IMPLICIT MEMORY FUNCTION DURING ANESTHESIA

J.F. Kihlstrom
University of Arizona

Well, here we are again. In 1989, this Symposium convened in Glasgow to discuss the effects of general anesthesia on awareness and memory. By definition, of course, adequate general anesthesia prevents conscious awareness: properly anesthetized patients are unresponsive to surgical events as they occur, and cannot remember them after the operation is over; moreover, they have no memory of experiencing pain or other distress while the operation was in progress. It is as if they were unconscious the entire time. At the same time, there were nagging suspicions that things might not be as they appeared to be. As early as 1947, only five years after the introduction of muscle relaxants made lighter planes of anesthesia possible,[1] Harroun and her colleagues[2,3] warned that some patients might consolidate memories of emotionally arousing surgical events, at least -- raising, by implication, the horrifying possibility that patients might have complete awareness of surgical events, and perhaps surgical pain as well, but be unable to indicate their situation by virtue of curare-induced paralysis; and, furthermore, that conscious access to traumatic memories for surgical events was subsequently lost through some repression-like process.

Of course, this possibility is mitigated to some extent by the observation in cases of local or regional anesthesia, or conscious sedation, that many surgical procedures, in and of themselves, are not particularly traumatic: in fact, patients are often keenly interested in what is going on. But it does underscore the fact that at least five elements of surgical anesthesia were conceptually distinguishable: sedation, analgesia, loss of awareness, lack of response, and amnesia. In any event, the incidence of retrospective awareness of surgery is reassuringly low.[4,5] But that does not mean that surgical events are not processed *outside* of awareness, or that traces of these events do not persist in memory, influencing the patients' postsurgical experience, thought, and action.

The Story So Far

In fact, long before the 1st Symposium convened, there were hints that this might be the case. There were Cheek's reports of the hypnotic recovery of memories of surgical events,[6] and of course Levinson's famous staging of a surgical crisis.[7] There were also studies, by Pearson and others, of the effectiveness of therapeutic suggestions administered during anesthesia[8-10] -- effects that logically depend on some level of perception and memory. But there was also the work of Trustman and Dubovsky that suggested quite strongly that evidence for auditory perception during anesthesia either didn't exist, or was an artifact of improper technique[11] -- a conscious imitation of the conclusion of Simon and Emmons about sleep learning, published more than two decades earlier.[12] Then, just when you thought it was safe to go back into the surgical suite, there appeared Tunstall's paper on the isolated forearm technique,[13] followed by Millar and Watkinson's finding of recognition memory for words presented during surgery,[14] and Bennett's groundbreaking work on postoperative motor responses established during anesthesia[15] (since confirmed by some,[16,17] but not others[18]), and we were off and running.

But something else happened: the field of memory changed, and we now had theoretical grounds for thinking that such effects just might be possible. In 1971, when this literature was reviewed by Cherkin and Harroun, the psychology of memory was focused on the distinction between short- and long-term memory, and on the problem of memory consolidation. But beginning in the mid-1970s several theoretical shifts began to take place. First, Craik and Lockhart introduced levels of processing theory as an alternative to multistore models of memory.[19] Then, Tulving argued that most failures of memory were attributable to disruptions of retrieval, rather than of encoding and storage.[20] Finally, and most important for our purposes, a number of investigators converged on what has come to be known as *implicit memory*.[20-22] As Schacter[24] described it, explicit memory involves the conscious recollection of some previous episode, usually in response to a query that makes more or less specific reference to some particular past event -- as in free or cued recall, or recognition. Implicit memory, by contrast, refers to any effect on the person's experience, thought, or action that is attributable to a past event, regardless of whether the subject is asked to remember something from the past. For example, the subject might show savings in learning a previously studied wordlist.

A very popular demonstration of implicit memory comes in the form of priming effects: after subjects have been presented with a list of words, they are more likely to perceive those words under conditions of brief tachistoscopic presentation or to use these words when completing stems and fragments, or to produce them as free associations or category instances; or they can recall factual information even though they forget where they learned it (a phenomenon known as source amnesia). Schacter showed that explicit and implicit memory were dissociable in at least three senses. First, people can show preserved implicit memory in the absence of explicit memory, as in the case of the amnesic syndrome,[25] posthypnotic amnesia,[26] or normal aging.[27] Second, it can be shown that variables either affect one form of memory but not another (what is known as a single functional dissociation), or affect the two forms of memory in different directions (a double functional dissociation). Third, it is often the case that explicit and implicit memory are stochastically independent, in that the fate of an item in implicit memory is independent of its fate in explicit memory.

