Memory priming during light anaesthesia with desflurane and remifentanil anaesthesia

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Background. Previous studies of memory priming during anaesthesia with EEG monitoring have observed implicit memory effects for words presented during light and deep anaesthesia with and without surgical stimulation. We hypothesized that memory priming occurs under each of five different combinations of anaesthesia and surgery, and no significant differences occur in memory priming among the five conditions or between the two test points such as, 12 vs 24 h after surgery.

Methods. Forty gynaecological patients (aged between 28 and 66 yr; median 44.5 yr) were included in the study. They received propofol and remifentanil induction followed by desflurane and remifentanil anaesthesia in conjunction with neuromuscular blocking agents. Each patient was exposed to 60 of 120 nouns in a double-blind randomized design. These 60 nouns were divided into 5 groups of 12 words, presented under one of the five different conditions, namely, intubation, skin incision, deep anaesthesia and moderate anaesthesia (both during surgery), and light anaesthesia during the emergence phase. The depth of anaesthesia was measured using the EEG monitor, Narcotrend™.

Results. No explicit memories were observed in a free recall or in a yes–no recognition test. A word-stem completion test revealed a significant implicit priming only for light anaesthesia (P<0.01). No significant differences were detected among the five conditions. An overall implicit memory effect occurred for the second test point (P<0.05).

Conclusions. Our hypotheses could not be verified. Implicit memory priming occurred only under light anaesthesia, when the patients were most probably conscious. Priming effects may be enhanced after night’s sleep.

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Previous studies have demonstrated memory priming of auditory information presented during light to moderate or deep anaesthesia. In typical studies, patients are exposed to common words during general anaesthesia. This can activate or prime the existing knowledge and enhance the performance on postoperative memory tests. While the consolidation of explicit memory is impaired by low doses of anaesthetics, unconscious information processing seems to be more resistant to drug effects. Patients do not show explicit memories in free recall tests or in yes–no recognition tests for intraoperative-presented words. Explicit memory effects would suggest conscious learning and awareness during anaesthesia. In implicit memory tests, for example, a word-stem completion test, patients demonstrate implicit memory priming by enhanced word-stem completion for the intraoperative-presented words. This is evidence for unconscious information processing during anaesthesia.

The combination of implicit memory tests and EEG monitoring of anaesthetic depth allows the exploration of memory priming processes under different anaesthetic depths; however, results are contradictory. While Lubke
and colleagues\textsuperscript{6} found indications for a correlation between memory priming and the depth of anaesthesia, Stapleton and Andrade\textsuperscript{7} failed to do so.

In the present study, we aimed to investigate whether unconscious or implicit memory priming occurs under each of five different combinations of anaesthesia and surgery: (1) tracheal intubation, (2) skin incision, (3) surgery on the uterus under deep anaesthesia, (4) surgery on the uterus under moderate anaesthesia, and (5) during emergence under light anaesthesia. The depth of anaesthesia was measured using the EEG Narcotrend monitor. We hypothesized that implicit memory priming, but no explicit memory effect, occurs under each of the five conditions, and no significant differences will occur among the implicit memory effects in the five conditions or between the two test points, 12 vs 24 h after surgery.

**Methods**

Approval for the study was obtained from the Bremen Medical Ethics Committee (\text{"A}rztekammer Bremen). The participants gave written consent. Only female patients (ASA I or II) undergoing elective major gynaecological surgery under general anaesthesia were eligible for the study. Non-German speakers were excluded, as were those with impaired hearing, language difficulties, neurological, psychiatric or memory disorders, or those who were taking medications known to affect memory or the central nervous system. Patients were exposed randomly to one of the two groups of 60 nouns, both groups consisting of 5 lists of 12 nouns, presented during one of the five different conditions of anaesthesia.

**Construction of experimental stimuli**

The word material consisted of 140 familiar German nouns selected from a baseline,\textsuperscript{8} 70 nouns with 5 letters and 70 with 6 letters. The three-letter word-stem of each noun could be completed with at least three common nouns (e.g. S-E-I\_ _ with Seife, Seide, Seite). Each letter of a single word-stem (e.g. S-E-I) and the complete noun (e.g. Seife) were recorded in the voice of the first experimenter at a sample rate of 44.1 kHz and 16 bit sample size, using a dynamic studio microphone (Monacor DM-700) and a Realtime Sound Processor software (Steinberg WaveLab 2.02). This was to ensure the identical sound of word-stems and nouns in all sections of the study.

