summary

Each of the theoretical perspectives discussed here—the drive theories, the incongruity perspective, and the competence approach—gives expression to one or more of curiosity's salient characteristics. Drive theories reflect the observation that curiosity is aversive, has motivational force, and can be stimulated internally (by boredom) or by external stimuli. Incongruity theories point to the importance of violated expectations as instigators of curiosity, and the competence perspective highlights the fact that curiosity is pronounced toward topics that involve one's self-concept. However, none of these theories offers a comprehensive account of curiosity that can explain the wide range of circumstances in which it arises. Furthermore, the question of curiosity's underlying cause is inherently unanswerable because it is always possible that curiosity stems from some as yet unidentified, more basic drive or motive. Perhaps the best one can do is to note the similarity between curiosity and a wide range of information-seeking phenomena that all seem to reflect a human need for sense making or, as Kagan called it, a "need to know."

Voluntary Exposure to Curiosity

Drive-based accounts of curiosity assume that unsatisfied curiosity produces aversive arousal. The desire to reduce such arousal produces the information-seeking that is curiosity's most basic behavioral manifestation. The assumption that curiosity is aversive, however, seems to imply, less plausibly, that people will avoid exposing themselves to curiosity in the first place. But, in fact, people frequently expose themselves intentionally to situations that they know will make them curious. As Hebb (1955) commented,

> It is nothing short of extraordinary what trouble people will go to in order to get into more trouble at the bridge table, or on the golf course; and the fascination of the murder story, or thriller, and the newspaper accounts of real-life adventure or tragedy, is no less extraordinary. (p. 250)

Such curiosity-seeking behavior, Hebb noted, posed a paradox for drive-based accounts of curiosity.

Hebb believed that his own account of curiosity, which assumed that people actually like limited levels of arousal, was not vulnerable to this paradox because it predicted curiosity seeking: "It appears that, up to a certain point, threat and puzzle have positive motivating value, beyond that point negative value" (1955, p. 250). Stated simply, Hebb's argument is that people seek out moderate amounts of curiosity because they find moderate levels more pleasurable or less aversive than low or high levels.

When Berlyne became aware of Hebb's challenge to his drive-based account of curiosity, he modified his theory in a manner that, although very similar to Hebb's, adhered to the behaviorist view of arousal as uniformly aversive. Berlyne drew a distinction between *arousal*, which referred to the individual's internal state, and *arousal potential* or *stimulus intensity*, which referred to the degree of stimulus complexity of the environment. He argued that low as well as high levels of stimulus intensity—very undifferentiated or highly complex environments—produced high levels of arousal. In other words, he postulated that boredom produces high levels of arousal. In an impoverished environment, stimulus intensity would be low and arousal high, and the individual would attempt to increase arousal by seeking curiosity-inducing stimuli. In a highly complex environment, both stimulus intensity and arousal would be high, and the individual would attempt to decrease them through curiosity-reducing exploration. Thus, Berlyne, too, predicted that organisms should be attracted to stimuli that have moderate arousal potential corresponding to moderate levels of curiosity. Ber-

lyne, however, did not seem particularly convinced by his own account and defended it against Hebb's with little more than the argument that he did not want to change his mind.[10]

Hebb's and Berlyne's accounts of curiosity seeking are very similar because both postulate an inverted U-shaped curiosity preference function. Both infer from curiosity seeking that people must like curiosity. It might appear somewhat circular and therefore uninteresting to explain curiosity-seeking by arguing that people like curiosity. However, such an account of curiosity seeking is not boring; it is wrong because it is inconsistent with commonly observed behavior. If people like positive levels of curiosity, why do they attempt to resolve the curiosity? Why do they not put mystery novels down before the last chapter or turn off the television before the final inning of a close ball game? Arguing that people seek curiosity because they like it simply shifts attention back to the original question of why people attempt to satisfy it. Thus, neither the drive nor the incongruity theories provide a viable account of curiosity seeking.

Advocates of the competence perspective have not grappled with the problem of curiosity seeking because they do not assume that curiosity is aversive and therefore do not view curiosity seeking as a paradox. Nevertheless, it is not difficult to imagine how competence theorists would account for curiosity seeking; they would argue that people seek out curiosity-inducing problems both to develop and demonstrate their competence.

Situational Determinants of Curiosity

Most of the theories reviewed earlier point to specific situational determinants of curiosity. Drive theories, for example, predict that curiosity will intensify if left unsatisfied and that curiosity can be "satisfied" and thus eliminated by exposure to suitable stimuli. Incongruity theories draw attention to the importance of violated expectations as a source of curiosity and postulate an inverted U-shaped relationship between curiosity and the extremity of expectation violations. The competence interpretation suggests that people should be curious about information that pertains to their competence. Most of these observations have been supported by empirical research. However, no theory provides a broad account of situational determinants, because few theorists have specified testable implications of their theories beyond the observations that originally motivated them. Thus, Hebb (1955), after laying out his own account of curiosity, acknowledged that "I know this leaves problems. It is not *any* . . . form of problem that is rewarding; we still have to work out the rules for this formulation" (p. 250). However, Hebb, and most other curiosity theorists, never got around to working out such rules.

Berlyne presents one major exception to this pattern. He conducted numerous empirical studies addressing the question of what stimulus properties are associated with high levels of arousal potential and thus induce curiosity. He identified a number of "collative" variables that, he predicted, would arouse cognitive conflict, stimulating curiosity. As noted previously, these included stimulus characteristics such as novelty, complexity, and surprise.

Berlyne tested several elements of his theory in one of the first experiments on curiosity involving human subjects. His experiment was fabulously complicated, involving three groups of subjects, a seven-stage procedure, and an endless series of ratings by subjects (Berlyne, 1954b). Distilled to its essentials, subjects were given questions about invertebrates, indicated which they found most curiosity evoking and surprising,[11] were presented with a randomly ordered list of answers, and then completed the initial questionnaire about invertebrates a second time.

Berlyne's main prediction was borne out. Questions rated as eliciting greater curiosity in the first questionnaire were more likely to be answered correctly in the second. The underlying logic was that the original questions that generated curiosity increased the individual's arousal level. As subjects heard the answers to these questions in the second stage of the study, their curiosity would be satisfied, and arousal would be successively reduced. The temporal association of arousal reduction with learning the answer to the questions that had piqued their curiosity would reinforce learning those particular answers. As Berlyne (1954b) expressed it, "the rehearsal of the answer would reduce the curiosity drive to a subliminal value, and this drive-reduction would reinforce the learning of the answer" (p. 257). Also as predicted, questions that were designated as surprising in the first questionnaire were more likely to be rated as evoking curiosity, thus supporting Berlyne's hypothesized link between conflict (approximated here by surprise) and curiosity. Numerous other predictions were also supported, although most, including those just discussed, have alternative interpretations that are simpler than those proposed by Berlyne (Cofer & Appley, 1964, p. 298).

