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Memory for Unconsciously Perceived Events: Evidence from Anesthetized Patients

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Studies investigating memory for events during anesthesia show a confusing pattern of positive and negative results. To establish whether there are any consistent patterns of findings across studies, we conducted a meta-analysis of the data from 2517 patients in 44 studies. The meta-analysis included two measures of the effects of positive suggestions on postoperative recovery: (a) the duration of postoperative hospitalization and (b) the amount of morphine administered via patient-controlled anesthesia, as well as two measures of memory for specific information presented during anesthesia: (c) direct tests and (d) indirect tests. The meta-analysis indicated that positive suggestions presented during anesthesia have little or no effect on postoperative recovery. On the other hand, the meta-analysis showed that specific information is remembered following surgery, as long as testing is not delayed longer than 36 h. Studies of memory for events during anesthesia provide a useful avenue for exploring unconscious cognition.

How would you feel if you were a patient undergoing surgery and you heard the following words while you were lying anesthetized in the operating room?

> Just a moment! I don't like the patient's colour. Much too blue.
> Her lips are very blue. I'm going to give a little more oxygen. . . .
> There, that's better now. You can carry on with the operation.
> (Levinson, 1965, p. 544)

Surgical patients who have been administered general anesthesia are not supposed to be aware of events during anesthesia, and they are not supposed to have any post-surgical memory for events that occurred during anesthesia. Indeed, anesthesiologists try to administer just the right mixture and dose of chemicals so that their patients experience no pain, no awareness, and no memory. And anesthesiologists assume success if their patients are unable to report any memory for events that occurred in the operating room while they were under the influence of general anesthesia. In most instances, patients respond ''No, nothing,'' when asked the simple and direct question ''Do you remember anything that may have occurred during your surgery?'' Such responses are taken by anesthesiologists as evidence of successful anesthesia.

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Of course, a simple yes–no question may not be a sensitive method for probing memory, and as early as 1961, there were researchers who claimed to have found evidence of memory for events during anesthesia when they used more indirect or more sensitive tests. For example, Pearson (1961) reported that positive suggestions during anesthesia decreased the duration of postoperative hospitalization following surgery, and Hutchings (1961) reported that positive suggestions reduced the pain experienced following surgery. Even more compelling was Levinson's (1965) observation that patients could perceive and remember significant events that occurred during anesthesia. Levinson (1965) staged a mock crisis while surgical patients were under the influence of general anesthesia. During surgery, 10 anesthetized patients had the statement ''Just a moment! I don't like the patient's color . . . '' recited to them. Following this statement the surgery was completed, and all 10 patients experienced normal recovery. Levinson's critical observations were made 1 month following the surgery when he hypnotized the patients to see if they could remember anything that may have occurred while they were anesthetized. Surprisingly, 4 of the 10 were able to provide an almost verbatim account of the statement made during the mock crisis, and another 4 had some memory for the message. Taken together, these early studies indicate that patients may in fact have memory for events during anesthesia (see also Cheek, 1959).

The observations of Levinson (1965), Pearson (1961), and Hutchings (1961) have important implications for investigations of unconscious perception. If we assume that surgical anesthesia induces unconsciousness, then any demonstration of memory for events during anesthesia constitutes strong evidence for unconscious perception. As such, studies of memory for events during anesthesia provide an attractive alternative methodology for investigating unconscious cognitive processes. The typical approach has been to induce conscious people to perceive unconsciously by presenting stimuli under suboptimal conditions. For example, visual stimuli may be presented for a very short duration (e.g., 50 ms) and be followed immediately by a visual mask (cf. Greenwald, 1992). What makes general anesthesia an attractive alternative approach is that unconsciousness is directly induced.

However, despite more than 30 years of research with a variety of experimental procedures, the findings show a confusing picture of significant and nonsignificant results (for reviews see Andrade, 1995; Ghoneim & Block, 1992). For this reason, it is not surprising that at a recent conference some psychologists (e.g., Bennett, 1993) and some anesthesiologists (e.g., Ghoneim & Block, 1993) reviewed the available data and concluded that there is convincing evidence of memory for events during anesthesia, whereas other psychologists (e.g., Merikle & Rondi, 1993) and other anesthesiologists (e.g., Chortkoff & Eger, 1993) reviewed the same data and concluded that there is no convincing evidence.

