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The Cognitive Unconscious

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Contemporary research in cognitive psychology reveals the impact of nonconscious mental structures and processes on the individual's conscious experience, thought, and action. Research on perceptual-cognitive and motoric skills indicates that they are automatized through experience, and thus rendered unconscious. In addition, research on subliminal perception, implicit memory, and hypnosis indicates that events can affect mental functions even though they cannot be consciously perceived or remembered. These findings suggest a tripartite division of the cognitive unconscious into truly unconscious mental processes operating on knowledge structures that may themselves be preconscious or subconscious.

SCIENTIFIC PSYCHOLOGY BEGAN AS THE STUDY OF CONsciousness. Wundt, Titchener, and others who founded the earliest psychological laboratories generally assumed that the mind was able to observe its own inner workings. For this reason they relied on the method of introspection, by which trained observers attempted to analyze their percepts, memories, and thoughts, and reduce them to elementary sensations, images, and feelings (*1*). Quite quickly, however, observations in both the laboratory and the clinic suggested that mental life is not limited to conscious experience. For example, Helmholtz concluded that conscious perception was the product of unconscious inferences based on the individual's knowledge of the world and memory of past experiences. Somewhat later, Freud asserted that our conscious mental lives are determined by unconscious ideas, impulses, and emotions, as well as defense mechanisms unconsciously arrayed against them. These 19th-century ideas exemplify the notion of the cognitive unconscious—mental structures and processes that, operating outside phenomenal awareness, nevertheless influence conscious experience, thought, and action.

Scientific inquiry on conscious and nonconscious mental life was interrupted by the radical behaviorism of Watson and his followers, who argued that consciousness was nonexistent, epiphenomenal, or irrelevant to behavior. Beginning in the 1950s, however, psychology abandoned a radically behaviorist point of view in what has since come to be known as the "cognitive revolution" (*2*). Cognitive psychology comes in various forms, but all share an abiding interest in describing the mental structures and processes that link environmental stimuli to organismic responses and underly human experience, thought, and action. In this manner, cognitive theories are distinct from biological theories, whose conceptual vocabulary is limited to the structures and processes of the brain and other portions of the nervous system, and from the approach of radical behaviorism, which thinks of the behaving organism as a "black box" whose internal workings, biological or cognitive, can remain unknown (*3, 4*). Recently, cognitive psychologists have joined with colleagues from anthropology, neurobiology, computer science, linguistics, philosophy, and other fields to form cognitive science, an interdisciplinary effort to unravel the mysteries of the human mind.

One of the most salutary by-products of the development of cognitive science has been a revival of interest in consciousness (*1, 5*). Still, many psychologists who are committed to the study of conscious perception, memory, and thought have been reluctant to admit that nonconscious mental structures and processes are psychologically important. This article discusses some strands of theory and research in cognitive psychology that offer new insights into the workings of nonconscious mental structures and processes.

The Information-Processing Perspective

The classic information-processing conception of human cognition, modeled after the modern high-speed computer, includes a set of structures for storing information, as well as a set of processes by which information is transferred from one structure to another (*6*). In this model, information from the environment, transduced into a pattern of neural impulses by the sensory receptors, is briefly held in the sensory registers, one for each modality. Information in the sensory registers is then analyzed by processes known as feature detection and pattern recognition. By means of attention, information that has been identified as meaningful and relevant to current goals is then transferred to a structure known as primary or short-term memory where it is subject to further analysis. At this stage perceptual information is combined with information retrieved from secondary or long-term memory. Primary memory, which has an extremely limited capacity to process information, is considered the staging area of the cognitive system, where processes such as judgment, inference, and problem-solving take place. Information resides in primary memory only so long as it is rehearsed. On the basis of an analysis of the meaning of the stimulus input, some response is generated; and finally, a trace of the event is permanently encoded in secondary memory.

In such an approach, the term "unconscious" describes those products of the perceptual system that go unattended or unrehearsed, and those memories that are lost from primary memory through decay or displacement before they can be encoded in secondary memory. In a more substantial sense, however, consciousness is identified either with attention and rehearsal, or with the cognitive staging area that holds those percepts, memories, and actions to which attention is being directed. Thus, nonconscious mental life is identified with early preattentive perceptual processes such as feature detection and pattern recognition; or with those latent memory traces that have not been retrieved from secondary

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storage and transferred to primary memory. The implication of this view is that unattended percepts and unretrieved memories make no contact with higher mental processes, and thus cannot influence conscious experience, thought, and action. Thus, the classic information-processing model, by regarding attention and rehearsal as prerequisites for a full-fledged cognitive analysis of the stimulus, and by implicitly identifying consciousness with higher mental processes, leaves little or no room for the psychological unconscious.