One of the predictions examined in the study by Berlyne—that conceptual controversy produces curiosity—was examined in a classroom setting by Lowry and Johnson (1981). The study was innovative in many respects, particularly the diversity of dependent measures used. Fifth and sixth graders working on class projects were randomly assigned to interact in groups in a manner intended either to foster intellectual consensus or to produce argument and epistemic conflict. The prediction was that conflictual group interactions would stimulate curiosity. Dependent measures of curiosity included achievement tests that measured the subjects' eventual mastery of the topic areas, scales measuring subjects' self-rated interest in the topics, and behavioral measures of information search including study time, use of information from special sources (e.g., the library), and attendance at an optional film shown during recess. All of these measures were affected significantly by the controversy

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[10] "It is tempting to suppose that the conditions that make for boredom will produce exceptionally low arousal, and that low arousal, as well as high arousal, must therefore be aversive. Such a hypothesis has been put forward by several writers (e.g., Hebb, 1955). Nevertheless, we shall stand firm against the temptation and refrain from adopting this hypothesis. Instead, we shall suggest, though with even more diffidence than accompanies our other theoretical suggestions, that boredom works through a *rise in arousal*" (Berlyne, 1954a, p. 188).

[11] The idea of a question being surprising is somewhat confusing, and Berlyne's (1954b) failure to report any of the specific questions that he asked subjects, surprising or not surprising, does not help to clarify the matter. The article stated that "incompatibility was judged by having subjects mark those questions in the fore-questionnaire which surprised them, and also by using a group of judges, who indicated which predicates seemed to them least applicable to animals" (p. 258).

manipulation. Indeed, 45% of controversy subjects gave up their recess to view the film, whereas only 18% of the noncontroversy group did so.

After publishing the experiment discussed above, Berlyne continued to test his own theory. However, after this experiment, which used self-reports of curiosity, he seemed to rediscover the behaviorist's aversion to subjective measures. In subsequent research, he switched from verbal to visual stimuli and measured curiosity not by asking subjects which stimuli evoked curiosity but by monitoring subjects' focus of attention. In numerous studies (e.g., Berlyne & Parham, 1968), which were followed by a flood of similar experiments by other researchers (e.g., S. Kreitler, Zigler, & Kreitler, 1975; Munsinger & Kessen, 1964; Nunnally, 1971), Berlyne presented subjects with geometric shapes that varied in complexity or novelty and measured curiosity by recording the amount of time subjects spent looking at them. In such experiments, there was no cost to subjects for looking at one stimulus item rather than another; they were expected to examine at least one. It is therefore possible that subjects were not curious about any of the stimuli but found one marginally less boring than the others. Such experiments provided no outlet for the expression of a positive motivation for looking at a particular stimulus. The *Random House Dictionary* defines curiosity as "the desire to learn or know about anything"; in these studies, however, subjects could learn little by selecting one stimulus item over another because no information was hidden. In this case, it seems natural that aesthetic considerations would influence subjects' allocation of attention to stimuli at least as much as curiosity.

Perhaps because attention to geometric shapes has little to do with curiosity, efforts to measure individual differences in curiosity using a similar setup (e.g., by examining the level of complexity of shapes that people attend to) have not proven reliable and do not correlate reliably with other measures of curiosity (S. Kreitler, Zigler, & Kreitler, 1974; Munsinger & Kessen, 1964; Munsinger, Kessen, & Kessen, 1964; Voss & Keller, 1983). Berlyne himself eventually seemed to recognize this problem because he subsequently repackaged this line of research as an investigation of aesthetics (Berlyne, 1974). Thus, although Berlyne set out to delineate situational (stimulus) determinants, he failed to achieve this goal as a result of his shift to a research paradigm that measured attention and aesthetic appreciation rather than curiosity.

Curiosity's Combination of Transience and Intensity

The final question that was not raised or addressed in either wave of curiosity research—but that is fundamental to achieving a comprehensive understanding of the phenomenon—concerns why curiosity possesses the curious combination of qualities described by Edmund Burke in the quote opening this article. First, curiosity tends to be highly transient but, at the same time, quite intense. Consider the curiosity one occasionally experiences about the facial features of a person seen from the back. In such cases, it is remarkable how quickly curiosity dissipates after one loses sight of the person. Likewise, the office—and hence telephone—of a colleague of mine is located adjacent to the departmental conference room. When his phone rings during a conference or seminar, he becomes curious about who is calling, often to the extent that he actually walks out of a seminar to take the call. However, when his phone is not ringing, he has no qualms about leaving his office for other parts of the building, and, out of hearing range from his phone, he is not distracted by the possibility that he may be receiving calls, nor does he wonder who might be calling. This latter observation reflects a closely related characteristic of curiosity: the degree to which it is stimulus bound.

Second, curiosity tends to be associated with impulsive behavior. People who are curious not only desire information intensely but desire it immediately and even seek it out "against their better judgment." Curiosity's connection to impulsivity is illustrated compellingly by the fact that curiosity has been used as an impulsivity induction method in experimental research comparing the effectiveness of alternative self-control techniques. Hartig and Kanfer (1973; see also Kanfer & Zich, 1974) instructed children in the use of alternative self-control techniques, told them not to turn around and look at an attractive toy display behind them, and then observed whether they were able to resist the temptation to do so. Such studies are premised on, and thus give additional support to, the notion of a link between curiosity and impulsivity.

The fact that curiosity can cause one to act knowingly against one's own self-interest is vividly illustrated in the confessions of St. Augustine (1943, p. 13) in a passage describing the experience of his law student friend Alypius in Rome. Alypius was "utterly opposed to and detesting" of gladiatorial shows. However, "one day [he] met by chance diverse acquaintances [who], with a friendly violence drew him, vehemently objecting and resisting, into the amphitheater, on a day of these cruel and deadly shows." He protested that "though you drag my body to that place, and there place me, can you force me to give my mind and lend my eyes to these shows?" and closed his eyes. However, after sitting there for a period, "upon the fall of one in the fight, a mighty cry from the whole audience stirring him strongly [and] he, overcome by curiosity, . . . opened his eyes, and was struck with a deeper wound in his soul than the other . . . on whose fall that mighty clamor was raised."

Finally, and not unrelated to curiosity's association with impulsivity, when curiosity is satisfied, the result is generally disappointing. For example, Felcher, Petrison, and Wang (1993) interviewed 30 people about their attitudes toward mail and found that although the daily mail delivery is looked forward to with anxious anticipation and impatience, most respondents reported almost always being disappointed by the actual mail they received. Likewise, the pleasure people obtain from a glimpse of the person they have been trailing on the sidewalk, or the satisfaction my colleague derives from learning who is calling him, is typically meager in comparison with the intensity of the curiosity that preceded these acts. Indeed, there are situations, such as Alypius's desire to know what the crowd was shouting about, in which people recognize from the start that the information curiosity impels them to obtain will bring no pleasure or even pain.