It is always possible that what appear to be inconsistent patterns of statistically significant and statistically nonsignificant findings across individual studies actually reflect more consistent patterns of findings when the results of individual studies are combined and the overall patterns of findings across studies are established. For this reason, we decided to conduct a meta-analysis of studies investigating memory for events during anesthesia. The advantage of using meta-analytic techniques is that they provide a method for combining and quantifying the results of individual studies so that it is possible to see the general trends across all relevant studies. Our primary goal was to establish whether the overall patterns of findings provide any support for the view that positive suggestions and specific information presented during anesthesia can lead to significant postoperative effects.

META-ANALYSIS

Measures of Memory

Most studies investigating memory for events during anesthesia have included a number of different measures. We selected four of the more objective and reliable measures for inclusion in the meta-analysis. Our selection of measures insured that results from almost all the known studies were included in the meta-analysis.

Two of the measures included in the meta-analysis assessed memory by evaluating whether positive suggestions presented during anesthesia can influence postoperative recovery. These measures were: (a) the duration of postoperative hospitalization and (b) the amount of morphine administered via patient-controlled analgesic (PCA) systems. The duration of postoperative hospitalization has been reported in the majority of studies that have investigated the effects of positive suggestions on postoperative recovery. PCA, on the other hand, has been used in only a few studies; nevertheless, it has the advantage of being an objective measure of the pain experienced by patients following surgery.

The other two measures included in the meta-analysis assessed memory for specific information presented during anesthesia. These measures were: (a) direct (explicit) tests of memory and (b) indirect (implicit) tests of memory. The basic distinction between direct and indirect tests involves the nature of the instructions given to the patients. In the case of direct tests, patients are asked to recall or to recognize events that had been presented to them during anesthesia. For example, in a forced-choice test of recognition, patients are presented with single words (e.g., apple, snow) during anesthesia, and then following anesthesia, they are presented with pairs of words (e.g., apple–house) and instructed to select the one word in each pair that had been presented during anesthesia (e.g., apple). The critical characteristic of direct tests is that the instructions make explicit reference to events during the intraoperative period. In contrast, the instructions for indirect tests make no reference to events during the intraoperative period. For example, one indirect test that has been used in a number of studies involves asking patients to produce words that complete particular word stems (e.g., mem ___; dir ___). Although words with these stems have been presented to the patients during anesthesia (e.g., *memory, direct*), no reference is made to this fact in the instructions. Rather, the patients are simply asked to complete each word stem with the first word that comes to mind. Evidence of memory is found if the patients tend to complete the stems with words presented during anesthesia (e.g., *memory* rather than *member*), despite the absence of any reference to the intraoperative period in the instructions.

A problematic issue with any direct test of memory concerns whether it has been administered under conditions that allowed patients to respond ‘‘No, I do not remember’’ to each of the items on the test. When patients are allowed to respond in this way, it is impossible to determine whether their ‘‘No, I do not remember’’ responses indicate a true absence of memory for the specific information or simply their *belief* that they have no memory for the specific information; both an absence of memory and the presence of a belief that there is no memory can lead one to state that nothing was perceived or remembered (cf. Adams, 1957; Merikle, 1992). The only way to ensure that performance on a direct test reflects memory and not simply one's beliefs concerning memory is to require patients to respond to every test item even if they believe they are only guessing. For this reason, the only direct tests of memory that we included in the meta-analysis were those that required patients to respond to most if not all of the specific items on the test. In this way, there was some assurance that any direct test of memory included in the meta-analysis was a measure of memory and was not simply a measure of beliefs regarding memory.