Quite a different perspective on nonconscious mental life is provided by more recent revisions of information processing theory, such as Anderson's ACT* (*7*). Models such as ACT* (which stands for Adaptive Control of Thought, the asterisk marking the final version) assume a single, unitary memory store. The contents of memory are then classified into declarative knowledge structures that represent the individual's fund of general and specific factual information, and the procedural knowledge repertoire of skills, rules, and strategies that operate on declarative knowledge in the course of perception, memory, thought, and action. Furthermore, declarative knowledge can be classified as either episodic or semantic in nature. Episodic memory is autobiographical in character, and contains more or less explicit reference to the self as the agent or experiencer of some event, and the unique environmental and organismic context in which that event occurred; semantic memory is the "mental lexicon" of abstract knowledge, stored without reference to the circumstances in which it was acquired.

Whether episodic or semantic in nature, declarative knowledge is represented by a graph structure, with nodes representing concepts and associative links representing the relations between them. Nodes in this network are activated by perceptual processes that encode mental representations of external stimulus events, or by internal thought mechanisms. In either case, activation then spreads from one cognitive unit to another along the associative links, activating still other nodes in the memory network. Similarly, procedural knowledge is represented as a system of productions consisting of nodes representing the person's processing goals and the conditions under which some cognitive or behavioral action will meet them. When declarative memory structures corresponding to relevant goals and conditions are activated, any procedure that includes them will be executed. The product of such a procedure is represented in memory as another activated declarative knowledge structure.

According to models such as ACT*, consciousness is identified with a temporary storage structure known as working memory, which is similar to the primary memory of the classic model but with a much larger capacity. Working memory contains activated representations of the organism in its current environment, currently active processing goals, and preexisting declarative knowledge structures activated by perceptual inputs or by the operations of various procedures. Thus, the revised model holds that people can become aware of declarative knowledge (about themselves, their environments and processing goals, and other relevant information), and that this awareness depends on the amount of activation possessed by the representations in question. However, it also holds that procedural knowledge is not available to introspection under any circumstances. Thus, procedural knowledge appears to be unconscious in the strict sense of the term. We are aware of the goals and conditions of procedures, and the products of their execution, but not of the operations themselves. In this way, ACT* and similar revisionist models afford a much wider scope for the cognitive unconscious than did the classic statements.

Similarly, a major place for nonconscious mental structures and processes has been created by a recent variant on information-processing theory known as connectionism or parallel distributed processing (PDP) (*8*). In PDP models the conceptual analog for the human information-processing system is provided by the brain itself, and especially the synaptic connections among neurons, rather than the microchips of the high-speed computer. Whereas ACT* and similar models assume the existence of a single central processing unit (such as primary or working memory), PDP models postulate the existence of a large number of processing units, each devoted to a specific but simple task. Each unit, when activated, excites and inhibits others along a rich network of associative links. This pattern of mutual influence continues until the entire system relaxes to a steady state of activation that represents the information being processed.

It is assumed in PDP models that information about an object or event is distributed widely across the processing system, rather than localized in any particular unit. Moreover, the activation of individual processing units can vary continuously as opposed to discretely. For these reasons, it is not necessary for an object to be fully represented in consciousness before information about it can influence experience, thought, and action. In addition, traditional information-processing theories tend to assume that various perceptual-cognitive functions are bound together in a unitary processing system operating under a single set of rules and under the control of a central executive. By contrast, PDP models assume that various systems (such as those supporting perception and language, for example) operate independently and under different rules. Only some modules are assumed to be accessible to awareness and subject to voluntary control. Finally, PDP models abandon the traditional assumption that information is processed in a sequence of stages. Parallel processing permits a large number of activated units to influence each other at any particular moment in time, so that information can be analyzed very rapidly. Both the number of simultaneously active processing units and the speed at which they pass information among themselves may exceed the span of conscious awareness.

In the final analysis, PDP models of information processing assert that consciousness is a matter of time rather than activation. By virtue of massive parallelism, processing systems tend to reach a steady state very rapidly, within about a half second. At this point of relaxation the information represented by the steady state becomes accessible to phenomenal awareness. Information may also reach consciousness if the relaxation process is slowed by virtue of ambiguity in the stimulus pattern; in this case, however, the contents of consciousness will shift back and forth between alternative representations. In either case, the clear implication of the PDP framework is that unconscious processing is fast and parallel, while conscious processing is slow and sequential. Originally formulated to account for certain phenomena in perception, PDP models have also been developed for domains of language, memory, and inference in which models such as ACT* have been so successful. Although the PDP framework is relatively new, these models are important precisely because they provide a unified theoretical account of a number of psychological phenomena that have heretofore been considered to be unrelated. In contrast to multistore information-processing theories that restrict the cognitive unconscious to elementary sensory-perceptual operations, PDP models seem to consider almost all information processing, including the higher mental functions involved in language, memory, and thought, to be unconscious.

It is not possible, on the basis of data available at present, to choose between these two approaches to human information processing. Models like ACT* and PDP may apply at different levels of the cognitive system. In any event, the important point is that both classes of models appear to agree that the cognitive unconscious encompasses a very large portion of mental life. With these theoretical perspectives in mind, we may turn to specific experimental studies that illustrate the cognitive unconscious at work.

