Memory and Awareness in Anaesthesia
Edited by Benno Bonke, William Fitch and Keith Millar

Anaesthesia, amnesia, and the cognitive unconscious

JOHN F. KIHLSTROM AND DANIEL L. SCHACTER

University of Arizona, Amnesia and Cognition Unit, Department of Psychology, University of Arizona, Tucson, Arizona 85721, USA.

The purpose of analgesia and anaesthesia is to render the surgical patient insensitive to pain. Analgesia accomplishes this without a general loss of consciousness. Analgesic drugs apparently operate on the peripheral nervous system and essentially block the transmission of pain impulses, or other afferent impulses that may be interpreted as pain signals, to higher cortical centres. Thus, the analgesic patient retains sensation in other modalities, such as vision and audition; and can feel pain in bodily loci other than those to which the analgesic agent has been applied. In contrast, general anaesthetics, as their name implies, operate directly on the central nervous system, and result in a general loss of consciousness that affects sensory awareness in all modalities and at all body loci.

Nevertheless, the anecdotal literature contains persistent claims that events that transpire in the surgical theatre are, or may be, perceived by the anaesthetized patient; and that this sensory/perceptual activity may leave persisting traces in memory. Under ordinary circumstances, these memories are held to be inaccessible to conscious recollection. But it is claimed that they can be brought into awareness by special means, such as hypnosis or a barbiturate interview. Furthermore, it is claimed that these traces can influence the patient's experience, thought, and action outside of awareness.

The story to 1977

The history of this claim goes all the way back to the beginning of chemical anaesthesia. In the very first public demonstration of ether, by the dentist Morton in 1846, the patient was heard to mutter during the surgery, and reported afterwards that he had experienced considerable pain. The autobiography of the great surgeon George Crile contains a case from 1907 in which a surgical resident recited the history of an anaesthetized patient – only to have the patient repeat his words, virtually verbatim, several days later [1].

Such cases are, thankfully, few and far between, and may have reflected nothing more interesting than levels of analgesia that were inadequate for surgery. There is an extensive literature on the effects of *sub*anaesthetic doses of anaesthetics on information-processing [2,3], but this literature is not relevant to our current concerns precisely because the subjects retain some degree of conscious awareness during the studies. For the purposes of this paper, we are concerned only with the possibility of information-processing during adequate planes of surgical anaesthesia – with 'adequacy' defined in terms of the patient's lack of both bodily response to surgical events (e.g., incision by scalpel), felt pain, and postoperative recollection of these events; that is, when the patient is apparently unconscious.

In this regard, a new dimension was added to the problem by Cheek [4-6], who investigated a number of surgical patients who had experienced a poor course of postoperative recovery. When these patients were hypnotized, Cheek reported that they recalled negative statements that had been made about them, during surgery, by members of the surgical team. The apparent success of hypnosis in eliciting memories of surgical events in adequately anaesthetized patients, and the apparent effects of these memories on their post-surgical experience, suggested that perception of, and memory for, surgical events might be more prevalent that previously believed.

The concerns expressed by this sort of anecdotal evidence have led to the appearance of a number of studies of the problem. A little more than a decade ago, Trustman et al. [7] reviewed seven case series and the results of seven formal investigations. For example, Faithfull [8] reported that only five of 1,328 anaesthetized patients had any memory of surgical events, and only one of these was able to recollect the events in any detail. Similarly, Wilson and Turner [9] queried women who had undergone Caesarian section about their experiences, verifying their reports against the surgeons' recollections. Of 150 patients, only three showed any degree of accurate recall; however, another 46 reported memories of dream-like experiences that bore some resemblance to actual events. So there seems to be very little by way of conscious recollection of surgical events, provided that the patients have been adequately anaesthetized to begin with.

However, alternate means of testing may yield somewhat different results. Certainly, the most notorious case series in the literature is that of Levinson [10], who staged a bogus crisis during surgery in 10 patients. None of these patients had any post-surgical recall of the incident, in line with the findings of other studies [8,9]. However, when subsequently interviewed under hypnosis, four patients quoted the anaesthetist's remarks verbatim, while another four became highly agitated. Levinson's study strongly suggests that the bogus crisis was perceived by at least some patients despite their anaesthetized state, and preserved in memory, although those memories might only be recoverable by means of special techniques.

So far as early experimental studies are concerned, Lewis et al. [11] played a tape containing a poem, the sound of a firebell, and a list of 15 low-frequency words to 10 subjects who underwent general anaesthesia without surgery. Tests of free recall and free association gave no evidence of memory for these materials. Similarly, Dubovsky and Trustman [12] presented paired-associates of the form, "A is for Apple" to 36 surgical patients, including a placebo control group. Neither a yes-no test of recognition for the stimulus letters, nor a four-alternative forced-choice recognition test for the response words, yielded any evidence of memory.

As if these negative findings were not enough, Trustman et al. [7] identified a number of more or less elementary methodological problems with the studies they reviewed. For example, few investigators had conducted their studies in a double-blind fashion, thus opening the door to a host of demand characteristic and experimenter effects. Moreover, the experimental studies generally failed to include baseline testing conditions or untreated control groups that would permit confident inferences about what had occurred during surgery. Much of the anecdotal evidence is based on retrospective reports of surgical events that are themselves difficult to verify, with respect to the events themselves or the 'depth' of anaesthesia at the time they occurred. And experimental rigour is threatened by the difficulty in providing surgical patients, as opposed to volunteer subjects, with a standard dose of a standard anaesthetic cocktail.

Trustman et al.'s review of the anaesthetic literature contained deliberate echoes of another review, published by Simon and Emmons [13] more than two decades earlier, of the literature on sleep learning. Examining the case and experimental literature in that area that had appeared since 1917, Simon and Emmons argued that none of the reports were convincing. In particular, the literature was confounded by the problem of establishing that the subjects were truly asleep – a problem analogous to that of establishing the adequacy of surgical anaesthesia. Simon and Emmons concluded, in essence, that sleep learning was possible to the extent that subjects stayed awake. Similarly, Trustman et al. concluded that "as experimental control is increased, auditory perception during general anaesthesia is less likely to be found" [7, p.94].

The backdrop for renewed research activity

As with Simon and Emmons' [13] review of sleep learning, the review by Trustman et al. [7] rather left the question of perception of, and memory for, events occurring during surgical anaesthesia at the level of the provocative anecdote. Nevertheless, over the past decade or so there has been a spate of studies that raise once again the question of information processing during surgical anaesthesia, and the post-surgical influence of memory for surgical events [for other recent reviews, see 14-18].