Studies

Our search for relevant studies to include in the meta-analysis was guided by the reference lists of three recent reviews of this research area (Andrade, 1995; Ghoneim & Block, 1992; Merikle & Rondi, 1993). Not only were all studies included in these reference lists considered, but the studies in the reference lists of the cited articles were also considered. We also reviewed all papers and reference lists published in the proceedings from two international symposia on memory and awareness in anesthesia (Bonke, Fitch, & Millar, 1990; Sebel, Bonke, & Winograd, 1993). In addition, we considered all papers presented at the *Third International Symposium on Memory and Awareness in Anaesthesia* held in Rotterdam in June 1995. Finally, we conducted a computer-assisted search of the *PsycLIT* and *Medline* databases. We are confident that our search has identified all relevant published studies, as well as a number of relevant unpublished studies.

To be included in the meta-analysis, a study had to satisfy the following criteria:

(1) The study had to have included one or more of the four selected measures of memory: (a) postoperative hospitalization; (b) PCA; (c) a direct test of specific memory; and (d) an indirect test of specific memory.

(2) The participants had to have been adult surgical patients undergoing general anesthesia supervised by a trained anesthesiologist. We did not include studies involving nonsurgical volunteers (for reviews see Andrade, 1995; Ghoneim & Block, 1992) or children (Bonke, van Dam, van Kleef, & Slijper, 1992: Standen, Hain, & Hosker, 1987) because we felt that these two groups may represent considerably different populations than the adult surgical patients used in the majority of studies. In addition, we did not include four studies involving cardiac surgery (Bethune et al., 1992, 1993; De Houwer, Demeyere, Verhamme, & Eelen, 1995; Schwender, Madler, Klasing, Peter, & Poppel, 1994) because it is generally agreed that the anesthesia used for cardiac surgery is not as deep as the anesthesia used for many other types of surgery (cf. Hug, 1993).

(3) The study had to have reported sufficient data to estimate an effect size or the investigators had to have made the data available in reply to our request. There were only three studies that failed to satisfy this criterion. These three studies all investigated the effect of positive suggestions on the duration of postoperative hospitalization (Abramson, Greenfield, & Heron, 1966; Furlong, 1990; Hutchings, 1961).

Forty-four studies involving a total of 2517 patients satisfied the three criteria and were included in the meta-analysis.

Data Analysis

The first step in the data analysis involved computing an effect size estimate for each relevant measure investigated in each study. Following Rosenthal (1991), we used the product–moment correlation coefficient (r) as the effect size estimate. Each effect size (r) indicated the degree of association between a manipulated variable (e.g., positive suggestions vs. no positive suggestions) and a measure of memory (e.g., postoperative hospitalization). We computed the effect size estimates either from the reported means and standard deviations or from the reported statistics (e.g., t, F) used to compare the relevant conditions in the experiments.

If a study included only one relevant measure of memory, then only one effect size estimate was computed for that study. However, if a study included more than one relevant measure, then an effect size estimate was computed for each measure. For example, in the study reported by Caseley-Rondi, Merikle, and Bowers (1994), there were four measures relevant to the meta-analysis: (a) postoperative hospitalization, (b) morphine administered via PCA, (c) a direct test of memory, and (d) an indirect test of memory; consequently four separate effect size estimates were computed for this study.

There were also a few cases in which a study included more than one direct test of memory or more than one indirect test of memory. For example, Westmoreland, Sebel, Winograd, and Goldman (1993) used three different indirect tests of memory (i.e., category member generation, free association, and homophone spelling). Whenever there were multiple versions of the same kind of test within a single study, we computed an individual effect size estimate for each test, and then we averaged the individual effect size estimates to yield one composite effect size estimate for the study as a whole. In this way, no more than one effect size estimate for direct or indirect tests of memory was ever extracted from a single study.

There were three instances in which we did not use the data from all direct tests or all indirect tests included in a study. In these three studies, identical direct or indirect tests involving the same test items were administered on two separate occasions following surgery (Cork, Kihlstrom, & Schacter, 1992; Kihlstrom, Schacter, Cork, Hurt, & Behr, 1990; Villemure, Plourde, Lussier, & Normandin, 1993). Given that responses to test items on the second administration of a test may simply reflect the patients' memory for the responses they gave on the first administration of the test rather than memory for events during anesthesia, we decided to include only the results of the first administration of the memory tests in these studies.