Twenty nouns were used to form a pre-surgery list. This list was presented to the patients on the day before the operation. For intraoperative presentation, the 120 nouns not presented before operation were divided into 2 groups of 60 nouns: group 1 and group 2. In both groups, the nouns were used to form 5 lists of 12 nouns (Fig. 1). The nouns in each list had a stem completion rate between 10 and 40%, evaluated under baseline conditions with undergraduate students (\(n=40\)).\textsuperscript{8} The average stem completion rate in each list was 23%. The spelled word-stem was played before each noun (e.g. S-E-I ... Seife) and presented twice. The sequence in each list was randomized. The presentation time for each 12-noun list was 1.44 min.

On the day of operation, during anaesthesia, patients were exposed randomly to five lists of nouns, either to nouns in group 1 or group 2. The experimenter and the patients were blinded to list assignment. The lists were presented over the CD-player and closed headphones. Distractor nouns for the postoperative tests were selected from the non-presented nouns. The intraoperative presentation of the first list commenced at the same time as tracheal intubation and the second list at the same time as skin incision. The next two lists were presented during uterine surgery when Narcotrend showed that the intended depth of anaesthesia had been reached, namely, deep anaesthesia \(E_0\) and moderate anaesthesia \(D_1\). The fifth list was presented in the emergence phase during Narcotrend-defined light anaesthesia \(C_1\). The short presentation time of each list ensured complete presentation at the intended depth of anaesthesia.

![Fig 1](image-url) The grouping and presentation of the word material in the study.
**Anaesthetic techniques and experimental procedures**

The patients were orally pre-medicated 30–60 min before induction of anaesthesia with midazolam 7.5–15 mg or promethazine 50 mg. Anaesthesia was induced with remifentanil 0.5 μg kg⁻¹ given for 1 min and propofol 2.5 mg kg⁻¹. The patients were pre-oxygenated and, after loss of consciousness, were ventilated with oxygen. Cisatracurium or vecuronium 0.075 mg kg⁻¹ was given to facilitate tracheal intubation. Anaesthesia was maintained with desflurane and a continuous infusion of remifentanil 0.20–0.25 μg kg⁻¹ min⁻¹. The desflurane was adjusted to achieve the intended depth of anaesthesia at each stage of the study. Further cisatracurium or vecuronium was given if required. Patients with a tendency to postoperative nausea and vomiting received granisetron 1 mg.

The depth of anaesthesia was measured using the automatic EEG classification system Narcotrend™ (version 2.0 AF, MT Monitor Technik, Bad Bramstedt, Germany), which provides a six-letter classification from A (awake), B (very light hypnosis), C (light hypnosis), D (moderately deep hypnosis), and E (deep hypnosis) to F (general anaesthesia with increasing burst suppressions, coma). These 5 stages are further divided to give a total of 15 substages. Thus, the depth of anaesthesia is given as a letter and a subscript, e.g. E₀. The monitor also gives a numerical index, ranging from 100 (awake) to 0 (coma). The Narcotrend monitor has been shown to correlate with the BIST™ monitor in an anaesthesia with propofol and remifentanil.9

**Memory tests**

We conducted memory tests on the day of the operation 12 h after surgery, and the second the next morning 24 h after surgery. In a structured interview with a fixed order similar to that used by Russell and Wang,10 the patients answered four questions orally to elicit explicit free recall. They were asked about the last occurrence they remembered before induction of anaesthesia, the first after anaesthesia and events of any kind, including dreams during anaesthesia. The other two tests were performed using a CD-player and loudspeakers. First, we conducted a yes–no recognition test to identify explicit memory for intraoperatively presented target nouns. At both test points, patients were asked to recognize 40 nouns in total, 10 of which were intraoperatively presented target nouns (two from each of the five presented lists), 10 not presented distractor nouns (two from each of the five non-presented lists), and 20 nouns presented in the pre-surgery list on the day before the operation. Explicit memory performance on the yes–no recognition test was scored as the number of ‘yes’ responses to a target noun minus the number of ‘yes’ responses to a distractor noun, expressed as proportion of the total number of intraoperatively presented nouns used in this test (explicit memory scores).