These more recent studies emerge from a background of research that shows that at least some information-processing functions remain intact, or at least operative to some degree, despite adequate levels of surgical anaesthesia [14-17]. Evidence for this conclusion comes from a wide variety of sources, including studies of event-related potentials (ERPs) in human subjects, and classical conditioning in non-human animals. If there were no ERPs, and no evidence of classical conditioning, there would be little reason to argue that surgical events could be perceived and remembered.

At the same time, intact ERPs and conditioned responses do not by themselves mean that all, or most, or even many, forms of cognitive activity are possible during anaesthesia. For example, the auditory ERP is a very complex response, with a number of different components [19,20]. Components arising within the first 10 ms reflect brainstem activity, those arising within 10-100 ms the activity of the primary auditory cortex, and those arising after 100 ms the activity of the cortical association areas. This is important, because studies by Jones and his colleagues [21] suggest that while early components of the ERP are unaffected by anaesthetic agents, the later, more cognitive, components exhibit a clear dose-related response. Similarly, conditioned responses can be established in almost any organism that has a nervous system, including decorticate animals [22,23]. But this extremely primitive form of learning should not be equated with the higher cognitive processes involved in intelligent perception, memory, and thought.

One thing is clear: whatever may be perceived during surgical anaesthesia is not recalled very well in the postoperative period [24-27]. However, this does not mean that nothing is perceived; nor does it mean that traces of surgical events do not remain available in memory. Let us consider, first, whether it would ever be possible to document perception during surgical anaesthesia at all. Perception has to do with forming a mental representation of the current stimulus environment. We know when someone has perceived an event because they can detect, locate, and describe it accurately. But these sorts of overt behaviours are clearly impossible in an adequately anaesthetized patient – except, perhaps, in applications of the isolated forearm technique, in which one arm is isolated from the effects of neuromuscular blocking drugs [28]. For this reason, the evidence for perceptual processing *during* surgical anaesthesia is based almost entirely on patients' *post*-surgical performance on various experimental tasks, most of which involve learning and memory.

This is perfectly reasonable, since memory is the trace of perceptual activity: without perception of some sort, there will be no memory. But the absence of memory does not mean the absence of perception. From a strictly logical point of view, surgical events may be adequately perceived, but subsequently lost to a kind of anterograde or retrograde amnesia. Something of this sort occurs in 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 mammillary bodies). When presented with a word or a picture, such patients can read or describe or evaluate the item perfectly well; but after a short period of distraction they are unable to remember what they have seen. Something similar happens when hypnotized subjects are asked to study a list of words, and then receive a suggestion for posthypnotic amnesia. Even though they mastered the list completely in hypnosis, virtuoso subjects will be unable to remember the words until the amnesia suggestion has been cancelled by a prearranged reversibility cue. By analogy, it may be that general anaesthesia leaves the patient's sensory and perceptual functions largely intact, but somehow impairs the formation of a permanent memory trace. From the standpoint of someone about to undergo surgery, this leaves open the horrible possibility that surgical patients are completely aware of what is happening to them during surgery, while the anaesthetic drugs produce an amnesia that effectively precludes postoperative recollection of their experiences. At a more theoretical level, the implications of the analogy are that the results of memory testing may give misleading evidence about what was perceived on-line. In any event, if we are forced by circumstances to rely on memory for evidence of what has been perceived, that evidence, when negative, will always be somewhat equivocal.

Given the fact that surgical patients cannot interact behaviourally with their environments, probably the only direct evidence for perceptual processing during anaesthesia will come from studies of event-related potentials, which do not require any overt behaviour on the part of the subject [for general reviews, see 19,20,29-32]. For example, the component known as P300 (a positive spike occurring about 300 ms after the stimulus) is elicited by unexpected events, while the N400 wave appears in response to the occurrence of semantic incongruity. Thus, the fate of P300, N400, and similar late, cognitive ERP components can give us some insight into what information patients can process during adequate surgical anaesthesia.

Implicit memory in amnesia

Let us now consider further the possibility that general anaesthesia produces an anterograde amnesia that affects memory for surgical events. As noted earlier, the evidence is clear that patients do not consciously remember these events. But just as the failure of conscious recollection does not necessarily imply a prior failure of conscious perception, neither does it imply a complete failure of memory. It is entirely possible that surgical events are perceptually processed, at least to some degree, that residual traces of this perceptual activity are encoded and remain available in memory storage, and that these memories can influence the patient's post-surgical experience, thought, and action – all outside of conscious awareness. In order to understand how this might be so, let us return to the two cases of amnesia discussed earlier: the amnesic syndrome and posthypnotic amnesia.

In a study of posthypnotic amnesia [33], a group of highly hypnotizable subjects memorized a list of 15 unrelated words, to a criterion of two perfect repetitions. Then they received a suggestion that upon awakening from hypnosis, they would be unable to remember the words they had learned, or even that they had learned any words at all, until the suggestion was cancelled. Upon arousal, the subjects received a test of free recall, on which they showed a dense amnesia. Next they were administered a free-association test, in which the experimenter presented a stimulus word and they were to report the first three responses that came to mind. Half the stimuli were selected to have one of the list items as a high-probability response; the other half targeted stimuli that had not been learned. Of course, the stimulus-response probabilities were matched between the critical and neutral lists. As it happens, the amnesic subjects were much more likely to give critical than neutral items as word-association responses. This is a priming effect of the previous learning experience. So, despite the failure of the amnesic subjects to show much conscious recall, the fact that they showed priming indicates that a memory trace of some sort was stored, and affected performance on some cognitive task [for reviews of other studies with similar effects, see 34-36].

Similar priming effects occur in patients with the amnesic syndrome [for reviews, see 37,38]. For example, such patients will fail to recall or recognize words (e.g., TABLE) that they have studied, but they will show priming effects of the study session when asked to complete word stems or word fragments; e.g., TAB__ [39,40]. As another example, patients who have studied paired associates comprising familiar English idioms (e.g, SOUR-GRAPES) and then cued with the stimulus term will produce the correct response when asked to produce the first word that comes to mind, but not when asked to use the stimulus as a cue to remembering targets from the study list [41].

On the basis of this sort of evidence, Schacter and Graf [37, 41,42] have drawn a distinction between explicit and implicit memory. Explicit memory requires the conscious recollection of a previous episode, including (in the canonical case) the spatio-temporal context in which the event occurred, and the self as the agent or experiencer of the event. Implicit memory is revealed by a change in task performance that is attributable to information acquired during such an episode. Thus, when a person who studied the paired-associate WINDOW-REASON, responds with REASON when asked to remember what was paired with WINDOW, he or she is showing explicit memory. When the same subject produces REASON when presented with WINDOW and asked to say the first word that comes to mind, he or she is showing implicit memory.

