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# *Does Memory Priming during Anesthesia Matter?*

THE article in this issue of ANESTHESIOLOGY by Iselin-Chaves *et al.*[1] consolidates recent evidence that memory "priming" persists during adequate anesthesia. We are now in a position to move on from wondering whether memory priming happens during anesthesia to asking how much happens, under what conditions does it happen, and what is its impact on patients' well-being. Research in psychology shows that even this very basic form of learning can have profound effects on behavior.

Early studies of learning during anesthesia produced equivocal results with interpretation hampered by inconsistent methodology.[2] An important recent development is the combining of careful memory testing with monitoring of intraoperative awareness or anesthetic depth. Iselin-Chaves *et al.* presented the repetitions of each stimulus word consecutively while recording the Bispectral Index (BIS), allowing estimation of the anesthetic depth at which each word was presented. They found implicit memory for words presented with BIS between 41 and 60. *Implicit memory* refers to memories that we are unaware of, that we cannot consciously recall or recognize, but that reveal themselves through changes in behavior. Implicit memory is often preserved after brain damage or experimental manipulations that abolish conscious recall.

The type of learning demonstrated by Iselin-Chaves *et al.* is actually very limited. If human memory is conceptualized as a network of nodes representing different pieces of information, the simplest form of learning is temporary activation of a single node, known as *perceptual priming* because it facilitates subsequent perception of stimuli against background noise or, as here, from fragments such as word stems. Spread of activation to related nodes (*e.g.*, tractor → farm) is known as *conceptual priming* because it facilitates perception of, or responding with, conceptually related information. Conceptual priming is prevented by adequate anesthesia.[3]

In contrast, perceptual priming seems to be preserved during anesthesia.[3] Lubke *et al.*[4] showed enhanced word stem completion performance for words presented during trauma surgery with isoflurane, with BIS between 40 and 60. The study by Iselin-Chaves *et al.* extends these findings to elective surgery with isoflurane. We found[5] and then replicated[6] word stem completion priming during elective surgery with relatively deep propofol anesthesia (median BIS = 42 and 40[5,6]). Perceptual priming thus seems to be a general feature of anesthesia, not a peculiarity of a particular anesthetic technique.

The findings are still mixed, however. Kerssens *et al.*[7] tested patients undergoing elective surgery and used a word stem completion task but found no evidence for priming during BIS-guided propofol or isoflurane anesthesia. They suggested that maintaining a constant anesthetic depth prevents priming. In the study of Iselin-Chaves *et al.*, moments of light anesthesia just before or after presentation of a particular word may have facilitated priming, but this explanation does not apply to our own demonstration of priming.[6] We found priming even in a retrospectively selected subgroup of patients for whom BIS happened to remain below 60 throughout word presentation. The evidence for priming during anesthesia is not simply an artifact of inadequate depth control.

It is generally true, though, that memory activation is more likely with lighter anesthesia. It is more likely to occur with opiate-based techniques than with volatile anesthetics that produce deeper hypnosis,[8] and it does not occur when BIS is less than 40.[1,4] The exact relation between priming and depth is not clear. Lubke *et al.*[4] found a significant although not very strong linear relation between memory and anesthetic depth at which words were presented. However, the measure of memory used in this analysis included explicit as well as implicit components. Using a measure specifically of implicit memory, Iselin-Chaves *et al.* found as much memory for words presented during anesthetic depths of BIS 41–60 as for words presented to volunteers receiving no anesthesia (and no surgery). Their inclusion of a group of awake participants is interesting because it raises the question of whether priming during anesthesia is a mere shadow of priming activity in the conscious brain or whether perceptual priming is insensitive to all but the most extreme manipulations of brain function. Their finding suggests that a sudden decrease in perceptual priming occurs when anesthetic depth decreases below BIS of 40, but until then, it is unaffected by the transition from consciousness to unconsciousness.

Another factor affecting memory priming is the presence of surgical stimulation. The sudden increase in concentrations of circulating catecholamines caused by surgery may enhance any residual memory function *via* the amygdala.[5,9] Fear conditioning occurs in the amygdala,[10] as does enhancement of memory consolidation during emotional events or when experimental applica-

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tions of norepinephrine mimic natural stress.[11] We found no evidence for priming when words were presented during anesthesia but before surgery, but significant priming at equivalent anesthetic depth during surgery.[5] Most stimulus presentation in the study of Iselin-Chaves *et al.* was completed before surgery began, making their priming effect more impressive than it might seem at first glance.