The implicit memory effect was assessed with a word-stem completion test. The patients were instructed to complete three-letter word-stems with the first noun that came to mind. The three spoken letters of a word-stem were spelled separately (e.g. S-E-I), but the real stem left unsaid (e.g. Sei ~ without the tail ~fe). So each cue consisted of the spoken three letters. At both test points, the patients completed 140 word-stems in total, 60 of which were word-stems from the intraoperatively presented target nouns, 60 from the not presented distractor nouns, and 20 from the pre-surgery nouns. Responses on the implicit word-stem completion test were scored as ‘hits’, if the patients completed the word-stems to a target noun or a distractor noun. Implicit memory scores were calculated by subtracting the number of hits on the distractor stems from the number of hits on the target stems. The differences were presented as proportion of all intraoperatively presented nouns (implicit memory scores).

In the pre-surgery test on the day before the operation, after an initial presentation of 20 nouns, the execution of a word-stem completion test was trained with these nouns. Thus, the patients were also tested for unknown memory disorders. In the postoperative yes–no recognition test, the pre-surgery nouns were included to prevent any answer tendency to answer ‘no’. This problem may occur when patients are unable to recognize at least some of the nouns. They may continue in a routine manner, answering with ‘no’ even when they recognize a single word.11 The word stems of the pre-surgery nouns were included in the implicit test to simplify the task for patients who had problems in finding completions and facilitating access to primed target nouns.

**Statistical methods**

A one-way analysis of variance with repeated measurement design (RM-ANOVA) was conducted to test differences in the depth of anaesthesia among the five examined conditions of anaesthesia, estimated with the Narcotrend EEG index. In the yes–no recognition and the word-stem completion tests, positive memory scores indicated possible priming effects that were checked for their significance using one-tailed, one-sample t-tests. With this test, we controlled whether the positive memory scores in each condition of anaesthesia significantly exceeded zero, for pooled data over both test points and separately for each one test point (12 vs 24 h after surgery). A multi-factorial RM-ANOVA with three factors [two categories of nouns (targets vs distractors), five conditions of anaesthesia, two test points] was used to detect an overall memory effect (memory score over all five conditions of anaesthesia) and to investigate interaction effects between the three factors, especially to make statements about differences in the memory scores among the five conditions of anaesthesia and between the test points. This was done for pooled data over both test points. Additionally, for each test point
was not significant in either explicit memory scores. There was no priming effect for nouns presented during light anaesthesia in the emergence phase. The patients had no explicit recall in the structured postoperative interview nor showed explicit memory effects in the yes–no recognition test for nouns presented during the five conditions of anaesthesia. This was also no interaction between the nouns, the five conditions of anaesthesia, and the two test points.

In the word-stem completion test for pooled data over both test points, only the implicit memory score for light anaesthesia $C_1$ exceeded zero significantly ($P<0.01$, with $t$-test), whereas no implicit memory effect was found in the other four conditions of anaesthesia; intubation, skin incision, surgery under deep or moderate anaesthesia. For each test time, no significant implicit memory effect was observed in each of the five conditions. Additionally, no significant differences in the memory scores were detected among the five conditions of anaesthesia. However, for the overall implicit memory performance, a borderline significant advantage occurred for the second test time, 24 h after surgery, compared with the first test time, 12 h after surgery ($P=0.054$). It was also possible to show an overall implicit memory effect at the second test time ($P<0.05$, with two-factorial ANOVA).

### Results

Data from 40 female patients, aged between 28 and 66 yr (median 44.5 yr), weighing between 53 and 103 kg (median 72.0 kg) were included in the statistical analysis, although 52 patients were randomly exposed to the stimuli during anaesthesia. Twelve patients were excluded from the study. Three refused the postoperative tests, one had complications during surgery, one in the postoperative process, and seven were excluded because of other protocol violations. The majority of the patients ($n=37$) underwent major gynaecological surgery such as hysterectomy or myomectomy. Three patients underwent vaginal hysterectomy. These patients accomplished the tests in exactly the same way as all the other patients; however, their data for the condition ‘skin incision’ were not included into the statistical analysis.

Anaesthesia lasted between 44 and 200 min (median 95.5 min). The concentrations of desflurane and remifentanil and the depth of anaesthesia defined by the Narcotrend monitor during the five conditions of anaesthesia are presented in Table 1. A one-way RM-ANOVA confirmed the significant difference in depth of anaesthesia among the five conditions ($P<0.001$).