Automatic Processes

Certainly a good deal of mental activity is unconscious in the strict sense of being inaccessible to phenomenal awareness under any circumstances (*9*). In conversational speech, for example, the listener is aware of the meanings of the words uttered by the speaker but not of the phonological and linguistic principles by which the meaning of the speaker's utterance is decoded. Similarly, during perception the viewer may be aware of two objects in the external environment but not of the mental calculations performed to determine that one is closer or larger than the other. Although we have conscious access to the products of these mental processes—in that we are aware of the meaning of the utterance or the size and distance of the objects, and can communicate this knowledge to others—we have no conscious access to their operations.

Unconscious procedural knowledge of this sort appears to be innate. In fact, Fodor has proposed that the mind consists of a number of innate, domain-specific cognitive modules controlling such activities as language and visual perception, hardwired in the nervous system and operating outside of conscious awareness and voluntary control (*10*). However, other cognitive procedures appear to be acquired through experience. In the case of skill learning, the process is initially accessible to consciousness—as indicated, for example, by the novice sailor's overt or covert rehearsal of the steps involved in tying a knot—and later becomes unconscious by virtue of practice—as indicated by the inability of many musicians, athletes, and typists to describe their skills to others, and by the fact that conscious attention to them actually interferes with their performance. In other words, skills that are not innate may become routinized through practice, and their operations thereby rendered unconscious. Employing a metaphor derived from computer science, this process is described as knowledge compilation, suggesting that the format in which the knowledge is represented has been changed (*1, 11*). In this way, both innate and acquired cognitive procedures may be unconscious in the strict sense of the term.

Unconscious procedural knowledge has also been described as automatic as opposed to controlled or effortful (*12, 13*). Automatic processes are so named because they are inevitably engaged by the presentation of specific stimulus inputs, regardless of any intention on the part of the subject. In addition, automatic processes consume little or no attentional resources. It is a fundamental premise of cognitive psychology that the amount of attention that can be allocated to various activities is limited, producing a bottleneck in information processing (*14*). Thus, our ability to perform two or more tasks simultaneously is limited by the demands they make on available attentional resources. If attentional demands exceed attentional resources, the tasks will interfere with each other. Nevertheless, routinized processes consume little or no attentional capacity (*13*). For this reason, it is possible for expert typists to carry on a conversation while transcribing even complicated material, or for skilled drivers to negotiate the road while listening to the radio news.

Nevertheless, automatic processing may have some negative consequences as well. The typist may not remember what he has typed, and the driver may not remember landmarks that she has passed along the way. Effective memory depends to a great extent on the amount and type of cognitive activity devoted to the event at the time of perception, and some automatized processes—however well suited they are for other tasks—may not encourage good encodings. For example, Spelke and her colleagues performed an experiment in which subjects were asked to read unfamiliar prose material and take dictation at the same time (*15*). On initial trials, performance on both tasks was quite poor. After 6 weeks of practice, however, the subjects were able to take accurate dictation and read simultaneously with at least 80 percent comprehension. Nonetheless, later tests showed that the subjects were generally unable to recall the words they had transcribed, and had little or no awareness of how the word lists had been structured. Thus, the dictation task, once automatized, no longer interfered with reading for comprehension; but neither did it yield highly memorable encodings of the dictated material.

The fact that automatized processes consume little or no attentional capacity has important consequences for consciousness. In the first place, of course, automatic processes are themselves unconscious, in that the person has no introspective access to their principles of operation—or even the fact that they are in operation at all. Thus, fluent speakers of English agree that the phrase "the big red barn" is grammatically better than the phrase "the red big barn," even though they are unable to articulate the underlying syntactical rule that guides such decisions. Similarly, in the social domain, speakers may like one face more than another, while being unable to say exactly why they have that preference. A large number of social judgments and inferences, especially those guiding first impressions, appear to be mediated by such unconscious processes (*16*).

Experiments on automaticity are important because they indicate that a great deal of complex cognitive activity can go on outside of conscious awareness, provided that the skills, rules, and strategies required by the task have been automatized. They expand the scope of unconscious preattentive processes, which were previously limited to elementary perceptual analyses of the physical features of environmental stimuli. Now it is clear that there are circumstances under which the meanings and implications of events can be unconsciously analyzed as well. Thus, people may reach conclusions about events—for example, their emotional valence (*17*)—and act on these judgments without being able to articulate the reasoning by which they were reached. This does not mean that cognitive activity is not involved in such judgments and inferences; it only means that the cognitive activity, being automatized, is unconscious in the strict sense of that term and thus unavailable to introspective awareness.

Subliminal Perception

Although the procedural knowledge structures guiding thought and action are unconscious, the declarative knowledge structures on which they operate are ordinarily available to consciousness. Thus, it should be possible for people to notice and describe the salient features of an object or event, even if they cannot articulate the way in which those features have been integrated to form certain judgments made about it. However, another implication of automatization is that the processes in question may operate on declarative knowledge structures that are not themselves fully conscious. According to the classic information-processing model, preattentive processes act on stimulus information before it has been encoded in short-term memory—which, according to the model, is the locus of conscious awareness. But, in the classic model, complex analyses of meaning were excluded from this domain. However, it now appears that complex analyses, once routinized, take on many of the properties of preattentive feature detection and pattern recognition. Accordingly, it may be possible to perform meaning analyses on information, which is not itself accessible to conscious awareness, by means of automatized, unconscious procedural knowledge.