An Integrative Interpretation of Specific Epistemic Curiosity

In an attempt to address the issues raised in the previous sections, I propose an integrative interpretation of curiosity—an

"information-gap" perspective—that combines insights from the theories just reviewed with ideas borrowed from Gestalt psychology, social psychology, and behavioral decision theory. Consistent with the conclusion of the section on the definition and dimensionality of curiosity, the theory deals exclusively with specific state curiosity (an intrinsically motivated desire for specific information). After presenting the basic components of the new perspective, I show how it addresses three of the questions considered earlier: the explanation for voluntary exposure to curiosity, curiosity's situational determinants, and the explanation for curiosity's intensity, transience, association with impulsivity, and tendency to disappoint. As noted earlier, the remaining question—the cause of curiosity—is inherently unanswerable. Nevertheless, I believe that the need for sense making discussed by Kagan and others provides a plausible account of the underlying cause of curiosity. Although somewhat vague, the appeal of such an account is that it draws a connection between curiosity and a wide range of other phenomena that involve information seeking.

Like virtually every idea in contemporary psychology, an early rendition of the information-gap perspective can be found in the work of William James. James (1890/1950) proposed that "scientific curiosity"—the type of curiosity that most closely corresponds to specific epistemic curiosity—arises from "an inconsistency or a gap in . . . knowledge, just as the musical brain responds to a discord in what it hears" (p. 429). Consistent with this view, the information-gap theory views curiosity as arising when attention becomes focused on a gap in one's knowledge. Such information gaps produce the feeling of deprivation labeled *curiosity*. The curious individual is motivated to obtain the missing information to reduce or eliminate the feeling of deprivation.

Curiosity as a Reference-Point Phenomenon

Like other types of gaps in attainments, an information gap can be defined by two quantities: what one knows and what one wants to know. What one knows is relatively objective (although people may misestimate their own degree of knowledge in different domains), but what one wants to know is highly subjective. In decision-theoretic terms, what one wants to know can be thought of as one's informational "reference point." The most developed application of the reference-point concept is in decision making under uncertainty. New reference-point theories of decision making under uncertainty, most prominently Kahneman and Tversky's (1979) prospect theory, underscore the subjective nature of attainments; the same absolute level can be viewed positively or negatively depending on the decision maker's reference point.

Curiosity, in this view, arises when one's informational reference point in a particular domain becomes elevated above one's current level of knowledge. The central insight gained by applying such a formulation to curiosity is that the same degree of knowledge can evoke or not evoke curiosity depending on the level of one's reference point.

Application of the reference-point concept to curiosity suggests an analogy between curiosity and other reference-point phenomena in which dissatisfaction depends on the discrepancy between one's actual level of attainment and a goal or aspiration level. For example, relative deprivation theories posit that negative feelings result from a comparison of one's own material position against that of people who have more. Of course, most people are surrounded by countless others who have more than they do. But people generally do not feel globally deprived; rather, they feel deprived only when they compare themselves with specific others. Similarly, in the case of curiosity, people are not always curious, even though they are surrounded by vast regions of ignorance. Dissatisfaction with one's state of knowledge, like dissatisfaction with one's material condition, depends on a contrast between one's objective situation and a subjective reference point.[12]

The informational reference point and information level concepts imply that quantity of information is a unidimensional concept that can be expressed as a single number. But information is inherently multidimensional. This creates an analytical problem that recurs in numerous domains that have been analyzed in terms of reference points. For example, an individual's feeling of material deprivation may result from comparing her or his own fancy car with the neighbor's swimming pool. Although it is possible, in theory, to treat such a problem multidimensionally, the wide range of possible possessions makes such an approach extremely cumbersome. To facilitate comparisons between people with heterogeneous possessions, relative deprivation researchers often collapse multidimensional material possessions into a unidimensional quantity by describing individuals' possessions in terms of dollar values.

The equivalent practice in regard to information is to use principles of information theory (e.g., see Attneave, 1959) to quantify an individual's level of information in a particular domain. Information theory interprets level of knowledge in terms of the fineness of "partitions" a person is able to draw. For example, early in a presidential campaign, there may be a wide range of candidates who cannot be ruled out as eventual victors. This can be viewed as a coarse partition, because many candidates are included in the same partition—the set of potential victors—and because there is little reason to favor one over another probabilistically. Clearly, the informational reference point—the goal—in this situation is to find out who gets elected to the presidency. As the campaign proceeds, with primaries weeding out candidates and public opinion polls providing further information, the range of possible victors decreases, probability estimates for those who remain become more varied, and the gap between what one knows and what one wants to know decreases.

Information theory's entropy coefficient provides a potential measure of the degree of one's information (actually one's ignorance) in situations such as a presidential election. Entropy is defined as

$$-\sum_{i=1}^{n} p_i \log_2 p_i, \tag{1}$$

where, in this example, n is the total number of candidates and

[12] This connection between curiosity and relative comparison in the material realm reinforces Abelson's (1986) view that people treat beliefs (or knowledge, in this case) as if they were material possessions.

p_i refers to the assessed probability that a particular candidate (subscripted by i) will prevail.[13]

Consider a race with 10 initial candidates. Let $w_i = 0, 1$ indicate a particular candidate's eventual success ($w = 1$) or failure ($w = 0$). If initially one has no idea who will win, then the best guess of the likelihood that any one candidate will win is $p = 1/10$, which can be written as $p(w_i = 1) = .1$ for $i = 1, 10$. The entropy coefficient in this situation is equal to 3.3 [-10*.1*$\log_2(.1)$] and would drop to 2.3 [-5*.2*$\log_2(.2)$] if primaries eliminated half of the candidates from the race [creating a new partition with $p(w_i = 1) = 0$ for $i = 1$ to 5 and $p(w_i = 1) = .2$ for $i = 6$ to 10]. The entropy coefficient can be applied to a wide range of curiosity-inducing informational settings (e.g., the possible solutions to a puzzle, the lineup of potential murderers in a "whodunit," or the range of frontal appearances one might anticipate for a person viewed from the back).

Quantifying the magnitude of an information gap requires entropy measures of 1) the individual's current situation, 2) the individual's informational goal, and, possibly, 3) a situation of total ignorance. The absolute magnitude of the information gap can be expressed as (2) − (1), and a common measure of the relative magnitude of the gap is [(2) − (1)]/[(2) − (3)]. In the case of a race that has been reduced to five equiprobable candidates, the individual's current level of information is equal to 2.3, the goal is to achieve a level of 0, and total ignorance (10 equiprobable candidates) equals 3.3. Thus, the absolute magnitude of the gap is -2.3 [0 − (2.3)], and the relative magnitude is .7.