The explicit and implicit memory test scores are shown in Table 2. Explicit memories did not occur for intraoperatively presented target nouns or dreams, either with the structured postoperative interview eliciting spontaneous free recall or with the yes–no recognition test. In the yes–no recognition test for explicit memory, the patients made more ‘yes’ responses to not presented distractor nouns than to intraoperatively presented target nouns; however, this was not significant in either explicit memory scores. There was also no interaction between the nouns, the five conditions of anaesthesia, and the two test points.

In the word-stem completion test for pooled data over both test points, only the implicit memory score for light anaesthesia $C_1$ exceeded zero significantly ($P<0.01$, with $t$-test), whereas no implicit memory effect was found in the other four conditions of anaesthesia; intubation, skin incision, surgery under deep or moderate anaesthesia. For each test time, no significant implicit memory effect was observed in each of the five conditions. Additionally, no significant differences in the memory scores were detected among the five conditions of anaesthesia. However, for the overall implicit memory performance, a borderline significant advantage occurred for the second test time, 24 h after surgery, compared with the first test time, 12 h after surgery ($P=0.054$). It was also possible to show an overall implicit memory effect at the second test time ($P<0.05$, with two-factorial ANOVA).

### Discussion

The aim of the study was to investigate whether memory priming occurs during EEG-controlled anaesthesia under each of five different combinations of anaesthesia and surgery, namely, during intubation, skin incision, during surgery under deep and moderate anaesthesia, and during light anaesthesia in the emergence phase. The patients had no explicit recall in the structured postoperative interview nor showed explicit memory effects in the yes–no recognition test for nouns presented during the five conditions of anaesthesia. There was no evidence for an implicit priming effect using the word-stem completion test in four of the five conditions. Significant implicit memory priming occurred only for nouns presented during Narcotrend-defined light anaesthesia $C_1$ in the emergence phase—without anaesthetic or surgical stimulation. Moreover, the observed memory effect during Narcotrend-defined light anaesthesia was probably primed during conscious awareness with subsequent amnesia.

According to studies of Russell,12,13 EEG values are not necessarily indicators of unconsciousness, especially in an anaesthesia with neuromuscular blocking agents, as was the case in our study. In this kind of anaesthesia, the isolated forearm technique allows the patients to respond to verbal commands such as ‘Squeeze my hand’, if

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**Table 1** Concentrations of desflurane, remifentanil, and the Narcotrend indices during the five different conditions of anaesthesia. Values are mean (SD)

<table>
<thead>
<tr>
<th>Conditions of anaesthesia</th>
<th>Average dose of desflurane (end-tidal vol.%)</th>
<th>Average dose of remifentanil (µg kg⁻¹ min⁻¹)</th>
<th>Narcotrend index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intubation ($n=40$)</td>
<td>Propofol (induction)</td>
<td>0.50 (0)</td>
<td>37 (11)</td>
</tr>
<tr>
<td>Skin incision ($n=37$)</td>
<td>4.96 (1.18)</td>
<td>0.23 (0.12)</td>
<td>40 (11)</td>
</tr>
<tr>
<td>Deep anaesthesia $E_0$ ($n=40$)</td>
<td>5.33 (0.77)</td>
<td>0.25 (0.11)</td>
<td>33 (4)</td>
</tr>
<tr>
<td>Moderate anaesthesia $D_1$ ($n=40$)</td>
<td>4.43 (0.96)</td>
<td>0.22 (0.11)</td>
<td>49 (4)</td>
</tr>
<tr>
<td>Light anaesthesia $C_1$ ($n=40$)</td>
<td>1.25 (0.68)</td>
<td>0.02 (0.05)</td>
<td>73 (9)</td>
</tr>
</tbody>
</table>

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Table 2 Data for the explicit and implicit memory tests with target scores, distractor scores and the resulting memory scores, for pooled data over both test points, and separately for both test points, 12 and 24 h after surgery. *P<0.05, **P<0.01. Values are mean (sd)