Now, as Schacter and I argued in Glasgow, the anesthesia results described above can be given a retrospective interpretation in terms of spared implicit memory.[28] In light of the findings obtained in other forms of amnesia, it seemed possible that we would find a dissociation in anesthesia as well: that explicit memory would be impaired (by definition), but implicit memory spared. The first experiment to put this proposition to a formal test, by Eich and his colleagues, yielded negative results.[11,29] But the same idea also occurred to others, and some of them were luckier. Thus, Stolzy, Couture, and Edmonds found that subjects rated infrequent words that had been presented during anesthesia to be more familiar than controls;[30] and Goldmann found evidence of source amnesia for factual information presented during surgery.[31] On the other hand, other investigators, including Stolzy et al. themselves[32] also obtained negative results. For example, Standen and her colleagues found no evidence of priming in children who heard a set of category instances during their surgery.[33] And finally, studies of response to therapeutic suggestions are relevant to the issue of implicit memory, because memory for the suggestions is obviously implicit in positive response to them. While Bonke[34] and Evans and Richardson[35] found significant positive effects of therapeutic suggestions administered during anesthesia, Woo[36] and Boeke[37] did not.

We heard about additional studies in Glasgow, again some positive and some negative, and there has been further work reported afterwards. Roorda-Hrdličková[38] found priming with a category-instantiation task, a finding subsequently confirmed by Jelicic.[39,40] Similarly, Block, Ghoneim, and their colleagues found a priming effect on word-stem completion and an exposure effect on ratings of nonsense words, but no priming effect on category instantiation.[17] Their subjects also showed significant recognition of critical targets, which seems to undermine the claims of explicit/implicit dissociation; however, as in the Millar and Watkinson study, it seems likely that performance on their recognition task was mediated by implicit memory. Cork, Schacter, and I got a priming effect on free associations in one experiment,[41] but not in another.[42] (for a further discussion of this research, see Cork, Kihlstrom, & Schacter, this volume). Winograd, Sebel, and their colleagues found no change in preferences for music exposed to patients while they were anesthetized;[43] a more recent study found no evidence of priming on any of three tasks (homophone spelling, free association, or category instantiation).[44] Furlong saw positive responses to therapeutic suggestion,[45] as did Münch and Zug,[46] McLintock and colleagues,[47] and Williams and Sweeney[48] but Block, Ghoneim, and their colleagues did not.[49] Wood and colleagues conducted an ingenious study in which children undergoing tonsillectomy and adenoidectomy heard therapeutic suggestions in English (which they could understand) or French (which they could not): outcomes were more favorable with the English tape (compared to white noise), but the differences were not significant.[50] This literature on adequate general anesthesia is supplemented by studies of the effects of subanesthetic doses of nitrous oxide,[51] and of the administration of benzodiazepines[52] such as diazepam[53,54] and midazolam.[55]

Table 1 shows a rough box score, consisting of studies published since the Trustman/Dubovsky review (I know that box scores are not in vogue, but I don't think the field is quite ready for a formal meta-analysis; for alternative box scores, see the debate among Bennett, Eger, Ghoneim, and Merikle, this volume). The reports are divided into the three main paradigms used in this research: motor expressions of implicit memory, (mostly verbal) expressions of cognitive or affective change, and response to therapeutic suggestion. By sheer count, the ayes would seem to have it (barely) over the nays, but there are some subtleties that the box score obscures. For example, the studies of motor responses give mainly positive results, but even then only for a few subjects; by contrast, the studies of cognitive and affective responses yield smaller effects, when they do yield effects, but for more subjects. Moreover, there are failures to replicate within as well as between laboratories, which suggests that the positive results are not the product of unknown factors idiosyncratic to some research group. Finally, in the Block/Ghoneim study, evidence of preserved implicit memory was obtained on three tests (counting recognition), but not the fourth. So, there's work to be done in resolving these puzzles.