This possibility raises the question of subliminal perception. Researchers in classic psychophysics assumed that each modality was associated with an absolute threshold (or limen), represented by the weakest detectable stimulus. By means of the method of limits, in which the intensity of a weak stimulus is increased until it is reliably detectable, and the intensity of a strong stimulus is decreased until it is no longer detectable, the limen is given by the smallest intensity

that can be detected 50 percent of the time. However, the probability of detection is directly related to stimulus intensity both above and below the threshold, suggesting that subthreshold stimuli are still processed by the sensory-perceptual system. Subliminal perception refers to the possibility that stimuli too weak to be consciously detected nonetheless have an impact on perceptual and cognitive functioning.

Subliminal perception is often studied by means of a tachistoscope, which can present stimuli for intervals (for example, less than 5 milliseconds) that are too brief to be consciously perceived. A number of investigators have found that such stimuli reappear in the subject's subsequent dreams (the Poetzel phenomenon) and otherwise affect the person's performance on some experimental task. Subliminal perception is also at the root of the so-called New Look in perception, which attempted to integrate the study of perception with that of personality and motivation. For example, Bruner and his colleagues, among others, reported that subjects had different thresholds for identifying "taboo" and neutral words (*18*). The clear implication of these findings was that stimuli could be analyzed for their emotional significance as well as for certain physical features and patterns before they reached awareness. This aspect of mental life may be called preconscious processing (*19*). However, it is not the processing itself that is preconscious. Rather, the term preconscious describes the declarative knowledge that is subject to cognitive processing.

For obvious reasons, subliminal perception is of considerable interest to the advertising community; it has also been of considerable interest to psychoanalysts and others who believe that people defend against potentially threatening percepts, memories, ideas, and impulses by excluding them from awareness (*20*). It has also been very controversial. Almost since the beginning, a variety of methodological critiques have sought to demonstrate that stimuli cannot be processed for meaning unless they have been consciously identified (*1, 21*). Recently, however, a number of compelling demonstrations of preconscious processing have appeared in the literature. For example, investigators have employed a priming protocol in which a stimulus word (called the prime) is followed by another word (called the target), and the subject has to decide whether the target is a meaningful word. Such judgments are facilitated when the prime is also a word. However, Marcel and others arranged to present the prime followed by a second stimulus (called the mask) consisting of randomly arranged letters, before the target appeared. The timing is such that subjects are unable to reliably detect masked primes. Nevertheless, such preconscious primes facilitate performance on the judgment task (*22*). Since lexical decisions obviously require some degree of semantic processing, it appears that meaning analyses are performed on stimuli that are themselves outside of conscious awareness.

Studies by Kunst-Wilson and Zajonc, among others, indicate that preconscious processing affects emotional as well as semantic judgments (*23, 24*). Many of these demonstrations rely on the mere exposure effect, which refers to the fact that repeated presentation of a previously unfamiliar stimulus tends to increase its attractiveness (contrary to folklore, familiarity does not necessarily breed contempt). Although the original effect was obtained with clearly perceptible stimulus materials, the finding holds even though the presentations are so brief (as little as 1 millisecond) as to render the stimuli undetectable by the subjects. Thus, by virtue of prior preconscious presentation, subjects come to prefer stimuli that they do not recognize as familiar.

It may be that preconscious declarative knowledge can only be subject to processing by unconscious, automatized procedures. After all, it seems contradictory to suggest that people can intentionally and deliberately process information of which they are unaware. Conscious awareness should be a logical prerequisite of conscious control. But it does seem that preconscious declarative knowledge is subject to analysis by unconscious procedural knowledge. Such information-processing activity would be nonconscious in a double sense: neither the stimuli themselves, nor the cognitive processes that operate on them, are accessible to phenomenal awareness. Such doubly nonconscious processes nevertheless exert an important impact on social interaction. Through the operation of routinized procedures for social judgment, for example, we may form impressions of people without any conscious awareness of the perceptual-cognitive basis for them.

Results such as these are important for cognitive theory because they indicate that a great deal of information processing takes place outside of working memory. Apparently, perceptual processing automatically activates preexisting semantic memory structures corresponding to the features of the stimulus event, as well as related nodes by virtue of spreading activation. If some of these nodes correspond to the goals and conditions of various production systems, certain procedures will be executed as well. However, none of this requires the involvement of working memory. Thus, in contrast to the implications of the classic model for human information processing, a great deal of complex cognitive activity can be devoted to stimuli that are themselves outside of phenomenal awareness.