An increasingly large literature from both patient and non-patient populations indicates that people can display implicit memory without having any conscious recollection of the experiential basis of the effect [37,43]. Thus, dramatic dissociations between explicit and implicit memory have been observed in hypnotized subjects [34-36], neurological patients with amnesic syndrome [37], and psychiatric patients with post-ictal amnesia following

ECT [44]. In each case, explicit memory is dramatically impaired, while implicit memory is wholly spared. This leads us to speculate whether other amnesias, such as those observed following a night's sleep or adequate general anaesthesia, might also show an explicit-implicit dissociation.

Of course, all of these demonstrations of implicit memory effects have been obtained in subjects who were consciously aware of the critical events at the time they occurred. As perceptual processing is likely to be impaired during anaesthesia, implicit memory effects might not be observed. However, several studies have demonstrated reliable implicit memory effects under conditions in which initial encoding of target materials is diminished or restricted in various ways. For example, non-semantic encoding tasks (e.g., counting vowels and consonants in target words) produce robust priming on implicit tests, and poor recall and recognition on explicit tests [45-47]. In a study by Eich [48], word pairs that biased the low-frequency interpretation of homophones (e.g., taxi-FARE) were presented on the unattended channel in a dual-task auditory shadowing paradigm. Eich found that these unattended pairs biased or primed subsequent performance on a test in which subjects were required to spell presented and non-presented words (e.g., FAIR vs. FARE) – even though explicit recognition of the words was at chance levels. Similarly, Kunst-Wilson and Zajonc [49] found that brief (1 ms) presentation of geometric shapes produced a reliable preference for previously presented items on a test in which subjects indicated which of two shapes they liked better. Yet explicit recognition of the shapes did not exceed chance. These studies thus indicate that implicit memory can be observed even under extremely impoverished encoding conditions.

Although the encoding conditions in the foregoing studies were probably not as degraded as those in general anaesthesia, there is also a mounting body of evidence for what we might call, by analogy to memory, implicit perception [for reviews, see 43,50; for a contrary opinion: 51]. The evidence we have in mind comes from experiments of the sort commonly labelled 'subliminal' perception. In a now classic experiment by Marcel [52], subjects were asked to perform a lexical decision task in which one word (the prime) is followed by another word (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, and especially when the prime and the target are related in some way – a phenomenon known as semantic priming. Marcel interpolated another stimulus known as a 'mask' and consisting of randomly arranged letters, between prime and target. The timing was such that subjects were unable to perceive the prime. But even primes that were masked affected lexical decision. As semantic priming obviously requires some degree of semantic processing, it is apparent that meaning analyses can be performed on stimuli that are themselves inaccessible to conscious perception.

Marcel's essential findings, although still somewhat controversial, have now been confirmed in many laboratories. Moreover, converging evidence for some form of implicit perception has been provided by neuropsychological studies of patients with various forms of brain damage. For example, patients with lesions in the striate cortex do not report conscious perceptual experiences when stimuli are presented in their damaged visual field. But when required to make guesses about the location and other features of presented stimuli, these patients often perform at above-chance levels on forced-choice tasks regarding stimuli that they cannot 'see' [53]. Some aspects of this phenomenon of *blindsight* remain controversial [54], but the evidence indicates that such patients have access to some implicit knowledge of perceptual events that are not represented in conscious visual experience.

A related phenomenon has been documented in patients who suffer prosopagnosia following bilateral damage to the occipital lobes. These patients are unable consciously to recognize familiar faces. Despite this failure of explicit recognition, however, evidence from both psychophysiological measures [55,56] and priming paradigms [57,58] demonstrates clearly that prosopagnosic patients possess considerable implicit knowledge of facial familiarity. Various other dissociations between implicit and explicit knowledge in neuropsychological syndromes have been reported, both in perceptual and non-perceptual domains [for review and discussion, see 59,60].

Thus, we have evidence for a category of implicit perception – that is, changes in task performance that are attributable to current (as opposed to past) events, in the absence of conscious perception of those events [61,62]. While most implicit memory effects involve situations where a consciously perceived event is subsequently lost to conscious recollection, this need not necessarily be the case. Since memory is the residual trace of perceptual activity, it stands to reason that even *implicit* perceptions can reveal themselves in memory-based task performance, even if it should turn out that implicit percepts produce only implicit memories. The point is, that we might expect to observe implicit memory for surgical events, even if it should turn out that surgical patients are *not* consciously aware of the events at the time they occurred.

A sample of contemporary studies

In fact, a number of studies have now appeared that show something like implicit memory for surgical events, in the absence of explicit memory. Pride of place goes to the work by Bennett et al., who reported two double-blind studies involving a total of 55 surgical patients divided into experimental and control groups. After induction of anaesthesia, the patients heard through earphones a complex, personalized message consisting of music, suggestions for postoperative comfort and rapid healing, and a suggestion for a specific response to be enacted during a post-surgical interview. In Study 1, the suggestion was to lift one's left index finger at a specific signal [15]; in Study 2, it was to pull on one's ear [63]. No patient reported any retrospective awareness of the contents of the tape. Yet 10 out of 13 patients (77%) in Study 1, and 9 out of 11 patients (82%) in Study 2 responded appropriately to the cue. This rate of response was much greater than that observed in patients in the control groups, whose earphones relayed only whatever conversation occurred in the operating room. The results of Bennett et al. have been replicated in a recent study [64], although a number of criticisms have been raised [65-70].

The study by Bennett et al. did not use a formal implicit memory paradigm, but it shows the influence of a surgical event – the suggestion – on subsequent behaviour, in the absence of any conscious recollection of the event itself. Appropriate response obviously requires fairly complex processing of auditory information during surgical anaesthesia: the suggestion must be processed, encoded, and retained in memory in such a form that it can be accessed later, when the pre-arranged cue is administered. Thus, the results of Bennett et al. qualify as evidence of implicit memory for surgical events. Still, it would be reassuring – at least to these authors – if their results were conceptually replicated using more conventional implicit memory paradigms.

Just such an attempt was made by Eich et al. [71], in a study involving 48 elective surgery patients. Once anaesthetized, these patients heard 12 presentations of a list of paired associates consisting of a homophone (e.g., EIGHT or ATE, PIECE or PEACE) accompanied by a disambiguating context (e.g., "Dinner at EIGHT" or "War and PEACE") that biased interpretation of the homophone toward its less common spelling. The patients' performance on a postoperative test of recognition was at chance, while memory was quite good in a control group of patients who heard the list before their surgery. Next, the subjects were presented with the homophones, and asked to spell the words. The idea was that performance on the spelling test might be influenced by the earlier disambiguating context, as shown by previous research [48,72]. Unfortunately, while patients in the preoperative control group showed a strong biasing effect, there was no evidence of implicit memory in those who got the tape during surgery [73].