Once we had computed an effect size estimate for each relevant memory measure in each study, the next step in the data analysis was to compute average or composite effect sizes across studies. Individual studies were weighted according to their sample size. These average effect sizes were computed by (a) transforming each r into a Fisher's z coefficient; (b) multiplying each Fisher's z by the number of patients; (c) summing the weighted Fisher's zs; (d) dividing each sum by the total number of patients; and (e) converting the resulting Fisher's z back to r.

TABLE 1
Postoperative Benefits of Positive Suggestions

Measure	*N* of studies	*N* of patients	Effect size (*r*)	*z*	*p*	Fail-safe *N*
Hospitalization	14	1092	.06	1.32	$<.0934$	—
PCA	4	234	.20	3.05	$<.0011$	10

To estimate the significance levels of the resulting combined effect sizes, we used the Stouffer method described by Rosenthal (1991). More specifically, we (a) converted each effect size estimate to a standard normal deviate (z); (b) weighted each standard normal deviate by the sample size; (c) summed the weighted standard normal deviates; and (d) divided this sum by the square root of the sum of the squared weights. The one-tailed probability (p) associated with each combined z was then used to estimate the significance level of each combined effect size.

A fail-safe N was also computed for each significant combined effect size ($p <$ .05). The fail-safe N is an estimate of the number of additional studies with an average effect size of 0 that would be necessary to change a statistically significant effect size to a statistically nonsignificant effect size. The fail-safe N thus provides another way of estimating the significance of each combined effect size.

RESULTS

Benefits of Positive Suggestions

Table 1 summarizes the results of the meta-analysis of the studies that assessed the benefits of positive suggestions on postoperative hospitalization and on PCA. The results are based on all studies listed in Appendices A and B with the exception of the two studies in Appendix A that involved patients undergoing cardiac surgery. For each measure of postoperative recovery, Table 1 shows the total number of studies (N), the total number of patients summed across studies (n), the combined or average weighted effect size (r), the combined weighted standard normal deviate (z) for each effect size, and the overall probability (p) associated with each z. In addition, the table shows the fail-safe N for each significant ($p < .05$) combined effect size.

As shown in Table 1, positive suggestions have much less of an effect on the duration of postoperative hospitalization (.06) than on the amount of morphine administered via PCA (.20). The small overall effect of positive suggestions on postoperative hospitalization was not statistically significant ($p < .0934$). However, the overall effect of positive suggestions on PCA was sufficiently large to reach statistical significance ($p < .0011$). These results provide mixed evidence regarding whether positive suggestions presented during anesthesia have a beneficial effect on postoperative recovery. Despite 14 studies involving 1092 patients, there is no strong evidence to indicate that positive suggestions presented during anesthesia significantly shorten the duration of postoperative hospitalization. On the other hand, based on 4 studies involving 234 patients, there is some evidence to indicate that positive suggestions influence the pain experienced by patients following surgery. However, the results

TABLE 2
Memory for Specific Information

Memory test	*N* of studies	*N* of patients	Effect size (*r*)	*z*	*p*	Fail-safe *N*
Less than 12 h	12	708	.23	5.51	<.000001	178
Indirect	11	548	.22	4.66	<.000001	96
Direct	1	160	.24	3.04	<.0012	2
12 to 36 h	10	560	.10	2.86	<.0021	32
Indirect	6	270	.02	0.52	<.3105	—
Direct	5	338	.15	2.95	<.0016	18
More than 36 h	7	224	.06	0.92	<.1788	—
Indirect	7	224	.06	0.95	<.1711	—
Direct	2	72	−.03	0.30	<.3821	—

based on the PCA measure must be interpreted with caution, given the rather small fail-safe *N;* it would take only a few additional studies with an average effect size of 0 to eliminate the significant effect size for this measure.