Preconscious processing can influence the ease with which certain ideas are brought to mind, and the manner in which objects and events are perceived and interpreted. For example, priming influences perceptual fluency by facilitating the perception of prime-related features in the target stimulus. Thus, when a prime and a target are identical it is easier to identify the target than when they are different; similarly, identification is easier when the prime and the target belong to the same conceptual category or are otherwise semantically related. A similar sort of influence may obtain when other judgments are to be made about the target. Consider, for example, a complex target (say, the name of a familiar person) some of whose features are socially desirable (for example, kind and warm) while others might be considered socially undesirable (for example, dull and unintelligent). Now, assume that presentation of the target has been preceded by a prime carrying wholly negative connotations. Activation from the memory node representing the prime will spread to nodes representing other undesirable attributes. Then, when the target is presented, activation will spread to nodes representing both desirable and undesirable features. However, more activation will accrue to nodes representing socially undesirable features, leading to a more negative impression of the target than would otherwise have occurred. Moreover, if the nodes representing the various features are also conditions of production systems whose goals have been activated in working memory, perceptual fluency may have tangible effects on the perceiver's actions with respect to the target.

Although the recent demonstrations of preconscious processing seem compelling, they do not necessarily constitute an empirical argument in favor of subliminal advertising and other forms of surreptitious social influence. On the affirmative side, it seems that preconscious processing can activate automatized procedural knowledge, and thus affect the way that consumers think about products, or perhaps even their actual buying behavior. The magnitude of these effects even may be increased because preconscious processing obviates the possibility of conscious countercontrol of these effects. Priming occurs automatically regardless of whether the prime is accessible to conscious awareness, but the automatic effects of consciously perceptible stimuli may be obviated by whatever processing strategies are deliberately deployed to analyze and respond to them.

On the negative side, many priming effects are extremely short-lived—activation dissipates as fast as it spreads—so that they may not last long enough for the person who views an advertisement on television, say, to get to the grocery store. Furthermore, the effects of preconscious stimulation may be mitigated to some degree by restrictions on the nature of the cognitive processing that it can instigate. For example, a recent series of experiments by Greenwald and his colleagues required subjects to evaluate the affective connotations of various target words (*24*). Preconscious presentation of positive and negative words speeded judgments when the prime and target were congruent (that is, both positive or both negative); however, no facilitation was obtained when the prime consisted of a positively toned phrase consisting of two negatively toned words (for example, "enemy fails"). Thus, preconscious processing may be limited to relatively simple meaning analyses, and may only operate to amplify preexisting tendencies. Finally, in order for preconscious processing to affect action it is necessary that relevant goal structures be activated in procedural memory. Thus, even if subliminal perception were theoretically possible, consumers would not be led to choose a particular brand of soft drink unless they were thirsty and intended to purchase some refreshments.

Implicit Memory

Because preconscious processing appears to be mediated by the activation of relevant mental representations already stored in memory, the question is raised whether analogous effects may be observed in memory itself. That is, just as there are palpable effects on experience, thought, and action of stimuli that cannot be consciously perceived, so there may be similar effects of events that cannot be consciously remembered. One such effect was observed in an experiment by Nelson on savings in relearning (*25*). The subjects were asked to memorize a list of paired associates consisting of a number and a word arbitrarily linked together. Four weeks later they were given tests of cued recall and recognition for these items. When forgotten pairs were presented along with entirely new pairs on a second set of learning trials, previously seen items that were not consciously recognized nonetheless had an advantage measured in performance on subsequent learning and memory tasks.

Some of the most dramatic instances of nonconscious memory appear in cases of the amnesic syndrome (sometimes called Korsakoff's syndrome), which results from bilateral damage to the medial temporal lobe (including the hippocampus) and diencephalon (including the mammiliary bodies) of the brain. Patients suffering from this disorder (which may reflect a number of different etiologies, including chronic alcoholism) manifest a gross anterograde amnesia, meaning that they cannot remember events that occurred since the onset of the brain damage; other intellectual functions remain relatively intact. Although it was originally thought that amnesic patients were unable to encode traces of new experiences, it now appears that their memory deficit is much more selective. For example, amnesic patients can learn new cognitive and motor skills, as well as new vocabulary items and other factual information; however, they appear unable to remember the episodes in which they acquired this knowledge (*26, 27*). In other words, the amnesic syndrome appears to impair the encoding of new episodic memories, while sparing procedural knowledge and semantic memory (*28*).

More recent evidence suggests that some aspects of episodic memory are preserved in these patients (*29*). Consider a case in which subjects are asked to study a list of familiar words and are asked to recall the words shortly thereafter. Compared to the performance of intact subjects, amnesic patients show gross impairments in memory. Different results are obtained when the subjects are asked to identify briefly presented words or to complete a word stem or other fragment with a meaningful word. Not surprisingly, intact subjects show superior performance on trials where the correct response is a word that had appeared on the previously studied list, compared to trials where the correct response is an entirely new word. This advantage of old over new items reflects a sort of priming effect of the previous learning experience. However, amnesic subjects also show normal levels of priming, despite the fact that they cannot remember the words they studied. In addition, Schacter and his colleagues provided amnesic patients with obscure factual information in a question-and-answer format (for example, "What job did Bob Hope's father have?—Fireman"). On later test trials, the patients were able to correctly answer questions on the material, but could not remember the circumstances under which they had acquired the information—a phenomenon known as cryptomnesia or source amnesia (*30*).