Table 1. Results of Studies Published Since 1977

Negative	Positive
MOTOR	
Jansen	Bennett
	Goldmann
	Block
COGNITIVE-AFFECTIVE	
Eich	Stolzy, 1986
Standen	Goldmann
Stolzy, 1987	Roorda-Hrdlicková
Winograd	Jelicic
Block (1/4)	Block (3/4)
Cork	Kihlstrom
Westmoreland	
THERAPEUTIC	
Boeke	Bonke
Woo	Evans & Richardson
Block	Furlong
Wood	Münch & Zug
	McLintock
	Williams & Sweeney

Implicit Memory in Nighttime Sleep

Another puzzle concerns the fate of implicit memory in sleep. Sleep is a common euphemism for anesthesia: in parallel with anesthesia, we know someone has fallen asleep because they fail to respond to environmental stimulation, and because they cannot remember events that occurred during the interval in question. Now, sleep and general anesthesia involve quite different brain states, but in the present context a comparison of the two effects on memory is potentially interesting. Recall that in dismissing the possibility of post-surgical memory, Trustman, Dubovsky, and Titley drew inspiration from Simon and Emmons' earlier critique of the sleep-learning literature, which concluded that sleep learning was possible to the extent that the subjects remained awake! As in the case of the anesthesia literature, however, tantalizing results continued to pop up, in both Eastern European and Western laboratories.[56,57] For example, habituation and classical conditioning are both possible during sleep, as is the response to conditioned stimuli established while awake.[58,59]

In a remarkable series of studies, Evans and his colleagues[60-62] found that some subjects could respond to cues like "Whenever you hear the word *itch*, your nose will feel itchy until you scratch it" delivered in alpha-free Stage REM sleep; response carried over into subsequent REM periods, and even into subsequent nights of testing, although the subjects had no awareness of these cues, or their responses, while awake. This outcome represents a form of implicit memory, and was one of the inspirations for Bennett's studies of anesthesia. In a followup experiment, subjects who had responded positively to behavioral cues were presented with verbal paired-associates of the form "A is for Apple". Upon awakening, they had no memory for the stimuli; but when presented with a series of words beginning with *A* and asked to check those they found familiar, they were more likely to choose words that had been presented -- a variety of recognition memory that, as in the anesthesia experiments of Millar and Watkinson and Block and Ghoneim, may have been mediated by implicit memory.

Unfortunately, these results are ambiguous. For example, Perry imposed additional controls (eg, sham cues and blind ratings) on Evans' sleep-suggestion experiment, and failed to replicate the earlier results.[63] And Evans reported that the paired associates that later proved to have been learned had been followed by a train of alpha activity in the EEG -- a clear index of cortical arousal.[62] In line with the conclusions of Simon and Emmons, Koukou and Lehmann found that sleep learning does not occur without such periods of arousal, raising the question of whether it should be called sleep learning at all.[64]

A doctoral dissertation completed by James Wood in the University of Arizona Sleep Research Laboratory is the first to conduct a formal comparison of explicit and implicit memory during sleep.[65] In one session, sleeping subjects (in Stage 2 or Stage REM) were presented with paired-associates of the form *tortoise-hare*, composed of a homophone target (hare, hair) and a disambiguating cue; in another session, they were presented with associates of the form *metal-gold*, consisting of a category label and a category instance. An attempt was made to present each list five times, but the tape was turned off whenever a subject showed any indication of arousal from sleep (movement artifact, EEG alpha, SEMs) or evidence of shifts in sleep stage. Subjects were awakened two minutes after presentation was completed and given tests of explicit and implicit memory. In one test, they were read a homophone and asked to spell it; in the other, they were read a category name and asked to generate a number of instances. Control subjects, who heard the tape while lying awake in a darkened room, showed clear priming effects on both tasks; but experimental subjects, who heard the tape while asleep, showed absolutely no evidence of priming.

One study does not a firm conclusion make, but Wood's results are very provocative. They suggest that implicit memory might be spared in general anesthesia, as some of us have found, but not in sleep. Why this should be is not clear. If we can get implicit memory in anesthesia, why shouldn't we get it in sleep? Or, put another way, if we can't get it in sleep, why should we ever think we can get it in anesthesia? Of course, it might very well be that uncontrolled arousals occur in anesthesia as well as in sleep, and that learning takes place during them. In many experiments, as in our own, the stimulus tape is played for a very long time, providing ample opportunity for adventitious arousal to occur. Thus, better means -- and, frankly, better criteria -- are needed for monitoring anesthetic depth. But even if positive results are shown to be mediated by momentary arousals from anesthesia, the point remains that the patients who show us implicit memory don't show us explicit memory. So, the evidence of explicit-implicit dissociations in surgical patients remains theoretically and practically interesting, even if it should be shown eventually that implicit memory is spared by virtue of momentary changes in plane of anesthesia.