Based on findings from other domains, it is likely that people are sensitive to both the absolute and relative magnitude of the information gap (Prelec & Loewenstein, 1991). For example, in decision making under uncertainty, the contrast between a .1 and .2 chance of winning a prize is seen as greater than the contrast between .8 and .9 because the ratio between the former is greater than that of the latter, even though the difference is the same. However, the contrast between .45 and .9 is seen as greater than that between .1 and .2 (even though the ratios are equivalent) because the difference is greater in the former. Applied to curiosity, the same reasoning suggests that the perceived magnitude of an information gap will depend on both the absolute and relative magnitude of the gap. Thus, the information gap when one knows 4 of the 5 states bordering the Pacific Ocean is likely to be perceived as larger than the gap inherent in knowing 49 of the 50 states in the country. However, the gap inherent in knowing 40 of the 50 United States will be seen as larger than that associated with knowing 4 of the 5 states bordering the Pacific.

Entropy values should be treated as crude proxies rather than as precise measures of the magnitude of information gaps. Entropy is typically difficult to measure in real-world settings, and its calculation often requires numerous simplifying assumptions that are of dubious validity. Furthermore, as Kreitler, Zigler, and Kreitler (1974) argued, there are forms of information that powerfully affect curiosity but are not captured by entropy. For example, in murder mysteries there are numerous facts about the characters and the overall situation that may not help to resolve the "whodunit" question but that nevertheless promote curiosity by bringing the characters and plot to life. These facts constitute real information but do not affect the entropy coefficient when it is defined as in the preceding illustration.

Fortunately, for research purposes it is frequently unnecessary to measure the precise magnitude of an information gap. Often, one makes only ordinal predictions (e.g., that curiosity will increase with information), in which case it is sufficient to establish experimental situations with more or less information. For example, in an experiment discussed later, subjects were shown from zero to three photographs of parts of a person's body. Although it is difficult to measure their level of information contingent on viewing a certain number of photographs, the amount of information is clearly an increasing function of the number of photographs viewed.

Furthermore, information gaps can be measured without recourse to entropy by eliciting from subjects subjective ratings of knowledge or ignorance. This is a common procedure in research involving constructs such as feeling-of-knowing, which are well understood at an intuitive level but are difficult to quantify. Subjects generally seem to have no problem coming up with a single number that represents their feeling-of-knowing, even though this judgment requires expressing inherently multidimensional quantities as a single number.

The Situational Determinants of Curiosity

Among the implications of the information-gap perspective, two are particularly fundamental. First, the intensity of curiosity directed at a particular item of information should be related positively to its ability to resolve uncertainty (i.e., to close the information gap). Because curiosity reflects a desire to close information gaps, it is natural to assume that curiosity will be greater toward information that more nearly accomplishes this task.

Support for this prediction was obtained in an experiment reported in Loewenstein, Adler, Behrens, and Gillis (1992). Subjects were exposed to two lists of states and were asked to guess the rule that had generated each list. One list was always twice as large as the other (10 states as opposed to 5), but list length was crossed with the actual rule. After guessing the rule for each list, subjects were asked to choose the rule they would like to learn. The prediction was that subjects would want to learn the rule that would shed light on the relationship between a larger number of states (i.e., the rule associated with the longer list). As predicted, approximately 70% of subjects chose to learn whichever rule was associated with the longer list even after controlling for the subjects' perceived and actual accuracy of guesses.

The ability of information to close a gap will also depend on other characteristics of the information set. Specifically, with insight problems there is a possibility that a single piece of information (i.e., the insight) can throw light on the entire problem. With incremental problems, in contrast, any single piece of information is unlikely to yield a sudden solution. Thus, the information-gap perspective predicts that, all else equal, curiosity should be greater for insight than for incremental problems.

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[13] This formula applies to situations in which information is in binary form (e.g., candidates can either win or lose). It is easily generalized to more complex informational settings.

A study reported in Loewenstein et al. (1992) tested this prediction. Although it is difficult to compare curiosity toward incremental and insight problems without varying the problem itself, an attempt was made to hold the problem essentially constant while varying its character (insight vs. incremental). This was done by allowing subjects to explore a visual matrix consisting of either pictures of different animals or a single enlarged picture of a single animal chosen randomly from the larger set. The former was intended as an incremental problem because subjects would learn a new animal each time they exposed a picture; the latter was more of an insight problem because subjects would be unable to determine which animal they were viewing at first but would eventually figure it out. Subjects recruited for a computer-controlled experiment were presented with what they were told was a "practice screen" that consisted of a 5 (wide) × 9 (high) grid of blank squares. They were told that they should click the mouse on at least 5 of the 45 squares to familiarize themselves with the operation of the mouse. Thus, subjects had no idea that the experiment had anything to do with curiosity. Clicking the mouse on a square revealed an image that was hidden behind the square. A 4-s delay was introduced to make information acquisition costly in terms of time. In one condition (multiple animals), each square contained a picture of a different animal; in the other (single animal), the entire screen contained a picture of a single animal that was randomly selected for each subject from the set of animals included in the multiple-animal condition. Curiosity was measured by how many squares a subject exposed over and above the required 5. The prediction was that subjects in the single-animal condition would become curious to solve the gestalt—to determine what image was contained on the screen—whereas those in the multiple-animal condition would be less curious to learn the full range of concealed animals. As predicted, subjects in the single-animal condition exposed a significantly larger number of squares.

A second and less intuitively obvious implication of the information-gap perspective is that curiosity should be positively related to one's knowledge in a particular domain. There are two reasons for anticipating such a relationship. First, as one gains information about a particular topic, there is an ever-increasing likelihood that one will focus on what one does not know rather than on what one knows. According to the information-gap perspective, such a focus on missing information is a necessary condition for curiosity. To illustrate, consider an individual who knows the capitals of only 3 of the 50 states. Such a person is likely to frame her or his knowledge as such (i.e., that she or he knows 3 state capitals). However, a person who knows the capitals of 47 states is more likely to frame her or his situation as one of not knowing 3 state capitals. Thus, as information about a topic increases, one's attention is more likely to be attracted to the gap in one's knowledge.

As a visual analogy, imagine a piece of paper (representing a coherent information set), one contiguous part of which is colored red (information possessed) and the rest of which is colored white (missing information). When the red area is small, it will be the focus of attention; the white area will be perceived as background. However, as the size of the red area increases relative to the white, a point will be reached at which attention will be drawn toward the white part. Such a shift of focus is characteristic of numerous gestalt illusions in which different images arise from the same visual display depending on what part one perceives as the "figure" and what part one perceives as the "ground."

A similar attention-shift phenomenon is observed in decision making under uncertainty. Consider a gamble that offers a p chance of winning $1,000. Initially an individual offered the gamble is likely to frame it as such: a p chance of winning $1,000. As p increases, however, at some point an abrupt reframing is likely to occur to a focus on what can be lost. Thus, a person with a .9 chance of winning $1,000 is likely to frame it as $1,000 with a .1 chance of losing the money (Elster & Loewenstein, 1992).