Priming and source amnesia show that task performance may be affected by residual memories of prior experiences, even though those experiences are not accessible to conscious recall. On the basis of results such as these, Schacter and others have drawn a distinction between explicit and implicit memory (*29, 31*). Explicit memory requires the conscious recollection of a previous episode, whereas implicit memory is revealed by a change in task performance that is attributable to information acquired during such an episode. An increasingly large literature from both patient and nonpatient populations indicates that people can display implicit memory without having any conscious recollection of the experiential basis of the effect. Implicit memory effects are conceptually similar to subliminal perception effects, in that both reveal the impact on experience, thought, and action of events that are not accessible to conscious awareness. However, the two effects should be distinguished. In contrast to subliminal perception, the events contributing to implicit memory effects were clearly detectable by the subject, attention was devoted to them, and they were represented in phenomenal awareness at the time they occurred. Still, both sets of phenomena illustrate the psychological unconscious, by showing perception and memory outside of phenomenal awareness.

Hypnotic Alterations of Consciousness

Although the domain of the psychological unconscious would seem to be exhausted by automatic processes, subliminal perception, and implicit memory, a somewhat different perspective is offered by the phenomena of hypnosis (*32–34*). Hypnosis is a social interaction in which one person, the subject, responds to suggestions offered by another person, the hypnotist, for experiences involving alterations in perception, memory, and action. One common aspect of these experiences is an alteration in phenomenal awareness, but the changes in consciousness are not precisely the same as those seen in automaticity, subliminal perception, and implicit memory.

For example, in hypnotic analgesia, hypnotized subjects may fail to experience discomfort from a normally painful stimulus (*35*). This reduction in pain is not mediated by placebo effects, endogenous opiates, or by the tranquilizing effects of hypnotic relaxation. Given the traditional models of human information processing, hypnotic analgesia might be interpreted as involving a failure to attend to and process normally painful stimuli. However, a number of findings indicate that the pain stimulus has been adequately registered by the sensory-perceptual system. For example, psychophysiological indices such as heart rate respond to painful stimuli, even though the subject reports feeling little or no pain. Similarly, perceptual representations of the pain stimulus may be accessed by the hidden

observer technique developed by Hilgard (*36*). After analgesia has been successfully established, the hypnotist attempts to communicate with a "hidden part" of the person that may have recorded the actual stimulus state of affairs. Under these circumstances, many analgesic subjects give pain reports comparable to those collected under normal conditions. The hidden observer is a metaphor for these nonconscious mental representations of stimulus input, and the means by which they may be accessed. The success of the technique indicates that analgesic subjects may be unaware of stimuli that have been thoroughly processed by the sensory-perceptual system.

Within the domain of memory, similar anomalies of awareness may be noted in posthypnotic amnesia (*37*). Following appropriate suggestions, subjects may fail to remember the events and experiences that transpired while they were hypnotized. However, the critical memories may be recovered after administration of a prearranged signal to cancel the amnesia suggestion. This property of reversibility clearly shows that posthypnotic amnesia reflects a disruption of memory retrieval, rather than a failure of encoding or loss from storage. However, the retrieval disruption is selective. For example, amnesic subjects may still make use of procedural and semantic knowledge acquired during hypnosis, even though—as in the phenomenon of posthypnotic source amnesia (*30*)—they do not remember the circumstances under which this knowledge was acquired. Even within the domain of episodic memory the effects of amnesia are selective. For example, subjects who are amnesic for a word list memorized during hypnosis will nonetheless be more likely to produce list items as word associations, category instances, or in word-fragment completion tasks, compared to carefully matched words that had not been memorized (*38*). Thus, amnesic subjects are affected by memories that have been adequately encoded, but are not accessible to conscious retrieval.

Alterations in subjective awareness occur in other hypnotic phenomena as well. For example, it may be suggested that after hypnosis has been terminated, the subject will engage in a particular action in response to a prearranged cue. Subjects responding to such posthypnotic suggestions often exhibit a dual lack of awareness: they may be unaware of the fact that they are performing the behavior that has been suggested; or, in the event that they do notice the activity, they may be unaware of the origins of their behavior in the hypnotist's prior suggestion (*39*). Although such behavior often strikes an observer as compulsive and involuntary, it is not automatic in the technical sense used in information-processing theory (*40*). In a recent experiment, for example, subjects were asked to search for two different digits simultaneously in strings of numbers presented on a computer screen. One search task was given as a posthypnotic suggestion and covered by amnesia, the other as a nonhypnotic instruction without amnesia. Even on trials where the suggestion and instruction were not in conflict, the subjects showed a tradeoff such that each search task interfered with the other. Thus, although the posthypnotic suggestion was executed outside of awareness, it nonetheless consumed attentional capacity.