<table>
<thead>
<tr>
<th>Conditions of anaesthesia at different test point</th>
<th>Explicit yes–no recognition test</th>
<th>Implicit word-stem completion test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target score</td>
<td>Distractor score</td>
</tr>
<tr>
<td>For pooled data over both test points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(12 and 24 h after operation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intubation (n=40)</td>
<td>0.05 (0.15)</td>
<td>0.02 (0.11)</td>
</tr>
<tr>
<td>Skin incision (n=37)</td>
<td>0.04 (0.18)</td>
<td>0.09 (0.23)</td>
</tr>
</tbody>
</table>
| Deep anaesthesia E 
(n=40)                        | 0.16 (0.24)  | 0.13 (0.25)      | 0.03 (0.30)  | 0.33 (0.14)  | 0.31 (0.11)      | 0.02 (0.17)  |
| Moderate anaesthesia D1 
(n=40)                   | 0.04 (0.18)  | 0.10 (0.26)      | -0.06 (0.28) | 0.27 (0.12)  | 0.28 (0.11)      | -0.01 (0.17) |
| Light anaesthesia C1 
(n=40)                      | 0.06 (0.17)  | 0.12 (0.22)      | -0.06 (0.26) | 0.30 (0.11)  | 0.24 (0.11)      | 0.06 (0.14)** |
| Overall five conditions                            | 0.07 (0.11)  | 0.09 (0.16)      | -0.02 (0.14) | 0.30 (0.13)  | 0.28 (0.11)      | 0.02 (0.17)  |
| First test point, 12 h after surgery               |              |                  |              |              |                  |              |
| Intubation (n=40)                                  | 0.00 (0.00)  | 0.00 (0.00)      | 0.00 (0.00)  | 0.29 (0.19)  | 0.34 (0.16)      | -0.05 (0.21) |
| Skin incision (n=37)                               | 0.03 (0.16)  | 0.08 (0.28)      | -0.05 (0.33) | 0.31 (0.21)  | 0.28 (0.17)      | 0.03 (0.29)  |
| Deep anaesthesia E 
(n=40)                        | 0.25 (0.44)  | 0.20 (0.41)      | 0.05 (0.60)  | 0.32 (0.18)  | 0.30 (0.15)      | 0.02 (0.24)  |
| Moderate anaesthesia D1 
(n=40)                   | 0.03 (0.16)  | 0.13 (0.34)      | -0.10 (0.38) | 0.24 (0.18)  | 0.32 (0.18)      | -0.08 (0.30) |
| Light anaesthesia C1 
(n=40)                      | 0.00 (0.00)  | 0.00 (0.00)      | 0.00 (0.00)  | 0.34 (0.17)  | 0.28 (0.17)      | 0.06 (0.22)  |
| Overall five conditions                            | 0.06 (0.11)  | 0.08 (0.14)      | -0.02 (0.16) | 0.30 (0.09)  | 0.30 (0.08)      | 0.00 (0.12)  |
| Second test point, 24 h after surgery              |              |                  |              |              |                  |              |
| Intubation (n=40)                                  | 0.10 (0.30)  | 0.05 (0.22)      | 0.05 (0.32)  | 0.34 (0.20)  | 0.29 (0.19)      | 0.05 (0.30)  |
| Skin incision (n=37)                               | 0.06 (0.23)  | 0.11 (0.32)      | -0.05 (0.33) | 0.20 (0.15)  | 0.15 (0.17)      | 0.05 (0.19)  |
| Deep anaesthesia E 
(n=40)                        | 0.08 (0.27)  | 0.08 (0.27)      | 0.00 (0.32)  | 0.33 (0.18)  | 0.32 (0.17)      | 0.01 (0.21)  |
| Moderate anaesthesia D1 
(n=40)                   | 0.05 (0.22)  | 0.08 (0.27)      | -0.03 (0.28) | 0.30 (0.17)  | 0.25 (0.16)      | 0.05 (0.20)  |
| Light anaesthesia C1 
(n=40)                      | 0.13 (0.34)  | 0.25 (0.44)      | -0.12 (0.52) | 0.26 (0.17)  | 0.20 (0.17)      | 0.06 (0.25)  |
| Overall five conditions                            | 0.08 (0.16)  | 0.11 (0.23)      | -0.03 (0.20) | 0.29 (0.09)  | 0.25 (0.09)      | 0.04 (0.11)*  |

Conscious. Consequently, the isolated forearm technique is the only direct method of detecting consciousness during general anaesthesia with neuromuscular blocking agents. In a recent study with the Narcotrend monitor, Russell13 demonstrated that some patients continued to respond to commands at EEG values, which were defined by the Narcotrend monitor as unconsciousness—in some patients even during ‘moderate’ or ‘deep’ anaesthesia. However, in our study, a consolidation in the explicit memory system did not take place. No explicit tests were able to reveal a learning effect. Only the implicit word-stem completion test demonstrated memory priming for nouns presented during light anaesthesia C1, when—according to Russell—the patients were most probably conscious.