The implication for curiosity is that an individual is likely to focus on the information that is present when most of the information from a set is missing. At this point, the informational reference set is effectively zero. As information is acquired, however, at some point a qualitative shift of attention is likely to occur from a focus on what is known to one on what is not known. This shift is the genesis of curiosity because, at that moment, the individual suddenly becomes focused on the gap in his or her knowledge. This suggests that curiosity is unlikely to arise in the absence of an existing knowledge base and that the likelihood of experiencing curiosity should increase as an individual obtains information about a particular topic. Marcel Proust (1924/1982) captured this tendency when he described his protagonist Swann as lacking "even the tiny, initial clue which, by allowing us to imagine what we do not know, stimulates a desire for knowledge" (p. 261).

There is a second reason for anticipating a positive relationship between curiosity and information. In numerous domains, such as animal behavior (N. E. Miller, 1944), social comparison (Messick & Sentis, 1989), and decision making under uncertainty (Kahneman & Tversky, 1979), researchers have found that motivation tends to increase at the margin as an individual approaches a reference state from below. The approach gradient estimated from animal studies exhibits an accelerating form; motivation increases as an organism physically approaches a goal. Applied to information, such an accelerating function would imply that the marginal value of information should increase as the individual accumulates information toward the goal of completing the reference set. Whereas the attention-shift effect discussed earlier is discontinuous, this effect is continuous. Thus, as information is accumulated, the information-gap perspective predicts a sudden increase in curiosity when the individual becomes focused on the missing information and then a more gradual increase as he or she approaches the goal of closing the information gap.

Although a positive relationship between curiosity and knowledge is a central prediction of the information-gap perspective, in practice, the relationship between information and curiosity may not be so simple because new information can change the perceived size of the information set, causing the reference point to shift. New information provides an ever-changing idea of what there is to be known. For example, when one sets out to learn a new language, the relevant information set may initially seem small, and curiosity should be commensurately strong. But as one begins to learn the language and becomes aware of its complexities, the perceived information

set—what there is to know—is likely to increase. Thus, curiosity may well decline early on rather than increase, even as one gains proficiency in the language.

There is a second reason why curiosity may not increase with knowledge. Sometimes, as one gains information, the objective value of a particular item of information declines, even though it remains unknown. For example, when one is completing a jigsaw puzzle of an unknown picture, there may be a particular moment at which one guesses with confidence the content of the picture (e.g., the Mona Lisa). At this point, one's curiosity to see a particular piece of the puzzle completed is likely to decline because one can infer its content with some accuracy. Similarly, in reading a murder mystery, one's curiosity to learn the identity of the murderer is likely to decline if one becomes extremely confident that one already knows the answer. The prediction that curiosity increases with knowledge, therefore, assumes that the objective value of the missing information remains constant as related information is acquired.

The general prediction that curiosity should increase with knowledge has already received some empirical support. In Berlyne's (1954b) experiment reviewed earlier, for example, questions about more familiar animals evoked greater curiosity. A similar finding was obtained by S. Jones (1979), who had subjects rate how curious they were to see the answers to questions and also tested them on their knowledge related to the questions. Jones anticipated that subjects who were more generally knowledgeable would also be more curious as individuals; however, he failed to find the correlation he hypothesized between overall knowledge and trait curiosity. Instead, and consistent with the relationship predicted here between knowledge in a particular domain and curiosity in that domain, Jones did observe a significant correlation (.51) between self-evaluated knowledge of a particular item and curiosity about that item. He concluded that "subjects were more curious toward items about which they already had some knowledge than toward those about which they had little or no knowledge" (S. Jones, 1979, p. 640).

A positive relationship between curiosity and knowledge was also found in two studies conducted by Loewenstein et al. (1992). In one study, subjects were shown, one by one, from zero to three photographs of different body parts (hands, feet, and torso) of a man or a woman. After all of the selected photographs had been turned over, subjects completed a form that elicited their self-reported curiosity to see the photograph of the whole person and were given a choice between seeing the photograph or getting a $.50 bonus payment. As predicted, curiosity increased significantly with the number of body parts viewed. In the second study (discussed in more detail later), they found a positive relationship between feelings of knowing and curiosity, consistent with the view that curiosity increases with perceived knowledge.

Voluntary Exposure to Curiosity

Like the drive theories but contrary to Hebb's perspective, the interpretation of curiosity proposed here assumes that curiosity is always aversive. The key to understanding curiosity seeking lies in recognizing that the process of satisfying curiosity is itself pleasurable. As William James commented in an autobiographical essay, movement from a "state of puzzle and perplexity to rational comprehension is full of lively relief and pleasure" (cited in Posnock, 1991, p. 39). Similarly, Piaget (1969) noted (but did not relate to curiosity) that, after an attempt at problem solving, "there follows, sometimes abruptly, a feeling of coherence and of necessity, the satisfaction of arriving at a system which is both complete in itself and indefinitely extensible" (p. 139). As an illustration, consider how unsatisfying is the information that the wife was the murderer in Turow's *Presumed Innocent* if one is not immersed in the book. However, figuring out or learning the identity of the killer is intensely satisfying when one is reading the book.

The pleasure derived from satisfying curiosity provides a simple explanation for voluntary curiosity seeking. It is perfectly sensible for people to expose themselves to curiosity-inducing situations if the expected incremental pleasure from obtaining the information compensates for the aversiveness of the curiosity itself. People often intentionally exacerbate aversive states such as hunger and thirst to heighten the pleasure they will derive subsequently from eating or drinking. In such situations, it is not hunger and thirst that are pleasurable, as earlier explanations of curiosity seeking implied by analogy, but their elimination. Fasting before a fancy meal and denying oneself water after exercising so as to better appreciate the customary post-jog beer are just two examples of a ubiquitous pattern of behavior. Likewise, it makes sense for people to expose themselves to curiosity-inducing stimuli if, by doing so, they enhance the pleasure subsequently derived from obtaining information.

Voluntary exposure to curiosity can be viewed as a type of gamble. Before exposing oneself to a particular curiosity-inducing situation, one must estimate the likelihood that one's curiosity will be ultimately satisfied and, if so, how long such satisfaction is likely to take. When the probability of satisfying the curiosity is low, or if it is likely that one will be left in a state of aversive curiosity for a long period, exposing oneself to curiosity will generally not be worth the gamble. By analogy, imagine that one was virtually certain of eating a large, delicious dinner in the evening. In such a case, fasting during the day would make sense. However, if there were only a small chance of such a dinner materializing, fasting would be a mistake. Therefore, one strong prediction that emerges from the information-gap perspective is that people will not expose themselves to curiosity-inducing situations in which there is only a slim chance of satisfying the curiosity or in which there would be a long delay before the information is received. As Feuerbach commented, "man only wants to know what *man* can know. What lies beyond this region has no existence whatever for him; so for him it is also the object of no drive or wish whatsoever" (cited in Blumenberg, 1966/1983, p. 442).