Despite the negative results of Eich et al., other recent work does provide some evidence of conventional implicit memory effects during anaesthesia. For example, Millar and Watkinson [74] presented a list of 10 low-frequency words to anaesthetized patients. None of the patients showed any memory for the list on a post-surgical test of recall, but when encouraged to guess on a recognition test, showed greater accuracy than control subjects who heard only radio static during surgery. While recall and recognition are both usually construed as measures of explicit memory, it is now believed that performance on recognition tests may be mediated by two quite different processes [75]. Subjects may explicitly recognize an event from the past by virtue of retrieving the spatio-temporal context in which the event took place, as well as the role of the self as the agent or experiencer of the event; alternatively, they may *judge* that an event had occurred previously because it 'rings a bell' and stands out in some way. This second process is more inferential in nature, and comes closer to what is meant by implicit memory. It is entirely possible that, when encouraged to guess, the patients based their recognition judgments on this feeling of familiarity rather than any explicit memory of prior occurrence.

This suggestion receives some support from a recent study where patients were played a tape consisting of repetitions of six low-frequency words [76]. None of the patients had any postoperative recall of the material. However, when presented with a longer list of low-frequency words, the patients identified more targets as familiar. Finally, Goldmann [77] presented patients with obscure facts (e.g., "What is the blood pressure of an octopus?"), followed by the correct answer. Comparing pre- and post-test performance, experimentals were more accurate than controls, even though they had no awareness of where they got the knowledge – a phenomenon originally discovered in hypnosis [78], and subsequently also documented in organic amnesia [79]. Such 'source amnesia' nicely demonstrates implicit memory.

The bottom line and prospects for the future

This reading of the literature suggests that it may be possible to observe postoperative memory for surgical events – not explicit memory, involving the conscious recollection of such events; but rather implicit memory, reflected in changes in task performance that are attributable to those events. However, it must be said that implicit memory for surgical events is not exactly a reliable phenomenon [17]. The bottom line is that implicit memory for surgical events is theoretically possible, and there are some tantalizing hints of it in the literature. But the phenomenon needs to be tamed, and brought under experimental control.

The current status of memory after general anaesthesia bears a strong resemblance to the situation that obtains in the sleep-learning literature [80,81]. There is little evidence of explicit memory for events that occur during sleep. On the other hand, studies of ERPs [30] and classical conditioning [82] do indicate that at least some information-processing functions remain intact during sleep [for reviews, see 83,84], thus raising the possibility that subjects might show implicit, if not explicit, memory for sleep events. However, the evidence for even implicit memory after sleep rarely rises above the level of the provocative anecdote [80,85].

Nevertheless, we are convinced that if there *is* any degree of complex information processing in either sleep or general anaesthesia, studies of implicit memory will give the best evidence for it. We know, in general terms, how to do these studies: how to conduct double-blind trials and how to test for implicit memory. The problem remains of adapting the available implicit memory paradigms for the purpose of studying information-processing in adequate general anaesthesia. Herewith we offer our own reading of what some of the methodological issues are.

Bennett [14,15] has suggested that the type of material used is very important: that post-surgical memory is more likely to be demonstrated with non-verbal as opposed to verbal responses. He reminds us that some of the best evidence for information-processing during sleep comes from studies of classical conditioning [82] and response to ideomotor suggestions [86]. It is certainly possible that the higher cortical centres involved in language processing are disabled during general anaesthesia. But even so, the fact that verbally administered suggestions are effective strongly implies that some language-processing functions remain intact during anaesthesia; and if so, memories for intraoperative events ought to be manifest in the subject's verbal behaviour. There seem to be no theoretical grounds for preferring non-verbal to verbal measures of post-surgical memory. Arguably, non-verbal memory is phylogenetically and ontogenetically prior to verbal memory, and Ribot's Law [87] does imply that non-verbal memory might be less vulnerable to the detrimental effects of general anaesthesia. Then again, the suggestions for non-verbal responses are administered verbally, so the application of Ribot's Law is not at all clear. In any event, we see no reason why the two lines of research, verbal and non-verbal, should not be pursued in parallel.

Of considerably greater potential importance may be the nature of the chemical agents employed to induce anaesthesia. Bennett [14,15] has reported that the use of diazepam premedication reduced his effect. On the other hand, Stolzy et al. [76] used diazepam premedication in their successful experiment. When Stolzy and her colleagues switched from isoflurane to fentanyl, their effect disappeared [88]. But Goldmann et al. [64] used fentanyl successfully in their replication of Bennett et al's study. One thing we know for certain is that the anaesthetic cocktail is complex and highly variable from one anaesthetist to another. Another is that the several drugs used in surgical anaesthesia vary widely in their effects on the brain and thus on information-processing. These two facts, taken together, spell trouble for research. With due regard for the legitimate medical concern for the best interests of the individual surgical patient, we strongly suspect that replication, whether between or within laboratories, will continue to elude us unless we can standardize the anaesthetic procedures.

Another potential methodological issue concerns the effects of the patients' expectations. Again, Bennett [14,15] has claimed that the patients' motivation is very important in this kind of research, and that success is most likely when they have an appropriate set. Although all modern experiments employ informed consent, some investigators have gone much further to personalize their procedures, to administer therapeutic suggestions (about which more later) as well as word-lists, and to convey to their patients both the importance of the experiment and the likelihood of a successful result. It is by no means certain how much of a role is played by personalized procedures and a positive pre-anaesthetic set. It is interesting to note, however, that the best evidence for sleep learning comes from studies, whether done in the West or the East, that attempt to induce positive attitudes and motivations in the subjects [80,85].

A related topic is the matter of individual differences. Even in the successful demonstrations of intraoperative perception and postoperative memory, some subjects show the effect and others do not. Perhaps this difference is due to variability in the experimental procedure, such as the precise mix of anaesthetics received by the patients. But it is also possible that there are individual differences in cognitive skills and dispositions that may be relevant. One possibility is hypnotizability [89]; hypnotizability itself is related to a broader trait variously known as 'absorption' [90] or 'openness to experience' [91], which has to do with the individual's tendency to become highly involved in fantasy, or in sensory, emotional, and imaginative experiences. Still another possibility is a relative invulnerability to cognitive failures, slips, and errors [92] suggestive of better capacity for attentional deployment.

A final issue is the time of testing. While it may be convenient for us to conduct our memory testing in the recovery room, there are hints in the literature that a more successful outcome may be obtained after a delay of several days. Why this should be so is not clear. It is possible that it takes time for the effects of the anaesthetic to wear off completely, and that until they do information-processing is impaired. But if sub-clinical doses of anaesthetic impair retrieval postoperatively, then what must the effects of an adequate dose of anaesthetic be on encoding during surgery itself? If there is a positive effect of retention interval, perhaps it is analogous to the hypermnesia effect sometimes observed in normal memory [93-95]. When subjects receive multiple recall tests, it is sometimes observed that items that were forgotten on an earlier test are remembered on a later one; perhaps something analogous happens to memory for material presented during surgical anaesthesia.