Memory for Specific Information

Time of test. We classified the studies that have measured memory for specific information with direct or indirect tests of memory in terms of the temporal interval separating the end of surgery and the administration of the memory test. We found that this way of viewing the studies adds considerable clarity to what initially appeared to be a bewildering pattern of positive and negative findings. The three temporal intervals that we chose reflect common research strategies. In 12 studies involving a total of 708 patients, the strategy was to measure memory as soon as possible after the patients regained consciousness (i.e., less than 12 h following surgery), whereas in 10 studies involving a total of 560 patients, the strategy was to test patients approximately 1 day following surgery (i.e., between 12 and 36 h following surgery). In the 7 remaining studies involving 224 patients, the memory tests were administered more than 36 h following surgery, including some instances in which the memory tests were administered more than 2 weeks following surgery. Table 2 shows the results of the meta-analysis of the studies that tested memory for specific information at each temporal interval.

Figure 1 shows the average effect size estimates at each temporal interval summed across direct and indirect tests. The pattern of findings is clear; the average effect size decreases systematically as the interval between the end of surgery and the administration of the memory test increases. Statistical analyses of these effect size estimates, summarized in Table 2, indicated that the overall average effect sizes are significant when memory was tested either less than 12 h following surgery ($p <$ .000001) or between 12 and 36 h following surgery ($p < .0021$). However, the very small average effect size (.06) when memory was tested at more than 36 h following surgery is not significant ($p < .1788$).

These findings provide strong evidence that specific information presented during anesthesia is both perceived and remembered. However, the overall pattern of results

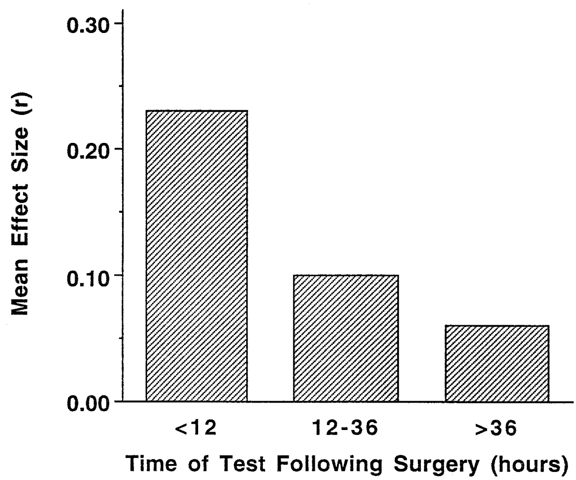

FIG. 1. Mean effect size of memory for specific information presented during anesthesia when tested at different temporal intervals following surgery.

also indicates that evidence of memory for specific information is more likely to be found when the patients are tested as soon as possible following surgery. In fact, the results of the meta-analysis show that when the memory tests are delayed for more than 36 h following anesthesia, there is no evidence of memory for specific information.

Indirect vs. direct tests. Indirect tests have been used much more often than direct tests to measure memory for specific information presented during anesthesia. The major reason indirect tests have been favored is the widespread assumption that indirect or implicit tests are more sensitive measures of unconscious perception and memory than are direct or explicit tests (e.g., Ghoneim & Block, 1992; Schacter, 1987). To evaluate whether indirect tests are more likely to reveal memory for specific information presented during anesthesia, we classified the studies at each temporal interval in terms of whether memory was assessed with indirect or direct tests. The detailed results of this classification are presented in Table 2.

Table 2 shows that there is no evidence to indicate that indirect tests are more likely to reveal memory for specific information than are direct tests. At the short temporal interval (i.e., less than 12 h following surgery), the effect size estimates for direct tests (.24) and indirect tests (.22) are very similar; at the intermediate temporal interval (i.e., 12 to 36 h following surgery), the average effect size estimate for direct tests (.15) is actually larger than the effect size estimate for indirect tests (.02); and at the long temporal interval (i.e., more than 36 h following surgery), both effect size estimates are small. Statistical analysis of these effect sizes, as shown in Table 2, indicated that the average effect sizes for direct tests were significant at both the short ($p < .0012$) and intermediate ($p < .0016$) temporal intervals; however, for indirect tests, the only significant effect size was at the short temporal interval ($p < .000001$).