The interpersonal and motivational context in which hypnotic phenomena arise renders interpretation of them difficult. From the perspective of information-processing approaches to cognitive psychology, they seem to make a prima facie case for a different type of nonconscious mental structures and processes than those indicated by automatic processing, subliminal perception, and implicit memory. For example, posthypnotic suggestion seems superficially similar to unconscious procedural memory, at least insofar as it shares the IF (cue)–THEN (response) structure of other procedural knowledge. However, posthypnotic responses are obviously not innate stimulus-response connections; nor have they had the opportunity to become automatized through routinization and practice; finally, their execution consumes attentional resources. Still, response to posthypnotic suggestions takes place outside of phenomenal awareness. Thus it appears that there are circumstances in which complex, deliberate, attention-consuming processes may operate nonconsciously.

Just as posthypnotic suggestion seems to expand the domain of nonconscious mental processes, hypnotic analgesia and posthypnotic amnesia appear to expand the domain of nonconscious mental structures. Although the registration of the pain stimulus outside phenomenal awareness would seem somewhat analogous to subliminal perception, it is important to note that the stimulus itself is in no sense subliminal. Analgesic subjects fail to feel the pain of stimuli whose intensity and duration are more than sufficient to produce that experience under nonhypnotic conditions. Similarly, the results of experiments on posthypnotic amnesia are reminiscent of the distinction between explicit and implicit memory. Again, however, there is a difference. In the standard demonstrations of implicit memory, the memories involved often are permanently inaccessible to conscious recollection: for example, there are no known circumstances in which patients suffering the amnesic syndrome are able to remember the experiences they have forgotten. In contrast, posthypnotic amnesia is easily reversible, so that the inaccessibility of the critical memories is only temporary.

Unconscious, Preconscious, and Subconscious

The results of these and other experiments, conducted in a wide variety of circumstances and with many different types of subjects, lead to a provisional taxonomy of nonconscious mental structures and processes constituting the domain of the cognitive unconscious (*34, 41*). One thing is now clear: consciousness is not to be identified with any particular perceptual-cognitive functions such as discriminative response to stimulation, perception, memory, or the higher mental processes involved in judgment or problem-solving. All of these functions can take place outside of phenomenal awareness. Rather, consciousness is an experiential quality that may accompany any of these functions. The fact of conscious awareness may have particular consequences for psychological function—it seems necessary for voluntary control, for example, as well as for communicating one's mental states to others. But it is not necessary for complex psychological functioning.

More specifically, there are, within the domain of procedural knowledge, a number of complex processes that are inaccessible to introspection in principle under any circumstances. By virtue of routinization (or perhaps because they are innate), such procedures operate on declarative knowledge without either conscious intent or conscious awareness, in order to construct the person's ongoing experience, thought, and action. These mental processes, which can be known only indirectly through inference, may be described as unconscious in the strict sense of that term.

In principle, declarative knowledge is available to phenomenal awareness, and can be known directly through introspection. Traditional information-processing analyses seem to imply that conscious access to declarative knowledge is a matter of activation. If a knowledge structure is activated above some threshold, it is conscious; if not, it is not conscious. There is the further implication that declarative knowledge structures activated at subthreshold levels are essentially latent. However, it is now clear that procedural knowledge can interact with, and utilize, declarative knowledge that is not itself accessible to conscious awareness. The phenomena of subliminal perception and implicit memory, then, suggest a category of preconscious declarative knowledge structures. Unlike automatized procedural knowledge, these percepts and memories would be

available to awareness under ordinary circumstances. Although activated to some degree by current or prior perceptual inputs, and thus able to influence ongoing experience, thought, and action, they do not cross the threshold required for representation in working memory, and thus for conscious awareness.

In addition to unconscious cognitive rules and skills operating on declarative representations and preconscious declarative representations that serve as sources of spreading activation, the phenomena of hypnosis and related states seem to exemplify a category of subconscious declarative knowledge. These mental representations, fully activated by perceptual inputs or acts of thought, above the threshold ordinarily required for representation in working memory, and available to introspection under some circumstances, seem nevertheless inaccessible to phenomenal awareness. In the 19th century, Janet described such structures as dissociated from conscious awareness (*32, 34, 42*). On the basis of his clinical studies of hysteria and other forms of psychopathology, he developed a theory of psychological automatism that anticipated in many respects current notions of modularity and parallelism. Such dissociative phenomena are of theoretical interest wherever they occur, because they imply that high levels of activation, although presumably necessary for residence in working memory, are not sufficient for conscious awareness.

Writing in the *Principles of Psychology* almost a century ago, William James suggested that the key to the consciousness is self-reference: "The universal conscious fact is not 'feelings exist' and 'thoughts exist' but '*I* think' and '*I* feel' " [(*43*), p. 226, emphasis added]. In other words, in order for ongoing experience, thought, and action to become conscious, a link must be made between its mental representation and some mental representation of the self as agent or experiencer—as well, perhaps, as some representation of the environment in which these events take place. These episodic representations of the self and context reside in working memory, but apparently the links in question are neither automatic nor permanent, and must be actively forged. In cases of subliminal perception and the amnesic syndrome they appear not to be encoded in the first place; in cases of implicit memory observed in normal subjects, they appear to have been available at one time, but no longer; in certain phenomena of hypnosis, they appear to be temporarily set aside. Without such linkages certain aspects of mental life are dissociated from awareness, and are not accompanied by the experience of consciousness.