The results of Russell12 13 suggest that during anaesthesia with neuromuscular blocking agents, the isolated forearm technique should be introduced as a clinical standard to protect patients from undetected consciousness during anaesthesia. However, in the emergence phase and specifically in some surgery indications (e.g. open heart surgery), phases of light anaesthesia or even consciousness cannot be prevented. During those phases, the anaesthetist should communicate with the patients and reassure them that everything is under control. As a minimum standard, the patients should at least be protected from noises in the operating theatre by introducing closed headphones and audio players presenting, for example, relaxation music.

Assuming the Narcotrend monitor indicated the correct depth of anaesthesia, demonstration of implicit memory priming effects under moderate or deep anaesthesia may have failed for a number of reasons. In the test phase of the word-stem completion test, only three spoken letters of a word-stem were presented (e.g. S-E-I) and not the real stem without the tail (e.g. Sei ~ without the tail ~e), as described in other studies.3 4 We used a different method: during anaesthesia, namely, the spoken letters were presented together with the complete word (e.g. S-E-I . . . Seife). So our cue consisted of the spoken three letters. However, this test method may not have reached a sensitivity high enough to elicit perceptual priming effects for nouns presented during moderate or deep anaesthesia. This is the crucial issue as during deep anaesthesia only perceptual but not conceptual priming seems to be possible.14 In our study, the cue ‘S-E-I’ perhaps did not match the primed percept of the complete word ‘Seife’. Furthermore, the nouns were only presented twice. Deeprose and colleagues3 4 presented each noun 15 times and Iselin-Chaves and colleagues5 presented 25 times. However, in a meta-analysis,15 no superior memory priming effect was found for a repeated presentation of words. Another reason could be that the patients in our study were constantly protected against pain using a continuous infusion of remifentanil. This may have prevented the patients from suffering severe pain induced by intraoperative stress. In addition, desflurane or the combination of desflurane and remifentanil has not been used in other studies investigating implicit priming effects during anaesthesia and may have impairing effects on the unconscious information processing, so that no implicit memory priming effect occurs. Finally, the borderline significant time effect in favour of the second test point (24 h after surgery) indicated superior implicit memory priming for
intraoperatively presented target nouns after night’s sleep, especially as a significant overall priming effect occurred in the word-stem completion test, performed at the second test point. This may be explained by reprocessing and consolidation processes, enabled during slow-wave sleep and rapid eye movement sleep in night’s sleep, as were shown for an implicit motor learning task and an implicit serial reaction time task.

In conclusion, our hypotheses could not be verified and our study does not clarify the contradictory findings of previous studies regarding implicit memory priming during deep anaesthesia. Deeprose and colleagues found evidence for surgical stimulation as the relevant variable facilitating memory priming, despite deep anaesthesia [Mean-BIS 43.6 (SD 16.4)]. However, the study of Iselin-Chaves and colleagues demonstrated memory priming during deep anaesthesia (BIS 41–60) even when the majority of the words were presented before surgery. In contrast, a recent study of Kerssens and colleagues showed that memory priming effects did not occur under deep anaesthesia during surgery [Mean-BIS 48.8 (SD 5.7)].

According to the results of Russell, EEG-defined depth of anaesthesia does not define a single ‘distinctive’ level, thus making it difficult to quantify the real depth of anaesthesia. Unlike Deeprose and colleagues, surgical stimulation was possibly the relevant variable facilitating memory priming despite unconsciousness, while in the study of Iselin-Chaves and colleagues, the presented words were perhaps primed during undetected conscious awareness with subsequent amnesia. Additionally, Iselin-Chaves and colleagues did not conduct a Bonferroni adjustment of the P value because of multiple comparisons (for three depths of anaesthesia: BIS 21–40, BIS 41–60, BIS 61–80). It is still to be determined why Kerssens and colleagues did not find priming effects even during surgery.

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