Several closely related phenomena have been observed in the domain of social comparison. A frequent observation in the social comparison literature is that people tend to compare themselves with others who are only marginally better off on some dimension than they are; most people do not make themselves miserable by comparing themselves with the rich and famous (Festinger, 1954; Wheeler, 1966). Similarly, Davies' (1962) work on revolutions that are caused by rising expectations argued that people become discontent and likely to rebel when they not only perceive that others possess what they do not but also

perceive what they do not have as potentially attainable. The idea that people tend not to be attracted to things that are out of their reach is also reflected in research (cited in Schelling, 1984) showing that addicts experience less painful withdrawal symptoms in detoxification institutions that have a reputation for inviolability. Perhaps for evolutionary reasons, people do not focus their feelings of deprivation on things that are impossible to attain. There is no reason to expect curiosity to be an exception to this rule.

Involuntary Curiosity

Although people sometimes expose themselves voluntarily to situations that they know will make them curious, it is probably more common for curiosity to arise spontaneously as a result of unintentional exposure to curiosity-inducing stimuli. The information-gap perspective predicts that curiosity will arise spontaneously when situational factors alert an individual to the existence of an information gap in a particular domain. This can occur either because the gap itself becomes salient or because the information set as a whole becomes salient and the individual recognizes that information is missing from the set. Situational factors that produce these effects include the following:

1. The posing of a question or presentation of a riddle or puzzle confronts the individual directly with missing information and is therefore perhaps the most straightforward curiosity inducer. Berlyne (1960) referred to curiosity-inducing questions as "thematic probes."

2. Exposure to a sequence of events with an anticipated but unknown resolution will almost inevitably create curiosity to know the outcome. This class of situations is exemplified by the desire to find out who wins an election or athletic event or to learn the identity of the murderer in a mystery novel. In Schank and Abelson's (1977) terms, curiosity arises from the desire to complete a "script." Such curiosity is exacerbated when an individual generates a prediction or forecast of the outcome, in which case curiosity about the outcome itself is combined with a desire to know whether the prediction was correct. The desire to know whether one's prediction was correct is closely related to White's competence motive.

3. The violation of expectations often triggers a search for an explanation (Hastie, 1984), and curiosity is frequently a major factor motivating the search. In addition to the work showing that violated expectations trigger causal attributions, recent research has shown that people tend to engage in effortful systematic, as opposed to heuristic, processing when presented with information incongruent with expectations, even when the resultant inferences have little practical importance to them (Maheswaran & Chaiken, 1991).

4. Possession of information by someone else also causes curiosity. Here, curiosity and social comparison are linked directly rather than by analogy. In some cases, another person's information set may become sufficiently salient to establish an informational reference point for oneself. Consider, for example, parents' curiosity to know the sex of a fetus when the information is known to their doctor or the burgeoning numbers of "900" telephone lines in which callers are promised that they will be the recipients of intimate secrets. Similarly, watching someone chuckle as he or she reads a news article is likely to make one curious to see the article.

5. Past attainments can serve as a reference point against which current attainments are compared. This has been shown in a number of studies of saving behavior and life satisfaction (e.g., Duesenberry, 1952). It is likely that past knowledge sets have a similar effect. Consider the enormous curiosity that is evoked by the recognition that one knew a piece of information but has forgotten it. In keeping with this prediction, Loewenstein et al. (1992) found that subjects were more curious about information that was reported to be "on the tip of the tongue" than about information that was not. Subjects were presented with a series of definitions and asked to guess the words to which the definitions applied. For words they were unable to identify, they were asked whether the word was on the tip of their tongue and to rate their feeling of knowing. The central prediction, that curiosity would be related positively to tip-of-the-tongue perceptions and feeling of knowing, was strongly confirmed.

Guessing and Feedback

The information-gap perspective implies that awareness of an information gap is a necessary precondition for experiencing curiosity. Thus, a failure to appreciate what one does not know would constitute an absolute barrier to curiosity. There is good reason to believe that such barriers are pervasive. Decision researchers have documented an "overconfidence" phenomenon (e.g., Lichtenstein, Fischhoff, & Phillips, 1982) whereby people underestimate the magnitude of gaps in their knowledge. In a slightly different vein, Charles Gettys and coauthors (Gettys, Pliske, Manning, & Casey, 1987) argued that people generally believe they have much more information about a topic than they actually do. He had subjects generate as many solutions as they could to various problems (e.g., solving the parking problem at the University of Oklahoma) and then asked them to guess how many additional good solutions to the problem existed. The typical subject generated a relatively small number of solutions but believed that he or she had come fairly close to exhausting the set of possible good solutions. Gettys et al. referred to this effect as the "fat but happy" hypothesis: Subjects have major knowledge gaps but are not aware of them. Convinced that they have generated most of the good solutions, they are unlikely to be curious about other potential ideas.

One way for people to gain an accurate perception of what they do not know is to have them make guesses and receive accuracy feedback. It is difficult to ignore or deny a gap in one's knowledge when one has guessed the answer to a question and been told that it is wrong. Without accuracy feedback, people may believe that they have guessed correctly when they have not, thus eliminating curiosity. Guessing with feedback not only may increase the salience of the gap but may create a type of Zeigarnik effect (Zeigarnik, 1927): an urge to complete successfully the task of guessing.

Consistent with this reasoning, Loewenstein et al. (1992) found that guessing combined with accuracy feedback increased curiosity. In one experiment, subjects rated their curiosity to learn the easternmost state of the United States. Half of the subjects first guessed which states were most southern,

northern, and western, whereas half did not, and half of the subjects were given the correct answer to each of these questions, whereas half were not. Neither manipulation alone had a significant effect, but the combination of guessing and feedback increased curiosity substantially. Although this study did not show a main effect for either guessing or feedback alone, a subsequent experiment did show a main effect for feedback. Subjects guessed the easternmost state three times and were told "right" or "wrong" either after each guess or after guessing all three. Few people gave the correct answer (which is Alaska; it crosses the international date line). Subjects who received feedback after each guess were significantly more curious to know the answer to the question than subjects who received feedback only after making all three guesses.

Curiosity's Combination of Intensity, Transience, and Impulsivity

Although they have not been discussed in the psychology literature, the four qualities of curiosity alluded to by Burke (1757/1958)—its intensity, transience, and association with impulsivity and the tendency for its satisfaction to disappoint—are easily explained by the information-gap perspective.

Curiosity's intensity is explained by the fact that it is a loss phenomenon; information seeking is motivated by the aversiveness of not possessing the information more than it is by the anticipation of pleasure from obtaining it. Considerable research has shown that losses have greater motivational impact than gains of comparable objective value (e.g., see Kahneman & Tversky, 1979). Theories such as White's competence perspective, which view curiosity as motivated by a desire for positive affect (e.g., a feeling of competence), naturally imply that curiosity is a relatively weak force. In contrast, drive theories and the information-gap perspective, which view curiosity as driven by the pain of not having information rather than by the pleasure of obtaining it, can account for the observed motivating power of curiosity.

Curiosity's transience is explained by the fact that curiosity requires attention, which is a limited cognitive resource (Kahneman, 1973; Treisman & Gelade, 1980). Because curiosity results from attention to an information gap, it will typically end when attention is distracted. This feature of curiosity differs from homeostatic drives such as hunger and thirst. Although one can be distracted temporarily from hunger and thirst, they will ultimately intensify if not satisfied.