The Nature of Implicit Memory

So anesthesia does appear to preserve implicit memory, at least under some circumstances. The next question is: What form of memory is implicit memory? Accordingly, let us turn our attention to the nature of the explicit/implicit dissociations themselves, and how they can be understood theoretically.[66] The phenomenological viewpoint which I tend to favor construes explicit and implicit tests as different expressions of memory, one involving conscious recollection -- the subjective experience that one is remembering an event from one's personal past -- and the other one not.[67,68] After all, memory is always manifested as the influence of some past event on future experience, thought, and action. When this influence is accompanied by conscious recollection of an event, or when the setting for this influence demands such awareness, the memory is explicit; otherwise, it is implicit. Explicit and implicit memory differ, in my view, in terms of the degree to which the knowledge retrieved from memory contains a representation of the self as the agent or experiencer of some event.[69] My own usage of these terms comes close to the distinction between direct and indirect measures of memory, proposed by Johnson and Hasher[70] and adopted by Richardson-Klavehn and Bjork.[71] Direct memory tasks make reference to some target event in the personal experience of the subject, and specify (more or less clearly) the spatiotemporal context in which it occurred ("What did you see when I showed you the list? Were there any animal names? Was *penguin* one of the words?"). Indirect tasks, perceptual identification or free association for example, merely ask the subject to engage in some task, thus providing an opportunity for performance to be affected by past experience. However, I wish to avoid the direct-indirect vocabulary for at least two reasons. First, it is task-oriented, rather than experience-oriented. Second, for reasons that will become clearer later, I wish to maintain a parallel between memory and perception, and the term direct perception already has a technical meaning that forbids use of a term like "indirect perception". The explicit-implicit vocabulary seems best, because perception and memory are implicit in the subject's task performance.[72,73]

One thing is fairly clear, and that is that explicit and implicit memory differ qualitatively, not just quantitatively. The evidence for this is found in the properties of functional dissociation and stochastic independence discussed earlier. If implicit memory were just a supersensitive variant on explicit memory, then the two forms of expression would be affected by the same variables, and performance on explicit and implicit tasks would be correlated with each other. But that's not the case: elaborative processing at the time of encoding affects explicit, but not implicit memory; and shifts in the language, modality, or physical properties of the item between study and test affect implicit, but not explicit memory. Now, I hasten to add that these results come from studies of repetition priming. The situation for other forms of priming (eg, orthographic, phonological or semantic) is not so clear, but the effects with repetition are enough to make a case for qualitative differences.

A persisting question is whether implicit memory merely involves the activation of pre-existing knowledge, or can support new learning as well.

According to the *activation view* proposed by Rozin, Mandler, and others,[74,75] perception involves two processes: activation, an automatic process that contacts pre-existing memory representations and achieves coherence among their constituent features; and elaboration, an effortful process that relates the activated items to other memory structures, including prior knowledge, other items in the study set, and spatiotemporal context. Mandler's view is that activation and integration support implicit memory, while elaboration is required for explicit memory. Thus, particular circumstances may prevent subjects from performing the elaborative activity required to encode a trace accessible as an explicit memory; yet traces from the automatic activation process will persist as implicit memories.

A rival *processing view* has been proposed in somewhat different forms by Johnson,[76,77] Jacoby,[78,79] and Roediger.[80,81]

Johnson's *multiple-entry modular* (MEM) theory argues that memory is composed of three subsystems: the sensory system processes such features as brightness, location, and movement; the perceptual system records the relationship of objects to each other; and the reflective system records the results of internal processes such as thinking and comparing; there are also distinguishable sub-subsystems, but they do not concern us. While many experiences will generate entries into all three systems, some will encode traces in only one or two systems, putting constraints on the circumstances in which that information can be retrieved. Many implicit (or indirect) memory tasks skirt the reflective module, and depend entirely on information stored in the sensory and perceptual systems.