One achievement of contemporary cognitive psychology is a clear theoretical framework for studying the nonconscious mental structures and processes that interested Helmholtz, Freud, James, and Janet. Such theories have led to the development of new experimental paradigms, and the improvement of old ones, that tentatively reveal a tripartite classification of nonconscious mental life that is quite different from the seething unconscious of Freud, and more extensive than the unconscious inference of Helmholtz. Now work must begin to clarify the nature of the processes by which cognitive and motoric procedures are automatized, the scope of preconscious processing of subliminal percepts and implicit memories, the process of self-reference, and the nature of dissociation.

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44. This work is based on research supported in part by National Institute of Mental Health grant MH-35856, an H. I. Romnes Faculty Fellowship from the University of Wisconsin, and the Program on Conscious and Unconscious Mental Processes of the John D. and Catherine T. MacArthur Foundation. I thank J. C. Chorny, L. A. Cooper, W. Fleeson, K. I. Forster, M. F. Garrett, R. Hastie, E. R. Hilgard, I. P. Hoyt, L. Canter Kihlstrom, S. B. Klein, L. Nadel, R. Nadon, L. A. Otto, P. A. Register, D. L. Schacter, D. Tataryn, B. A. Tobias, and J. Wood for helpful discussions and comments during the preparation of this manuscript.

After Insulin Binds

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Three recent advances pertinent to the mechanism of insulin action include (i) the discovery that the insulin receptor is an insulin-dependent protein tyrosine kinase, functionally related to certain growth factor receptors and oncogene-encoded proteins, (ii) the molecular cloning of the insulin proreceptor complementary DNA, and (iii) evidence that the protein tyrosine kinase activity of the receptor is essential for insulin action. Efforts are now focusing on the physiological substrates for the receptor kinase. Experience to date suggests that they will be rare proteins whose phosphorylation in intact cells may be transient. The advantages of attempting to dissect the initial biochemical pathway of insulin action include the wealth of information about the metabolic consequences of insulin action and the potential for genetic analysis in *Drosophila* and in man.

INSULIN IS ONE OF THE BEST STUDIED VERTEBRATE PROTEINS. The first protein to be completely sequenced (*1*) and chemically synthesized (*2*), it has been the protein used in seminal analyses of hormone processing (*3*) and quantitation (*4*). Structures of the crystal forms of insulin have been elucidated in remarkable detail (*5*), the genes for insulin have been cloned (*6*), and structural mutations have been discovered (*7*). In 1980, human insulin became the first recombinant protein to be made available for clinical use (*8*). This impressive history is matched by a half-century of fundamental discoveries pertinent to the physiological effects of insulin on glucose homeostasis and intermediary metabolism (*9*).

In this article, I summarize some of the current approaches to the study of the biochemical mechanism of insulin action. The review is limited to recent advances in our understanding of the structure and function of the insulin receptor and the view that protein phosphorylation and dephosphorylation of seryl, threonyl, and tyrosyl residues are the central mechanisms by which insulin affects cell function.

Insulin

Insulin is considered a vertebrate hormone although insulin-like polypeptides have also been identified in invertebrates [(*10*) and this review]. The physiological effects of insulin in mammalian systems include stimulation of hexose, ion, and amino acid uptake (*11*); modification of the activities of rate-limiting enzymes such as glycogen synthase, hormone-sensitive lipase, and pyruvate dehydrogenase by net dephosphorylation (*9*); phosphorylation of seryl residues in proteins such as ribosomal S6, acetyl coenzyme A carboxylase, and adenosine triphosphate (ATP) citrate lyase (*9*); regulation of gene expression for a small number of regulatory enzymes (thus far) (*12*); redistribution of membrane proteins such as the glucose transporter and the insulin-like growth factor II (IGF-II) and transferrin receptors (*13*); and promotion of cell growth (*14*). Many of these effects are tissue- or cell-specific and involve only a discrete subset of proteins. The chronology varies. Transcription of the gene encoding phosphoenolpyruvate carboxykinase is inhibited within seconds of the addition of insulin, whereas growth promotion requires hours of exposure (Table 1). Many of the rapid actions of insulin, such as stimulation of hexose transport and alterations of enzyme activities, do not depend on synthesis of new proteins or nucleic acids. Even this incomplete summary of the actions of insulin, however, invokes seryl and threonyl phosphorylations and dephosphorylations of cytosolic and mitochondrial proteins, membrane translocations with the likelihood of cytoskeletal protein involvement, and nuclear action. If a simplifying assumption is made that a single mechanism is involved in initiating all of these biological effects, and certainly there is precedent in the multihormone-sensitive adenylate cyclase system for a reductionist approach, then the analysis should begin with the first essential and common step in insulin action, interaction with the insulin receptor.

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