These results indicate that both direct and indirect tests can reveal memory for events during anesthesia, *as long as patients are required to respond to all the items on the test.* Thus, the results of the meta-analysis provide no support for the assumption that indirect or implicit tests are more sensitive tests of unconscious memory than are direct or explicit tests. Rather, the results are more consistent with the view that both direct and indirect tests can be sensitive measures of unconsciously perceived and remembered information (e.g., Jacoby, Toth, & Yonelinas, 1993; Merikle & Reingold, 1991; Richardson-Klavehn & Bjork, 1988). Given these results, there are no longer any compelling reasons for the strong bias to use indirect rather than direct tests to measure memory for specific information presented during anesthesia.

DISCUSSION

The results of the meta-analysis lead to a number of conclusions regarding the conditions that are most likely to reveal memory for information presented during anesthesia. In general, positive suggestions presented during anesthesia have little effect on postoperative recovery. There is no evidence that positive suggestions reduce the duration of postoperative hospitalization, and the evidence indicating that positive suggestions reduce the amount of morphine administered via PCA following surgery is based on so few studies that it would be premature to reach any strong conclusions. On the other hand, the meta-analysis provides considerable evidence that specific information is both perceived during anesthesia and remembered following surgery. The meta-analysis also indicates that memory for specific information becomes weaker the longer the memory test is delayed following the end of surgery. In fact, the results suggest that there is no memory for specific information when testing is delayed more than 36 h following surgery.

Given the assumption that surgical anesthesia induces unconsciousness, the results of the meta-analysis indicate that unconscious patients perceive information during surgery and remember this unconsciously perceived information following surgery for approximately 24 h. These results complement the results from more traditional studies in which conscious people are induced to perceive stimuli unconsciously by presenting the stimuli under suboptimal conditions. The meta-analysis shows that comparable results are found when stimuli are presented under optimal conditions and unconsciousness is induced directly.

Is it possible that general anesthesia does not cause patients to become unconscious of all external events and that memory for events during anesthesia actually indicates that patients experience fleeting moments of awareness during surgery? Given that the depth of anesthesia fluctuates during surgery, it could be argued that any memory for information presented during anesthesia may simply reflect brief periods of time during surgery when patients have some low level of awareness for external events. It is not possible to give a definitive answer to this question because there is no method available for continuously monitoring the depth of anesthesia (see Andrade, 1995); consequently, there is no method available for assessing moment-to-moment levels of awareness during anesthesia. Of course, this problem is not unique to studies of memory for events during anesthesia. In more traditional studies, there is also no method for assessing awareness at the moment a degraded stimulus is presented, and the inference that a stimulus is unconsciously perceived is always made at a later point in time, albeit only a few seconds later. Hence, it is also possible to argue that subjects tested with more traditional methods experience fleeting awareness of the stimuli at the moment they are presented.

Despite the remote possibility that some patients may experience moments of awareness during anesthesia, we believe that it is reasonable to assume that patients who are undergoing general anesthesia are in fact unconscious of all external events for the entire duration of surgery. Given the reports from thousands and thousands of patients indicating no subjective awareness of any events during anesthesia, it seems improbable that patients have experiences during anesthesia that are similar in any way to the subjective experiences normally associated with conscious perception of external events. Thus, a reasonable working hypothesis is that patients are unconscious during surgery. Given this hypothesis, studies of memory for events during anesthesia provide an interesting avenue for exploring unconscious cognition.

An important new finding revealed by the meta-analysis is that the impact of unconsciously perceived information can last for periods of time measured in hours or days. In more traditional studies of unconscious perception, memory has typically been assessed just a few seconds following presentation. Obviously, if the impact of unconsciously perceived information lasts only a few seconds, the concept of unconscious perception has less importance and less generality than if the impact of unconsciously perceived information lasts for hours or days. Thus, by showing that memory for unconsciously perceived information can last for hours or even days, the results of the meta-analysis indicate that the concept of unconscious perception may be considerably more important than can be inferred from the results of studies that have measured memory for unconsciously perceived events over temporal intervals lasting no more than a few seconds.