Roediger's *transfer-appropriate procedures* framework relies on a distinction between "conceptually driven" processes such as elaboration, organization, and reconstruction, and "data-driven" processes that do little more than analyze the surface features of a stimulus item. It also depends on the principle of encoding specificity, by which memory is best when the procedures engaged at the time of retrieval are the same as those engaged at the time of the original encoding. From these two assumptions it follows that subjects who are prevented from engaging in conceptually driven processing at the time of encoding cannot show memory in response to a conceptually driven test like free recall; but they can display memory in response to a data-driven test like perceptual identification.

Jacoby's *process dissociation* framework has its origins in the difference between conceptually driven and data driven processes, but has now evolved into a distinction between processes that are automatic and those that are controlled. According to Jacoby, every memory task has both an automatic component, which occurs as a passive consequence of stimulation, and is independent of cognitive capacity, and a controlled component, which reflects the person's intentions and is limited by available attentional resources. Implicit memory, in this view, reflects the contribution of the automatic component to task performance.

A third rival, the *memory systems* view, also comes in at least two forms, as proposed by Squire[82,83] and by Schacter and Tulving[84,85] (Johnson's MEM model might also be construed in terms of memory systems). Squire follows Winograd[86] in distinguishing between declarative (factual) and procedural (skill) knowledge; more recently, procedural knowledge has been characterized merely as "nondeclarative", in recognition of its heterogeneity. Schacter and Tulving expand on Tulving's[87] original distinction between two forms of declarative knowledge -- semantic (context-free) and episodic (autobiographical) memory -- to include a third memory system, the perceptual representation system, which represents the form and structure, but not the meaning or function, of perceptual objects. The perceptual representation system is essentially independent of other memory systems, and is disconnected from consciousness. In either case, the argument is that these memory systems have different neural substrates, which can be selectively damaged or impaired. According to Squire, priming and other forms of implicit memory reflect the preservation of the nondeclarative knowledge system; similarly, Schacter and Tulving argue that repetition priming, and other memory effects on perceptual tasks, are mediated by information stored in the perceptual representation system.

Now, this is not the place to review research intended to test these rival ideas, or the competitors within each camp, although there is plenty of work to review. Each viewpoint has its assets and liabilities, and there haven't been any particularly critical tests (although considerable effort has been devoted to discovering the limits of implicit memory for new, as opposed to pre-existing, associations). Eventually, at least some of these rivals may be reconciled with each other. What is most important in the present context is that each viewpoint can be used to explain dissociations between explicit and implicit memory, including those observed in anesthesia. Thus, for example, we might assume that general anesthesia limits the ability of the person to perform those elaborative, reflective, conceptually-driven, or controlled processes deemed necessary to encode consciously accessible memories of specific experiences. However, it may very well spare the activation, sensory-perceptual, data-driven, or automatic processes that underlie priming. Alternatively, we can assume that anesthesia temporarily disrupts the brain systems involved in processing declarative knowledge, and especially episodic memory, but leaves intact the nondeclarative memory system, and especially the perceptual representation system, that supports priming. I hasten to add that none of the theorists cited here have offered a theoretical explanation of implicit memory following surgical anesthesia. I am only sketching what their explanations might look like, were they inclined to do so.

But it should be noted that this account places strict limitations on the form that implicit expressions of memory can take in general anesthesia. To select an example, if anesthetic agents disrupt semantic and episodic memory, and leave the perceptual representation system intact, then we would expect to see only those forms of priming that are based on the perceptual properties of the stimuli in question -- what they look like, rather than what they mean or what they do. Thus, we would expect to see repetition priming, which depends on the perceptual similarity between the prime and the target, but not semantic priming, which depends on conceptual similarity. Moreover, we would expect to see priming reduced, if not abolished, if subjects receive a visual test of memory following auditory presentation. Finally, we would not expect to see the sorts of discriminative responses to instruction observed by Bennett, which require the capacity to analyze the meaning of the spoken words; nor would we expect to find specific responses to the wording of therapeutic suggestions, although such suggestions might have beneficial effects simply by virtue of their prosody. We don't have the body of data that would allow us to test these hypotheses definitively yet. But the exponential increase in research on this topic since 1977, including those studies presented at or stimulated by our last Symposium, coupled with the many papers presented at the 1992 meeting, suggest that perhaps we are approaching that point.