Curiosity's association with impulsivity is also easily accommodated by the information-gap perspective. Research on delay of gratification has shown that people are more likely to behave impulsively—to opt for inferior immediate rewards—when failing to select the immediate reward exposes them to deprivation. For example, Walter Mischel (1974) found that when young subjects were placed in immediate proximity to candy, they were more likely to take a small piece of candy immediately instead of waiting for a large piece of candy. Presumably, seeing and smelling the candy produced a feeling of deprivation that made it difficult for them to wait. In a recent article, Steve Hoch and I presented diverse evidence supporting a link between impulsivity and deprivation and argued that this association results from the fact that delay of gratification in a given situation depends in large part on the pain one would experience if consumption were deferred (Hoch & Loewenstein, 1991). The association of curiosity with impulsivity, therefore, like the explanation for curiosity's intensity, follows naturally from the view of curiosity as a form of cognitively induced deprivation.

Finally, the disappointment often experienced when curiosity is satisfied can also be explained by the fact that curiosity is driven by deprivation. Eliminating curiosity eliminates the deprivation but leaves one in a neutral hedonic state. A similar pattern seems to be characteristic of other drives, such as hunger, that leave one in a neutral state when satisfied. But assimilating food is a more drawn out process than assimilating information; thus, with food, there is a period of pleasure when hunger is slowly diminishing. Information, in contrast, is typically assimilated almost instantly, so the transition from aversive deprivation to a neutral state is exceedingly fleeting.

Curiosity has much in common with the sex drive, which is also a powerful motivator, highly stimulus bound, and associated with impulsive behavior and disappointment. Indeed, for men, the disappointment is recognized to the point of possessing its own label: *postcoitus triste*. The sex drive also shares other characteristics with curiosity. As is true for curiosity, people sometimes put off having sex, even when it makes them feel deprived in the present, because they think it will enhance future pleasure. However, people also expose themselves to sexually stimulating materials, such as pornography, without the prospect of imminent sexual release. This raises the question of whether, contrary to the theory espoused here, there are situations in which people derive pleasure from curiosity even when they have no hope of satisfying it.

Discussion

Despite widespread recognition of its importance for education, scientific progress, and other domains of human activity, a century of research and theorizing has left large gaps in our understanding of curiosity. This is particularly true of its epistemic, specific state variant. As Kakar (1976, p. 185) noted, "epistemic behavior, or intellectual activity in search of knowledge, is a form of curiosity which is of utmost importance in the process and planning of education. Yet this is a field where our knowledge is quite scanty." Educational attainment and scientific exploration both involve specific epistemic curiosity, but most curiosity research has focused on its diversive and perceptual variants. Likewise, policies designed to stimulate curiosity in students require an understanding of state curiosity, but most recent curiosity research has investigated issues relating to trait curiosity.

In this article, I have addressed the gap in our understanding of curiosity by proposing a new account of specific epistemic state curiosity that starts with existing theoretical accounts of curiosity and integrates insights from Gestalt psychology, behavioral decision theory, and other subdisciplines in psychology. Like drive theories, the new account views curiosity as aversive; it incorporates elements of homeostatic and stimulus-based theories by assuming that curiosity is stimulated by both external and internal factors.

The new account is also consistent with the incongruity the-

orists' position that cognition can provide its own motivation even in the absence of any physiological tissue needs and with the assumption that curiosity can arise from violated expectations. However, the information-gap interpretation of curiosity parts ways with Hebb, Piaget, and Hunt when it comes to their claim that information seeking is connected to a search for an optimal level of incongruity. An information gap refers to a discrepancy between what one knows and what one wishes to know. Incongruity, on the other hand, as used by these researchers, refers to violated expectations (i.e., a discrepancy between what one perceives and what one expected to perceive). Although violated expectations are an important factor leading to the identification of knowledge gaps and, thus, to curiosity, they do not represent the only source of such gaps.

Finally, filling information gaps is an important aspect of achieving competence (White, 1959), and curiosity is certainly particularly strong when it comes to knowledge pertaining to one's own competence. However, not all curiosity can be understood as a desire to feel competent, even if one adopts the broadest possible meaning of the term.

Limitations of the Proposed Theory

The proposed theory views curiosity as occurring when an individual's informational reference point becomes elevated in a certain domain, drawing attention to an information gap. Curiosity is the feeling of deprivation that results from an awareness of the gap. However, it needs to be acknowledged that people often seek information in the absence of curiosity. In some situations, external rewards motivate information search, as in the case of a student who studies solely to obtain a high grade. Even more commonly, people seek information because they believe they will find it interesting, even though its absence is not viewed as a deficiency. Such a situation would not be classified as curiosity according to the theoretical position proposed here. Although both extrinsic rewards and intrinsic interest are important determinants of information seeking, in neither case would one expect to observe the most salient symptoms of curiosity: the intensity of motivation, transience, association with impulsivity, and disappointment when information is successfully assimilated.

Curiosity arises from the landscape of an individual's preexisting interests when one's informational reference point becomes elevated in a particular domain. Preexisting interests, by focusing attention, play an important role in determining what information is salient to an individual and, thus, which informational reference points become elevated. Interest can also provide a weak motive contributing to the accumulation of information. Because curiosity is more likely to occur and will tend to be stronger as information is accumulated, interest, in effect, primes the pump of curiosity. Therefore, a comprehensive theory of curiosity would need to explain why certain people become interested in certain topics and why certain topics (e.g., anything having to do with the self) are almost universally interesting. However, the goal of constructing such a theory is extremely ambitious. No theory that I know of provides much insight into individual differences in interests. The one area of research that one might expect to deal with this problem—that of intrinsic motivation—has been preoccupied with a single narrow issue: the effect of extrinsic rewards on intrinsic motivation. There has been a prevailing belief that extrinsic rewards tend to diminish intrinsic motivation, although a recent meta-analysis of the literature casts doubt on the validity of this central assumption (Wiersma, 1992).

Interests arise from a number of situational and dispositional factors associated with culture, socialization, age, sex, and genes. Some people are fascinated by brain teasers or physics problems, whereas others are interested in what makes people tick or in world events. The current theory does not attempt to delineate these factors but, rather, seeks to identify some situational determinants that will influence the onset and magnitude of curiosity—all else held constant—and to shed light on some of curiosity's salient characteristics.

Potential Research Directions

The information-gap interpretation of curiosity suggests several natural directions for future research. First, the notion that curiosity is a reference-point phenomenon suggests numerous predictions that have yet to be tested. For example, one important reference point for individuals is the attainments of others. If individuals adopt other people's information sets as their own informational reference points, then they should often become curious to know what others know. It would be easy to test whether an individual's curiosity increases with the knowledge that another person possesses a piece of information, all else held equal. Another untested prediction of the theory is that people will be more curious to know something if they think it is knowable or if they expect to know it in the future. Ruderman (1986) found that dieters who had previously resisted eating began to eat when they were told that they would be served food in an hour, as if knowing that they would eat in the future made them hungry in the present. It would be interesting to test whether a similar pattern would hold for curiosity.