It is interesting to note that the results of the meta-analysis regarding the duration of memory for unconsciously perceived information are consistent with the results of Poetzl's (1917/1960) classic study. Poetzl showed subjects a complex picture for a brief 10-ms exposure and then measured the subjects' conscious recollection of what they had seen by immediately asking them both to describe and to draw everything they remembered about the picture. Following this interrogation, Poetzl asked the subjects to record any dreams they had that night and to return the following day. When the subjects returned the next day and described their dreams, Poetzl discovered that the dream imagery contained aspects of the original picture that the subjects had failed to report the previous day. Given the assumption that Poetzl's initial interrogations of his subjects adequately assessed what they perceived consciously, his studies, as well as the successful replications of his studies (e.g., Fisher, 1954; Shevrin & Luborsky, 1958), provide another line of evidence showing that unconsciously perceived information can be remembered for many hours.

Is it possible that memory for unconsciously perceived information lasts longer than the 24 to 36 h suggested by the results of the meta-analysis? We think that there is reason to believe that unconsciously perceived information may be remembered for considerably longer. One reason memory has been demonstrated only at the shorter temporal intervals may be that at the shorter intervals there is a greater similarity between the context in which the information is perceived and the context in which memory is tested. For example, when patients are tested in the recovery room immediately after they regain consciousness, the sounds and smells and other features of the external environment are similar to those of the operating theater. Also, patients in the recovery room are probably still experiencing some of the residual effects of the drugs administered during surgery, so that the patient's physiological state at the time of testing is likely to be similar to his or her physiological state at the time of learning. Given how important the similarity between presentation and retrieval contexts is for determining the success of memory retrieval (e.g., Eich, 1980; Godden & Baddeley, 1975; Tulving & Thomson, 1973), the greater similarity between the perception and test contexts at the shorter temporal intervals would be expected to increase the likelihood of finding evidence of memory for events during anesthesia. Conversely, when temporal intervals between perception and test are longer, the decreased similarity between the context in which the information is perceived and the context in which the memory is tested would be expected to make retrieval more difficult, so that evidence for memory is less likely to be found.

Another reason memory has not been demonstrated over intervals longer than 36 h is that the stimulus materials have had no particular personal relevance for the patients. In a typical experiment, a list of common words was presented repeatedly during the time the patients are anesthetized. This is exactly the type of stimulus material that may be subject to considerable decay and interference in memory as the interval between initial perception and the test of memory increases. In contrast, when unconsciously perceived information is personally relevant and meaningful, it is possible that the impact may last for weeks. Recall, Levinson's (1965) intriguing observations regarding memory for the mock crisis he staged while surgical patients were undergoing general anesthesia. These observations were based on interviews he conducted 1 month following surgery. The fact that 8 of the 10 patients he studied had some memory for the mock crisis is striking and invites speculation. Although Levinson's findings are not definitive, they do suggest that unconsciously perceived information may have a relatively long-lasting impact if the material is personally relevant and meaningful.

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APPENDIX A

Duration of Postoperative Hospitalization: Effect Size and Sample Size for Each Study

Study	*r*	*N*
Bethune, Ghosh, Walker, Carter, Kerr, & Sharples (1993)[a]	.37	33
Block, Ghoneim, Sum Ping, & Ali (1991a)	−.01	209
Boeke, Bonke, Boiuwhuis-Hoogerwerf, Bovill, & Zwaveling (1988)	.12	53
Bonke, Schmitz, Verhage, & Zwaveling (1986)	.06	55
Caseley-Rondi, Merikle, & Bowers (1994)	−.11	96
De Houwer, Demeyere, Verhamme, & Eelen (1995)[a]	.18	40
Evans & Richardson (1988)	.50	39
Furlong & Read (1993)	−.13	108
Jelicic, Bonke, & Millar (1993)	.10	82
Korunka, Guttmann, Schleiitz, Hilpert, Haas, & Fitzal (1992)	.03	108
Liu, Standen, & Aitkenhead (1992)	−.13	48
Liu, Standen, & Aitkenhead (1993)	.14	82
Pearson (1961)	.28	81
Steinberg, Hord, Reed, & Sebel (1993)	.19	60
Van der Laan, van Leeuwen, Sebel, Winograd, & Bonke (1996)	.13	40
Woo, Seltzer, & Marr (1987)	.20	31

[a] Patients undergoing cardiac surgery. Study not included in the meta-analysis.