At the present time, the literature on surgical perception and post-surgical memory strikes an observer as a curious scattershot of studies, with a "now you see it, now you don't" quality to them. Everyone is using different patients, different anaesthetic cocktails, and different procedures; and everyone is getting different experimental results. What the field needs for the time being is to focus on a fairly standardized procedure and see if we can get reliable results within and across laboratories. If the optimal conditions involve positive pre-surgical set, no barbiturate premedication, personalized testing procedures, and moderately long retention intervals, we should use them and see if we can get an effect. Then we can manipulate the parameters to see what the important elements are. But first we have to get reliable effects.

Theoretical and practical significance

Even if we got an effect reliably, and were able to bring it under experimental control, why should anyone be interested? After all, many concerns about surgical awareness could be ameliorated by the simple expedient of providing the patient with earplugs! While this may be true to some extent, we think that there are also several practical and theoretical implications of information-processing during surgical anaesthesia, and that these are sufficient to motivate the work.

The first practical implication is obvious, and harkens back to the anecdote from George Crile [1], and from the cases of Cheek and LeCron [4-6]. If surgical patients can process auditory events in the operating room, and memories for these events can negatively affect postsurgical recovery and the doctor-patient relationship, then we had better be careful what we say in their presence. This is really just a matter of medical ethics, if not simple etiquette, and it would be reasonable to argue that we should not be saying unpleasant things about our patients, and their prognoses, even if they could not overhear our conversations.

The second practical implication is more subtle, and a little harder to accept. If patients can register what is said to them during surgery, it may be possible for them to act on what is said, in a manner that will benefit their postoperative recovery. Trustman et al. [7] reviewed several studies in which anaesthetized patients received suggestions for speeded postoperative recovery, diminished pain, and the like: Some of them yielded positive results [96], but others did not [97]. More recently, Woo et al. [98] obtained negative results [see for criticism 99], while Evans and Richardson [100, 101] reported very dramatic success for such procedures. Bonke and his colleagues have done two studies, one of which yielded positive results [102] while the other did not [103].

Remembering intraoperative events is not the same as acting on postoperative suggestions, and it is not at all clear how such effects could be achieved (although analogous effects are commonplace in hypnosis). However, from the standpoint of medical psychology and behavioural medicine, the therapeutic possibilities are interesting. Perhaps the conditions under which patients show implicit memory for surgical events will also be the conditions under which patients show positive response to post-surgical suggestions for pain relief.

On a more theoretical level, studies of post-surgical memory should offer a new perspective on the conditions under which implicit memories are formed and expressed. At the present time, one of the central issues in implicit memory is whether these effects reflect only the activation of old, pre-existing knowledge, as opposed to the formation of entirely new memory structures [37]. For example, severely amnesic patients show good implicit memory for materials such as SOUR-GRAPES and SMALL-POTATOES, which are based on familiar speech idioms; but not for recombinations of these idioms such as SOUR-POTATOES and SMALL-GRAPES. This suggests that implicit memory in amnesia is restricted to the priming of old associations, as opposed to the formation of new ones. More recently, however, Schacter and Graf [41,42,104-106] have produced evidence of implicit memory for new associations (such as WINDOW-REASON) in normal subjects, and to some extent in amnesic patients. However, there are at least two important differences between implicit memory for old and for new associations. First, the former is independent of the activity of the subject at the time of encoding, while the latter occurs only if the subject engages in some degree of elaborative processing of the material at the time it is presented. Second, implicit memory for new associations is difficult to oberve in severely amnesic patients. While there are conditions under which even severely amnesic patients can show implicit memory for new associations [107-109], it seems that we may be approaching the limit of the phenomenon.

Surgical anaesthesia is relevant to this issue because the information-processing abilities of the anaesthetized patient would seem to be severely limited. Anaesthetized patients may be able to execute some highly automatized information-processing functions, but probably not the kind of elaborative processing required to encode an entirely new memory trace. For this reason, it may be that whatever implicit memory effects are observed might be confined to the activation of pre-existing knowledge; or that implicit memory for new associations might be observed only in patients who received a relatively light plane of anaesthesia; or that both might be the case. Just as there is a continuum of processing demands, from rather 'shallow' tasks that focus on the orthographic or acoustic properties of the words to rather 'deep' ones that require their use in a meaningful sentence, there may also be a continuum of processing capabilities, ranging from the normal waking state, to REM and NREM sleep, to adequate anaesthesia, to coma. In order to understand better the nature of implicit memory, we will want to know how these organismic conditions affect the ability to activate old associations, and form new ones.

Surgical anaesthesia also provides us with an opportunity to investigate the conditions under which implicit memories might become explicit ones. Consider an amnesic patient who shows implicit memory for an item like ASSASSIN or SOUR-GRAPES, but who cannot consciously remember that such items were presented on an earlier study trial. There appear to be no circumstances under which such a patient could subsequently show retrospective awareness of the study episode – that is, to consciously remember that ASSASSIN or SOUR-GRAPES were presented in a list at some time in the past. Such a shift from implicit to explicit memory does occur, however, after suggestions for posthypnotic amnesia are cancelled by a prearranged reversibility cue. The question is whether such shifts can occur in surgical anaesthesia. We have some provocative results from the Levinson [10] study, in which some surgical patients became consciously aware of the bogus crisis after they were hypnotized. Once we have established some implicit memory phenomenon in general anaesthesia, it will be interesting to follow up Levinson's observations and determine whether, by means of hypnosis, or barbiturate sedation, or perhaps reinduction of a very light plane of anaesthesia, the implicit can be made explicit.

Assuming that we can bring implicit memory for surgical events under experimental control, it seems likely that the paradigm might tell us something new about the biological basis of memory and consciousness [110]. Although we do not yet have a totally satisfactory theory of general anaesthesia, it seems reasonable to suggest that anaesthetic agents have selective effects on brain functions, and that the various preparations differ among themselves in this respect. Suppose, now, that we discover that some anaesthetic agents produce dissociations between explicit and implicit memory, impairing one but sparing the other, while others impair both. As our psychopharmacological colleagues come to a better understanding of just how anaesthesia works, such evidence may allow us to generate hypotheses about the brain structures that are differentially involved in these two forms of memory. This information would then complement that derived from studies of brain-injured patients, as well as the lesion evidence from non-human animals.