Therefore, some memory function persists during clinically adequate anesthesia. Patients do not learn new information or even new associations between already familiar information. All that happens is slight activation of existing representations of words in memory detectable on a carefully designed memory test. Given that patients are unlikely in everyday life to be asked to complete memory tests, is this any cause for concern? Research in psychology suggests it may be, showing profound effects on behavior of even this very rudimentary memory activity. In what has become a classic experiment, Bargh *et al.*[12] asked participants to rearrange word lists into sentences. When the lists included words relating to the concept of old age (*e.g.*, conservative, wrinkle), participants subsequently walked away from the laboratory more slowly than participants exposed to neutral words, even though they had not noticed the repeated occurrence of references to old age. Conversely, priming of the concept of professor improved performance on a test of general knowledge.[13] Physiology is not immune to these priming effects: Hull *et al.*[14] found that subliminal exposure to an "angry" prime increased blood pressure relative to exposure to a "relax" prime.

You can only prime behaviors that are likely to happen anyway. Surreptitious exposure to words related to speed led to better performance on a timed test of intelligence than exposure to neutral words, but only when participants already had the goal of working quickly.[15] People poured themselves a larger drink, and drank more of it, after subliminal presentations of smiling faces compared with angry faces, but only if they were already thirsty.[16] Subliminal priming of the concept "blacks" led white participants to form a more negative impression of someone described verbally, but only if they already had high levels of prejudice.[17]

These laboratory studies show that priming of concepts in memory, occurring without participants' awareness, can affect behavior in many ways, making people seem slower, thirstier, more prejudiced, or more intelligent. Iselin-Chaves *et al.* have shown that priming can still happen when patients are anesthetized. Comments made in the operating room about a patient's prognosis, appearance, or state of consciousness could exacerbate their existing anxieties about the operation, about themselves, or about the anesthetic and may contribute to postoperative anxiety, depression, and insomnia even in patients with no explicit recollection of surgery.

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## References

1. Iselin-Chaves IA, Willems SJ, Jermann FC, Adam SR, Van der Linden M: Investigation of implicit memory during general anesthesia for elective surgery using the process dissociation procedure. ANESTHESIOLOGY 2005; 103:000–000
2. Andrade J: Learning during anaesthesia: A review. Br J Psychol 1995; 86:479–506
3. Deeprose C, Andrade J: Is priming during anesthesia unconscious? Conscious Cogn 2005; (in press) AQ: 1
4. Lubke GH, Kerssens C, Phaf H, Sebel PS: Dependence of explicit and implicit memory on hypnotic state in trauma patients. ANESTHESIOLOGY 1999; 90:670–80
5. Deeprose C, Andrade J, Varma S, Edwards N: Unconscious learning during surgery with propofol anaesthesia. Br J Anaesth 2004; 92:171–7
6. Deeprose C, Andrade J, Harrison N, Edwards N: Unconscious auditory priming during surgery with propofol and nitrous oxide anaesthesia: A replication. Br J Anaesth 2005; 94:57–62
7. Kerssens C, Ouchi T, Sebel P: No evidence of memory function with propofol or isoflurane with close control of hypnotic state. ANESTHESIOLOGY 2005; 102:57–62
8. Ghoneim MM, Block RI, Dhanaraj VJ, Todd MM, Choi WW, Brown CK: Auditory evoked responses and learning and awareness during general anesthesia. Acta Anaesth Scand 2000; 44:133–43
9. Stapleton C, Andrade J: An investigation of learning during propofol sedation and anesthesia using the process dissociation procedure. ANESTHESIOLOGY 2000; 93:1418–25
10. LeDoux JE: Emotion: Clues from the brain. Annu Rev Psychol 1995; 46:209–35
11. Cahill L, Prins B, Weber M McGaugh JL: Beta-adrenergic activation and memory for emotional events. Nature 1994; 371:702–4
12. Bargh JJ, Chen M, Burrows L: Automaticity of social behaviour: Direct effects of trait constructs and stereotype activation on action. J Pers Soc Psychol 1996; 71:230–44
13. Dijksterhuis A, van Knippenberg A: The relation between perception and behavior, or how to win a game of Trivial Pursuit. J Pers Soc Psycho 1998; 74:865–77
14. Hull JG, Slone LB, Meteyer KB, Matthews AR: The nonconsciousness of self-consciousness. J Pers Soc Psycho 2002; 83:406–24
15. Sheeran P, Webb TL, Gollwitzer PM: The interplay between goal intentions and implementation intentions. Pers Soc Psychol B 2005; 31:87–98
16. Winkielman P, Berridge KC, Wilbarger JL: Unconscious affective reactions to masked happy versus angry faces influence consumption behavior and judgments of value. Pers Soc Psychol B 2005; 31:121–35
17. Lepore L, Brown R: Category and stereotype activation: Is prejudice inevitable? J Pers Soc Psycho 1997; 72:275–87