APPENDIX B

Patient-Controlled Analgesia (PCA): Effect Size and Sample Size for Each Study

Study	*r*	*N*
Caseley-Rondi, Merikle, & Bowers (1994)	.23	74
McClintock, Aitken, Downie, & Kenny (1990)	.29	60
Steinberg, Hord, Reed, & Sebel (1993)	.20	60
Van der Laan, Van Leeuwen, Sebel, Winograd, Bauman, & Bonke (1996)	−.04	40

APPENDIX C

Memory Tested Less Than 12 h Following Surgery: Effect Size and Sample Size for Each Study

Study	*r*	*N*
Indirect measures		
Bonebakker, Bonke, Klein, Wolters, & Hop (1993)	.13	81
Charlton, Wang, & Russell (1993)	.15	44
Cork, Kihlstrom, & Schacter (1992)	−.14	25
De Roode, Jelicic, Bonke, & Bovill (1995)	−.08	83
Donker, Phaf, Porcelijn, & Bonke (in press)	.09	58
Jelicic, Bonke, Wolters, & Phaf (1992)	.29	50
Jelicic, De Roode, Bovill, & Bonke (1992)	.48	43
Khilstrom, Schacter, Cork, Hurt, & Behr (1990)	.31	25
Roorda-Hrdlickova, Wolters, Bonke, & Phaf (1990)	.59	81
Villemure, Plourde, Lussier, & Normandin (1993)	.54	10
Westmoreland, Sebel, Winograd, & Goldman (1993)	.08	48
Direct measures		
Bonebakker, Bonke, Klein, Wolters, Stijnen, Passchier, & Merikle (1996)	.24	160

APPENDIX D

Memory Tested 12 to 36h Following Surgery: Effect Size and Sample Size for Each Study

Study	*r*	*N*
Indirect measures		
Block, Ghoneim, Sum Ping, & Ali (1991b)	.06	72
Dwyer, Bennett, Eger, & Peterson (1992)	.00	45
Humphreys, Asbury, & Millar (1990)	−.13	20
Jelicic, Asbury, Millar, & Bonke (1993)	.04	41
Stolzy, Couture, & Edmonds (1987)	−.04	32
Van der Laan, Van Leeuwen, Sebel, Winograd, Bauman, & Bonke (1996)	.07	60
Direct measures		
Block, Ghoneim, Sum Ping, & Ali (1991b)	.03	48
Bonebakker, Bonke, Klein, Wolters, Stijnen, Passchier, & Merikle (1996)	.21	153
Dubovsky & Trustman (1976)	−.09	36
Millar & Watkinson (1983)	.39	53
Parker, Oates, Boyd, & Thomas (1994)	−.03	48

APPENDIX E

Memory Tested More Than 36 h Following Surgery: Effect Size and Sample Size for Each Study

Study	*r*	*N*
Indirect measures		
Bethune, Ghosh, Gray, Kerr, Walker, Doolan, Harwood, & Sharples (1992)[a]	.31	44
Brown, Best, Mitchell, & Haggard (1992)	−.25	10
Caseley-Rondi, Merikle, & Bowers (1994)	−.04	48
De Houwer, Demeyere, Verhamme, & Eelen (1995)[a]	.03	40
Eich, Reeves, & Katz (1985)	.02	24
Jackson, Brown, & Best (1994)	−.10	20
Schwender, Madler, Klasing, Peter, & Poppel (1994)[a]	.30	45
Stolzy, Couture, & Edmonds (1986)	.46	40
Westmoreland, Sebel, Winograd, & Goldman (1993)	−.01	48
Winograd, Sebel, Goldman, Clifton, & Lowden (1991)	.01	34
Direct measures		
Caseley-Rondi, Merikle, & Bowers (1994)	−.04	48
De Houwer, Demeyere, Verhamme, & Eelen (1995)[a]	.01	40
Eich, Reeves, & Katz (1985)	−.02	24

[a] Patients undergoing cardiac surgery. Study not included in the meta-analysis.

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