Conclusion

The question of memory for surgical events has not yet been settled. On the contrary, so long as it is clear that we are talking about implicit rather than explicit memory, it is very much alive. This is a topic of considerable theoretical and practical importance, and we now have the conceptual and methodological tools required for further systematic research.

Author notes

The point of view represented in this paper is based on research supported in part by NIMH Grant MH-35856 to John F. Kihlstrom, and by a Biomedical Research Support Grant to Daniel L. Schacter; participation in the Symposium was supported by a foreign travel grant from the Office of International Programs, University of Arizona. We thank our colleagues Jill Booker, Jeffrey Bowers, Meryl Butters, Randall Cork, Larry Couture, Suzanne Delaney, Elizabeth Glisky, Martha Glisky, Irene Hoyt, Catherine Hurt, Susan McGlynn, Elizabeth Merikle, Douglas Tataryn, Mindy Tharan, and Betsy Tobias for their comments during the preparation of this paper.

References

1. Crile G. *An Autobiography*. Philadelphia: Lippincott, 1947.
2. Adam N. Disruption of memory functions associated with general anesthetics. In: Kihlstrom JF, Evans FJ, eds. *Functional Disorders of Memory*. Hillsdale, N.J.: Erlbaum, 1979: 219-238.
3. Ghoneim MM, Hinrichs JV, Mewaldt SP. Dose-response analysis of the behavioural effects of diazepam: 1. Learning and memory. *Psychopharmacology* 1984; 82: 291-295.
4. Cheek DB. Unconscious perception of meaningful sounds during surgical anesthesia as revealed under hypnosis. *American Journal of Clinical Hypnosis* 1959; 1: 101-113.
5. Cheek DB. Surgical memory and reaction to careless conversation. American *Journal of Clinical Hypnosis* 1964; 6: 237.
6. Cheek DB, LeCron LM. *Clinical hypnotherapy*. New York: Grune & Stratton, 1968.
7. Trustman R, Dubovsky S, Titley R. Auditory perception during general anesthesia: Myth or fact? *International Journal of Clinical and Experimental Hypnosis* 1977; 25: 88-105.
8. Faithfull NS. Awareness during anaesthesia. *British Medical Journal* 1969; 2: 117.
9. Wilson J, Turner DJ. Awareness during caesarean section under general anaesthesia. *British Medical Journal* 1969; 1: 280-283.
10. Levinson BW. States of awareness during general anaesthesia: Preliminary communication. *British Journal of Anaesthesia* 1965; 37: 544-546.
11. Lewis SA, Jenkinson J, Wilson J. An EEG investigation of awareness during anaesthesia. *British Journal of Psychology* 1973; 64: 413-415.
12. Dubovsky SL, Trustman R. Absence of recall after general anesthesia: Implications for theory and practice. *Anesthesia and Analgesia 1976*; 55: 696-701.
13. Simon CW, Emmons WH. Learning during sleep? *Psychological Bulletin* 1955; 52: 328-342.
14. Bennett HL. Learning and memory in anaesthesia. In: Rosen M, Lunn JN, eds. *Consciousness, Awareness and Pain in General Anaesthesia*. London: Butterworths, 1987: 132-149.
15. Bennett HL. Perception and memory for events during adequate general anesthesia for surgical operations. In: Pettinati HM, ed. *Hypnosis and Memory*. New York: Guilford, 1988: 193-231.
16. Guerra F. Awareness under general anesthesia. In: Guerra F, Aldrete JA, eds. *Emotional and Psychological Responses to Anesthesia and Surgery*. New York: Grune & Stratton, 1980: 1-8.
17. Millar K. Assessment of memory for anaesthesia. In: Hindmarch I, Jones JG, Moss E, eds. *Aspects of Recovery from Anaesthesia*. London: Wiley, 1987: 75-91.
18. Rosen M, Lunn JN. *Consciousness, Awareness, and Pain in General Anaesthesia*. London: Butterworths, 1987.

19. Hillyard S, Kutas M. Electrophysiology of cognitive processing. *Annual Review of Psychology* 1983; 34: 33-61.
20. Hillyard S, Picton T. Electrophysiology of cognition. In: Plum F, ed. *Handbook of Physiology -- The Nervous System V: Higher Functions of the Brain, Part 2.* American Physiological Society, 1987: 519-584.
21. Jones JG. Use of evoked responses in the EEG to measure depth of anaesthesia. In: Rosen M, Lunn JN, eds. *Consciousness, Awareness and Pain in General Anaesthesia.* London: Butterworths, 1987: 132-149.
22. Razran G. The observable unconscious and the inferable conscious in current Soviet psychophysiology. *Psychological Review* 1961; 68: 81-147.
23. Razran G. Recent Soviet phyletic comparisons of classical and of operant conditioning: Experimental designs. *Journal of Comparative and Physiological Psychology* 1961; 54: 357-367.
24. Brice DD, Hetherington RR, Utting JE. A simple study of awareness during anaesthesia. British *Journal of Anaesthesia* 1970; 42: 535-542.
25. Eisele V, Weinreich A, Bartle S. Perioperative awareness and recall. *Anesthesia and Analgesia* 1976; 55: 513-518.
26. McIntyre JWR. Awareness during general anaesthesia: Preliminary observations. *Canadian Anaesthetists' Society Journal* 1966; 13: 495-499.
27. Terrell RK, Sweet WO, Gladfelter JH, Stephen CR. Study of recall during anaesthesia. *Anesthesia and Analgesia* 1969; 48: 86-90.
28. Tunstall ME. Detecting wakefulness during general anaesthesia for Caesarean section. *British Medical Journal* 1977; i: 1321.
29. Kutas M. Review of event-related potential studies of memory. In: Gazzaniga MS, ed. *Perspectives in Memory Research.* Cambridge: MIT Press, 1988: 181-217.
30. Kutas M. Event-related brain potential (ERP) studies of cognition during sleep: Is it more than a dream? In: Bootzin R, Kihlstrom JF, Schacter DL, eds. *Sleep and Cognition.* Washington, D.C.: American Psychological Association, 1989, in press.
31. Kutas M, Hillyard S. Event-related potentials in cognitive science. In: Gazzaniga M, ed. *Handbook of Cognitive Neuroscience.* New York: Plenum, 1984: 387-409.
32. Kutas M, Van Petten C. Event-related brain potential studies of language. In: Ackles PK, Jennings JR, Coles HGH, eds. *Advances in Psychophysiology (Vol. 3).* Greenwich, Ct.: JAI Press, 1988: 139-187.
33. Kihlstrom JF. Posthypnotic amnesia for recently learned material: Interactions with "episodic" and "semantic" memory. *Cognitive Psychology* 1980; 12: 227-251.
34. Kihlstrom JF. Conscious, subconscious, unconscious: A cognitive perspective. In: Bowers KS, Meichenbaum D, eds. *The Unconscious Reconsidered.* New York: Wiley-Interscience, 1984: 149-211.
35. Kihlstrom JF. Posthypnotic amnesia and the dissociation of memory. In: Bower GH, ed. *The Psychology of Learning and Motivation (Vol. 19).* New York: Academic, 1985: 131-178.