Implicit Memory, Implicit Perception, and the Question of Awareness

Three years ago, we only had hints. Now we have more and firmer evidence, although admittedly the data is mixed, that at least under some circumstances, surgical events can leave traces in memory that can influence postsurgical experience, thought, and action.

It should be understood, of course, that the preservation of implicit memory does not necessarily imply that patients are aware of surgical events while they are ostensibly anesthetized. We are concerned with implicit memory, but there are two routes to get there. In the one case, subjects lose explicit memory for events of which they were aware at the time they occurred. This is what happens in the amnesic syndrome, or posthypnotic amnesia, or aging memory. In the other case, subjects lack explicit memory precisely because they were *not* aware of the events when they happened.

In this latter instance, implicit memory is a byproduct of implicit perception.[88] In proposing the concept of implicit perception, I draw a parallel with the concept of implicit memory. By analogy, explicit perception refers to the person's conscious perception of some object or event in the current (as opposed to the past) stimulus environment, while implicit perception refers to any change in experience, thought, or action that is attributable to some element in the current stimulus field, even in the absence of conscious awareness of that event. Admittedly, it is sometimes difficult to draw a clear line between implicit perception and implicit memory -- if for no other reason than that memory is the residual byproduct of perceptual activity; moreover, implicit perception is commonly displayed on implicit memory tasks. Still, there are instances of unconscious influence that seem to involve perception rather than memory. Examples are to be found in the so-called 'subliminal' perception associated with degraded stimuli that are too weak, or too brief, to be consciously perceived, or conditions where the subject's attention is directed elsewhere; they are also to be found in cases of 'blindsight' associated with damage to the striate cortex. These may be considered examples of preconscious processing, where the subject is, for whatever reason, prevented from engaging in the sorts of processing necessary to bring an event to conscious awareness. (In other cases, such as the dissociative disorders comprising classic 'conversion' hysteria[89] or the perceptual disorders associated with hypnosis, I see evidence of *sub*conscious processing.[90] That is, complex processing occurs, but the representations are still inaccessible to phenomenal awareness.)

General anesthesia may be another condition that permits only preconscious processing, impairing explicit perception (and thus denying conscious awareness) but sparing implicit perception, and thus leaving traces of the past expressible as implicit memories. If so, this only underscores the question of the limits of implicit memory following surgical anesthesia. Greenwald has recently argued that there are severe limitations on the degree to which unattended stimuli can be processed.[91,92] For example, evaluative judgments can be primed by a single word (eg, *enemy* or *loses*) whose connotations are congruent with the target, but not by a two-word phrase (eg, *enemy loses*) whose connotations are the opposite of those of its constituent words. Preconscious processing can encompass the physical features of stimulation (perhaps analogous to what is held in Schacter's perceptual representation system) and a limited analysis of denotative and connotative meaning. More complicated, more intelligent analyses require correspondingly more attentional resources, of which the anesthetized subject may well be deprived. Detailed study of implicit memory effects can provide valuable information about the extent of information processing possible during general anesthesia. We need to know the extent to which implicit memory can transcend modality shifts, and the degree to which semantic priming can meet Greenwald's 'two-word challenge' and other manifestations of complex meaning analyses.

But implicit memory is one step away from implicit perception, and so we need on-line measures of perceptual processing in order to firmly resolve this issue. Of course, the isolated forearm technique aside, the condition of general anesthesia, muscle relaxation and all, effectively prevents patients from communicating what is going on inside their heads. Accordingly, psychophysiological measures of information processing, including (but not limited to) EEG methods like the event-related potential (ERP), are going to be increasingly important in this research. The so-called cognitive components of the ERP, such as N100 (indicating the direction of attention), N200 (the detection of a mismatch), P300 (revision of mental models), N400 (semantic mismatch) and the readiness potential and contingent negative variation (preparation to respond) are especially critical in this regard. (Of course, the ERP and other psychophysiological measures can be used to provide nonverbal assessments of implicit memory as well as implicit perception.[93]) Unfortunately, as in the case of sleep,[94] there are few relevant studies in the literature; and the programming of most clinical monitoring devices does not facilitate this kind of research. Some steps in this direction already have been taken by Plourde and Picton, who have studied the N100 and P300 waves during induction of anesthesia, surgery, emergence, and recovery;[95] but much remains to be done.