A second potentially fruitful focus for empirical research involves the characteristics of curiosity—its transience, intensity, association with impulsivity, and tendency to disappoint—that have heretofore been ignored, and thus not examined critically, by psychologists. Transience could be examined by determining how rapidly curiosity subsides when a curiosity-inducing stimulus is removed. Impulsivity could be researched by looking at the difference between what people will pay to obtain curiosity-satisfying information immediately or at some point in the future. Finally, the disappointment hypothesis could be tested by asking people how they feel after their curiosity has been satisfied. Although the satisfaction one obtains from satisfying curiosity will undoubtedly occasionally exceed one's expectations, the prediction is that these cases will be outnumbered by those in which the information one receives is seen as disappointing.

Practical and Social Implications of the Proposed Theory

The information-gap perspective has significant implications for education. Educators know much more about educating motivated students than they do about motivating them in the first place. As Engelhard and Monsaas (1988, p. 22) stated, "historically, education research has focused primarily on the cog-

nitive outcomes of schooling" rather than on motivational factors. The theoretical framework proposed here has several implications for curiosity stimulation in educational settings. First, it implies that curiosity requires a preexisting knowledge base. Simply encouraging students to ask questions—a technique often prescribed in the pedagogical literature—will not, in this view, go very far toward stimulating curiosity. To induce curiosity about a particular topic, it may be necessary to "prime the pump" to stimulate information acquisition in the initial absence of curiosity. The new research showing that extrinsic rewards do not quell intrinsic motivation suggests that such rewards may be able to serve this function without drastically negative side effects.

Second, to stimulate curiosity, it is necessary to make students aware of manageable gaps in their knowledge. The importance of knowing what one does not know may explain the success of the "Socratic method" of teaching, which, according to Malone (1981), has the effect of "systematically exposing incompleteness, inconsistencies, and unparsimoniousness in the learner's knowledge structures" (p. 364).

The finding that curiosity increases with knowledge has several ramifications that go beyond the realm of education. First, the positive relationship between curiosity and knowledge creates a powerful impetus toward specialization. As people gain knowledge in a particular area, they are not only likely to perceive gaps in their knowledge, but those gaps will become smaller relative to what they already know. Thus, people are likely to become progressively more curious about the topics that they know the most about. The seeming ever-increasing drive toward specialization in academia may therefore reflect intrinsic as well as extrinsic incentives. Moreover, such specialization may have its origin in relatively minor and often chance differences in initial knowledge accumulation. As Arthur (1989) has pointed out, systems exhibiting increasing returns (in this case, the positive relationship between curiosity and knowledge) tend to have unstable properties whereby small perturbations in early periods produce large long-run effects.[14]

The relationship between curiosity and information gaps also has implications for social stereotyping. It is well established that people possess well-articulated social schemata and that they use these schemata to infer missing information about individuals whom they meet (Fiske, 1982; Gilovich, 1981). Thus, for example, one might assume that a Native American on a reservation is unemployed. The failure to perceive a gap in one's information, because one has filled in the gap automatically with a social stereotype, is likely to reduce or negate the amount of curiosity one experiences about the individual's actual occupational status. Lack of curiosity about others as a result of the failure to recognize information gaps may be a contributing factor to the well-documented resistance of stereotypes to change. At the same time, however, the information-gap theory suggests a possible solution to the problem. If people are made aware of their stereotypes and of the predictions they make on the basis of them, they may become curious to know whether their predictions are correct.

Finally, the proposed theoretical framework may help to explain why certain nonsanctioned exploratory behaviors (e.g., experimentation with drugs, sex, and cigarettes) are so difficult to discourage. In all of these cases, numerous factors conspire to increase the salience of the information gap for those who fail to experiment: The information set (the experience itself) is well defined, the information is relatively easy to obtain, and the individual is typically surrounded by others who already possess the information. The information-gap perspective predicts that all of these factors will strengthen the intensity of curiosity. Unfortunately, it is far easier to create such conditions than to eliminate them.

Concluding Comments

As I have attempted to highlight in this review, research and theorizing about curiosity has been largely moribund during the past two decades. Although the research on scale creation has shed light on the issue of curiosity's definition and dimensionality, other fundamental questions such as curiosity's underlying cause and its situational determinants have not been addressed. This state of affairs can be attributed to the triumph of the cognitive paradigm in psychology and to the general loss of interest in motivational phenomena such as curiosity.

The extremity of this shift in focus is evident in the substantial literature on problem solving, which has extensive applications both to cognitive development and learning and to scientific discovery. Virtually all of this research has examined the cognitive strategies that people use to solve problems (e.g., see Duncker, 1945; Mayer, 1983). Amazingly, there has been almost no research on why people are so powerfully driven to solve such problems, even though many researchers studying problem solving in the laboratory and in naturalistic settings have been struck by the intensity of individuals' efforts to solve problems in the absence of material rewards.

Although theoretical accounts of creativity, problem solving, and scientific discovery tend to emphasize the cognitive dimension, personal accounts of the scientific process often betray an important motivational component. For example, in reflecting on his discovery of shock waves, Mach wrote that "the first questions are formed upon the intention of the inquirer by practical considerations; the subsequent ones are not. An irresistible attraction draws him to these; a nobler interest which far transcends the mere needs of life" (cited in Seeger, 1970, p. 60). In a similar vein, Herbert Simon (1992) stated that through scientific inquiry, "scientists are relieved of the itch of curiosity that constantly torments them"[15] (p. 3).

Curiosity involves an indissoluble mixture of cognition and

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[14] The same mechanism could lead to significant individual differences in curiosity as a result of small initial environmental or dispositional differences. As McDougall (1918) commented, "these differences [in curiosity] are apt to be increased during the course of life, the impulse growing weaker for lack of use in those in whom it is innately weak, stronger through exercise in those in whom it is innately strong" (p. 61).

[15] Curiosity manifests itself at all levels of cognitive and emotional life. For example, the *Philadelphia Inquirer* (Rozansky, 1993) reported the predicament of a secretary who was given a mobile phone and could not muster the willpower to turn it off, even for a brief period. The *Inquirer* reported that she "hoped no one would flush while she answered a call in a stall in the second floor ladies room in Porter Hall. 'I could turn it off in there, I could. It's two minutes,' she said, 'but I'm afraid I will miss something good' " (p. D12).

motivation. As Hunt (1963) expressed it, curiosity refers to a "motivation inherent in information processing" (p. 35). Curiosity is influenced by cognitive variables such as the state of one's knowledge structures but may, in turn, be one of the most important motives encouraging their formation in the first place. Positioned at the junction of motivation and cognition, the investigation of curiosity has the potential to bridge the historical gulf between the two paradigms.

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