36. Kihlstrom JF, Hoyt IP. *Hypnosis and the psychology of delusions.* In: Oltmanns TF, Maher BA, eds. Delusional Beliefs. New York: Wiley-Interscience, 1988: 66-109.
37. Schacter DL. Implicit memory: History and current status. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1987; 13: 501-518.
38. Shimamura AP. Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology* 1986; 38A: 619-644.
39. Graf P, Squire LR, Mandler G. The information that amnesic patients do not forget. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1984; 10: 164-178.
40. Warrington EK, Weiskrantz L. The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia* 1974; 12: 419-428.
41. Schacter DL. Priming of old and new knowledge in amnesic patients and normal subjects. *Annals of the New York Academy of Sciences* 1985; 444: 41-53.
42. Graf P, Schacter DL. Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1985; 11: 501-518.
43. Kihlstrom JF. The cognitive unconscious. *Science* 1987; 237: 1445-1452.
44. Squire LR, Shimamura AP, Graf P. Independence of recognition memory and priming effects: A neuropsychological analysis. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1985; 11: 37-44.
45. Graf P, Mandler G. Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior* 1984; 23: 553-568.
46. Jacoby LL, Dallas M. On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology (General)* 1981; 110: 306-340.
47. Schacter DL, McGlynn SM. Implicit memory: Effects of elaboration depend on unitization. *American Journal of Psychology* 1989; 102: 151-181.
48. Eich E. Memory for unattended events: Remembering with and without awareness. *Memory and Cognition* 1984; 12: 105-111.
49. Kunst-Wilson WR, Zajonc RB. Affective discrimination of stimuli that cannot be recognized. *Science* 1980; 207: 557-558.
50. Cheesman J, Merikle PM. Distinguishing conscious from unconscious perceptual processes. *Canadian Journal of Psychology* 1986; 40: 343-367.
51. Holender D. Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: A survey and appraisal. *Behavioral and Brain Sciences* 1986; 9: 1-66.
52. Marcel AJ. Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology* 1983; 15: 179-237.

53. Weiskrantz L. *Blindsight.* New York: Oxford University Press, 1986.
54. Campion J, Latto R, Smith YM. Is blindsight an effect of scattered light, spared cortex, and near-threshold vision? *Behavioral and Brain Sciences* 1983; 6: 423-486.
55. Bauer RM. Autonomic recognition of names and faces is prosopagnosia: A neuropsychological application of the guilty knowledge test. *Neuropsychologia* 1984; 22: 457-469.
56. Tranel D, Damasio AR. Knowledge without awareness: An autonomic index of facial recognition by prosopagnosics. *Science* 1985; 228: 1453-1454.
57. DeHaan EHF, Young A, Newcombe F. Face recognition without awareness. *Cognitive Neuropsychology* 1987; 4: 385-415.
58. Young AW, DeHaan EHF. Boundaries of covert recognition in prosopagnosia. *Cognitive Neuropsychology* 1988; 5: 317-336.
59. Schacter DL. Toward a cognitive neuropsychology of awareness: Implicit knowledge and anosognosia. *Journal of Clinical and Experimental Neuropsychology* 1989 (in press).
60. Schacter DL, McAndrews MP, Moscovitch M. Access to consciousness: Dissociations between implicit and expicit knowledge in neuropsychological syndromes. In: Weiskrantz L, ed. *Thought Without Language.* Oxford: Oxford University Press, 1988: 242-278.
61. Kihlstrom JF. Cognition, unconscious processes. In: Adelman G, ed. *Neuroscience Year: Yearbook of the Encyclopedia of Neuroscience.* Boston: Birkhauser Boston, 1989, in press.
62. Kihlstrom JF, Tobias BA. Anosognosia, consciousness, and the self. In: Prigatano GP, Schacter DL, eds. *Awareness of Deficit Following Brain Injury: Theoretical and Clinical Aspects.* New York: Oxford University Press, 1989, in press.
63. Bennett HL, Davis HS, Giannini JA. Non-verbal response to intraoperative conversation. *British Journal of Anaesthesia* 1985; 57: 174-179.
64. Goldmann L, Shah M, Hebden M. *Memory and cardiac anaesthesia. Anaesthesia* 1987; 42: 596-603.
65. Bonke B, Rupreht J. Response to intraoperative conversation. *British Journal of Anaesthesia* 1986; 58: 134.
66. Bonke B, Schmitz PIM, Verhage F, Zwaveling A. Unconscious perception during general anaesthesia. *British Journal of Anaesthesia* 1987; 59: 1335-1336.
67. Millar K. Unconscious perception during general anaesthesia. *British Journal of Anaesthesia* 1987; 59: 1334-1335.
68. Wilson ME, Spiegelhalter D. Unconscious perception during general anaesthesia. *British Journal of Anaesthesia* 1987; 59: 1333.
69. Bennett HL. Response to intraoperative conversation. *British Journal of Anaesthesia* 1986; 58: 134-135.
70. Bennett HL. Unconscious perception during general anaesthesia. *British Journal of Anaesthesia* 1987; 59: 1335-1337.
71. Eich E, Reeves JL, Katz RL. Anesthesia, amnesia, and the memory/awareness distinction. *Anesthesia and Analgesia* 1985; 64: 1143-1148.