Along the same lines, the question of information-processing outside of awareness has been raised with respect to the persistent vegetative state (PVS) often observed following severe head injury. Although PVS is usually construed as an eyes-open state of unconsciousness, the possibility of implicit perception may be investigated through psychophysiological techniques.[96] A substantial number of PVS patients eventually regain consciousness,[97] so the possibility of implicit memory must also be considered.

For now, however, we can be pleased with the start that we have made. The reconceptualization of the problem of surgical awareness in terms of implicit memory seems to have caused a kind of sea-change in the field, and opened up a number of new directions for research. We can hope to see continued use of available paradigms for the study of implicit memory after general anesthesia, as well as the application of the new technologies of cognitive psychophysiology for the study of implicit perception during surgery itself. As we continue our work, we might find out that we were right, that information-processing of some sort goes on while patients are deeply anesthetized, and that this finding is of theoretical and practical significance. Alternatively, we may find out that we were wrong, and that the appearance of information processing is an artifact of uncontrolled arousal. In the final analysis, it doesn't matter what the answer is. What matters is that we find out.

Perhaps, as some argue, the onus is on those who take an affirmative position on this question. Indeed, that has always been the case, and we can be glad that there are some who will pursue this issue in the spirit of open inquiry. In 1985, the question of awareness and memory in anesthesia was closed. By 1989, when this Symposium convened in Glasgow, it was wide open, partly owing to the evidence of implicit memory in amnesic patients. In this context, it is worth remembering the history of the amnesic syndrome. It was once thought that anterograde amnesia was a failure of consolidation, such that amnesic patients couldn't learn, and couldn't display memory. Then some experimenters started getting evidence that learning and memory were spared, at least to some extent. At first, people didn't know what to do: the finding was inconsistent with everything we thought we knew about memory. One response was to dismiss the evidence as uncontrolled clinical observation. Another was to attribute evidence of learning to incomplete amnesia. But then the evidence got better, and now our understanding of both memory and amnesia has changed entirely.

It is this new understanding of memory, combined with the odd clinical anecdote and experimental finding, that has revived the issue of memory and awareness during anesthesia. Maybe in 1995, when this Symposium convenes in Rotterdam, the issue will be closed again, and maybe it will stay closed for good. But at least the question will have been addressed by experimental research, instead of by argument from authority. That's how good science works.

Author Notes

The point of view represented here is based on research supported in part by Grant #MH-35856 from the National Institute of Mental Health. I thank Terrence Barnhardt, Randall Cork, Lawrence Couture, Jennifer Dorfman, Elizabeth Glisky, Martha Glisky, Lori Marchese, Susan McGovern, Sheila Mulvaney, Robin Pennington, Michael Polster, Victor Shames, Lyn Turkstra, Michael Valdessari, and James Wood for their comments.

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MEMORY AND AWARENESS IN ANESTHESIA

Peter S. Sebel (Editor in Chief)
Emory University School of Medicine, Atlanta, U.S.A.

Benno Bonke
Erasmus University, Rotterdam, The Netherlands

Eugene Winograd
Emory University, Atlanta, U.S.A.

P T R Prentice Hall, Englewood Cliffs, NJ 07632

Memory and awareness in anesthesia / Peter S. Sebel, editor in chief ;
Benno Bonke, Eugene Winograd, [editors].
p. cm.
Includes indexes.
ISBN 0-13-489873-7
1. Anesthetics--Psychotropic effects--Congresses. 2. Anesthesia--Psychological aspects--Congresses. 3. Memory--Effects of drugs on--Congresses. 4. Awareness--Congresses. I. Sebel, Peter.
II. Bonke, Benno, 1951- III. Winograd, Eugene.
[DNLM: 1. Anesthesia, General--psychology--congresses. 2. Memory--drug effects--congresses. 3. Awareness--drug effects--congresses.
4. Suggestion--congresses. WO 275 M5332 1993]
RD82.M453 1993
617.9'6--dc20
DNLM/DLC
for Library of Congress 93-3793
CIP

A Simon & Schuster Company
Englewood Cliffs, New Jersey 07632

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ISBN 0-13-489873-7

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Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-489873-7

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
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Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*