72. Jacoby LL, Witherspoon D. Remembering without awareness. Canadian *Journal of Psychology* 1982; 36: 300-324.
73. Bennett HL, Boyle WA. Selective remembering: Anaesthesia and memory. *Anesthesia and Analgesia* 1986; 65: 988-989.
74. Millar K, Watkinson N. Recognition of words presented during general anaesthesia. *Ergonomics* 1983; 26: 585-594.
75. Mandler G. Recognizing: The judgment of prior occurrence. *Psychological Review* 1980; 87: 252-271.
76. Stolzy S, Couture LJ, Edmonds HL. Evidence of partial recall during general anesthesia. *Anesthesia and Analgesia* 1986; 65: S154.
77. Goldmann L. Further evidence for cognitive processing under general anaesthesia. In: Rosen M, Lunn, LN, eds. *Consciousness, Awareness and Pain in General Anaesthesia* London: Butterworths, 1987: 132-149.
78. Evans FJ. Contextual forgetting: Posthypnotic source amnesia. *Journal of Abnormal Psychology* 1979; 88: 556-563.
79. Schacter DL, Harbluk JL, McLachlan DR. Retrieval without recollection: An experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior* 1984; 23: 593-611.
80. Eich E. Learning during sleep. In: Bootzin R, Kihlstrom JF, Schacter DL, eds. *Sleep and Cognition*. Washington, D.C.: American Psychological Association, 1989, in press.
81. Schacter DL, Kihlstrom JF. Functional amnesia. In: Boller F, Grafman J, eds. *Handbook of Neuropsychology*. Amsterdam: Elsevier, 1989, in press.
82. Badia P. Memories in sleep: Old and new. In: Bootzin R, Kihlstrom JF, Schacter DL, eds. *Sleep and Cognition*. Washington, D.C.: American Psychological Association, 1989, in press.
83. Arkin AM, Antrobus JS, Ellman SJ. *The Mind in Sleep: Psychology and Psychophysiology*. Hillsdale, N.J.: Erlbaum, 1978.
84. Bootzin RR, Kihlstrom JF, Schacter DL. *Sleep and Cognition*. Washington, D.C.: American Psychological Association, 1989, in press.
85. Hoscovec J. Hypnopaedia in the Soviet Union. A critical review of recent major experiments. *International Journal of Clinical and Experimental Hypnosis* 1966; 14: 308-315.
86. Evans FJ. Behavioral responses during sleep. In: Bootzin R, Kihlstrom JF, Schacter DL, eds. *Sleep and Cognition*. Washington, D.C.: American Psychological Association, 1989, in press.
87. Ribot T. *Diseases of Memory: An Essay in the Positive Psychology*. New York: Appleton, 1896.
88. Stolzy S, Couture LJ, Edmonds HL. A postoperative recognition test after balanced anesthesia. *Anesthesia and Analgesia* 1987; 67: A377.
89. Hilgard ER. Hypnotic Susceptibility. New York: Harcourt, Brace, & World, 1965.
90. Tellegen A, Atkinson G. Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology* 1974; 83: 268-277.

91. McCrae RR, Costa PT. Openness to experience. In: Hogan R, Jones WH, eds. *Perspectives in Personality (Vol. 1)*. Greenwich, Ct.: JAI Press, 1985: 145-172.
92. Broadbent DE, Cooper PF, Fitzgerald P, Parkes KR. The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology* 1982; 21: 1-16.
93. Erdelyi MH. The recovery of unconscious (inaccessible) memories: Laboratory studies of hypermnesia. In: Bower GH, ed. *The Psychology of Learning and Motivation (Vol. 18)*. New York: Academic, 1984: 95-127.
94. Payne DG. Hypermnesia and reminiscence in recall: A historical and empirical review. *Psychological Bulletin* 1986; 101: 5-27.
95. Roediger HL, Challis BH. Hypermnesia: Improvements in recall with repeated testing. In: Izawa C, ed. *Current Issues in Cognitive Processes: The Tulane Floweree Symposium on Cognition.* Hillsdale, N.J.: Erlbaum, 1989, in press.
96. Pearson RE. Response to suggestions given under general anesthesia. *American Journal of Clinical Hypnosis* 1961; 4: 106-114.
97. Abramson M, Greenfield I, Heron W. Response to or perception of auditory stimuli under deep surgical anesthesia. *American Journal of Obstetrics and Gynecology* 1966; 96: 584-585.
98. Woo R, Seltzer JL, Marr A. The lack of response to suggestion under controlled surgical anaesthesia. *Acta Anaesthesiologica Scandinavica* 1987; 31: 567-571.
99. Bonke B, Jelicic M, Van Strik R. Comment (reply to Woo et al.). *Acta Anaesthesiologica Scandinavica* 1988; 32: 712-713.
100. Evans C, Richardson PH. Improved recovery and reduced postoperative stay after therapeutic suggestions during general anaesthesia. *Lancet* 1988; 8609: 491-493.
101. Evans C, Richardson PH. [Reply to D.S. Mackie.] *Lancet* 1988; 8617: 955-956.
102. Bonke B, Schmitz PIM, Verhage F, Zwaveling A. Clinical study of so-called unconscious perception during general anaesthesia. *British Journal of Anaesthesia* 1986; 58: 957-964.
103. Boeke S, Bonke B, Bouwhuis-Hoogerwerf ML, Bovill JG, Zwaveling A. Effects of sounds presented during general anaesthesia on postoperative course. *British Journal of Anaesthesia* 1988; 60: 697-702.
104. Schacter DL, Graf P. Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1986; 12: 432-444.
105. Schacter DL, Graf P. Modality specificity of implicit memory for new associations. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1989; 15: 3-12.
106. Graf P, Schacter DL. Selective effects of interference on implicit and explicit memory for new associations. *Journal of Experimental Psychology (Learning, Memory, Cognition)* 1987; 13: 45-53.

107. Cermak LS, Blackford SP, O'Connor M, Bleich RP. The implicit memory ability of a patient with amnesia due to encephalitis. *Brain and Cognition* 1988; 7: 145-156.
108. McAndrews MP, Glisky EL, Schacter DL. When priming persists: Long-lasting implicit memory for a single episode in amnesic patients. *Neuropsychologia* 1987; 25: 497-506.
109. Moscovitch M, Winocur G, McLachlan D. Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzheimer's disease and other neurological disorders. *Journal of Experimental Psychology (General)* 1986; 115: 331-347.
110. Squire LR. *Memory and brain.* New York: Oxford University Press, 1987.

Memory and Awareness in Anaesthesia

Benno Bonke (Editor-in-Chief)
Erasmus University Rotterdam, The Netherlands
William Fitch
Glasgow Royal Infirmary, Scotland
Keith Millar
University of Glasgow, Scotland

SWETS & ZEITLINGER B.V. AMSTERDAM / LISSE PUBLISHERS

SWETS & ZEITLINGER INC. ROCKLAND, MA / BERWYN, PA

Library of Congress Cataloging-in-Publication Data

(Applied for)

CIP-gegevens Koninklijke Bibliotheek, Den Haag

Memory

Memory and awareness in anaesthesia / ed. by Benno Bonke (editor-in-chief), William Fitch, Keith Millar. - Amsterdam [etc.] : Swets & Zeitlinger
Met Lit. opg., index
ISBN 90-265-1020-9 geb.
SISO 608.1 UDC 616-089.5 NUGI 719
Trefw. : anesthesie.

Cover design by Rob Molthoff after a drawing by Detlef Greinert
Cover printed n the Netherlands by Casparie, IJsselstein
Printed in the Netherlands by Offsetdrukkerij Kanters B.V., Alblasserdam

ISBN 90 265 1020 9
NUGI 719