

Psychology in the operating theatre

Michael Wang, Catherine Deeprise, Jackie Andrade and Ian F. Russell ask what general anaesthesia can tell us about consciousness, learning and memory

The aim of anaesthesia is to provide a temporary state of oblivion, from which a patient will awake without memory for surgery. Unfortunately, we will show here that absence of memory for surgery does not guarantee that oblivion was successfully achieved. The operating theatre has become a laboratory for psychologists to investigate the boundaries of consciousness, learning and memory.

I gratefully look forward to oblivion, but I must be sure of it.

Taylor Caldwell

In 1965, Dr Bernard Levinson, a practising psychiatrist and former anaesthetist, dosed 10 dental patients with thiopentone, nitrous oxide and ether in order to perform an unusual experiment. Mid-way through the operation, he staged a mock crisis in which he exclaimed, 'Stop the operation. I don't like the patient's colour. His/her lips are much too blue. I'm going to give a little more oxygen.' Thereafter, surgery continued and all patients were reported to have made an uneventful recovery. However, under hypnosis one month later, four of the patients repeated verbatim Levinson's statement, and another four had some recall for intra-operative events.

This study is in many ways methodologically flawed: for example, Levinson conducted both the mock crisis and the hypnosis. However, the startling findings provided a starting point for research into psychological aspects of anaesthesia. This research really took off when psychologists provided appropriate tools and frameworks for researching implicit memory (Andrade & Deeprise, 2006; Deeprise & Andrade, 2006). At that point, the operating theatre became a laboratory in which to investigate the boundaries of consciousness, learning and memory.

The main message from this research is that the boundaries are blurred, with loss of consciousness involving gradual

changes in sensation, cognition and memory rather than a sudden switch from awake to asleep. In this article, we address some key questions about anaesthesia and what it can tell us about the mind.

What does general anaesthesia involve?

We often talk about sending patients 'off to sleep', but sleep is not an accurate analogy for anaesthesia. EEG studies demonstrate that general anaesthesia does not have the same electroencephalic signature, architecture or sleep stages of natural somnolence (Schwartz, 2010). Unlike sleep, unconsciousness resulting from anaesthesia is a state created through artificial means, and, by definition, there is an absence of response to very strong stimulation.

Generally it is held that there are three common aims of general anaesthesia:

- | analgesia (loss of sensation, to prevent physiological shock);
- | hypnosis (unconsciousness or oblivion); and
- | muscle paralysis (to allow for surgical access).

Often at least three different drugs are responsible for these components, and thus they are relatively independent. It is possible to be given sufficient muscle relaxant to produce effective paralysis, with insufficient hypnotic, leaving the patient conscious but unable to move.

A further complication is that the effect of the hypnotic component of the anaesthetic cocktail, that is the anaesthetic proper, is determined by the balance between the dose of anaesthetic and the level of surgical stimulation and psychological arousal. Just as you may have difficulty sleeping in a noisy environment, so you will need more anaesthetic to keep you unconscious during an invasive surgical procedure than during a more minor superficial procedure. As a patient, your state of consciousness or unconsciousness exists on a continuum of 'depth of anaesthesia' between fully awake

questions

What mechanisms might underlie the phenomenon of intraoperative consciousness followed by postoperative amnesia?

What is meant by implicit *emotional* memory?

resources

Deeprise, C. & Andrade, J. (2006). Is priming during anaesthesia unconscious? *Consciousness and Cognition*, 15(1), 1–23. – Reviews the anaesthesia and memory literature from a psychological perspective

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and fully unconscious. Where you are on this continuum will vary during an operation, and a difficulty for the anaesthetist is to determine how close you are to moving into the 'wakeful' end of the continuum before it is time for you to do so. The reader at this point may wonder why the anaesthetist does not just continually give an overdose of anaesthetic, and often they do, but there are dangers here of increased medical morbidity and (rarely) mortality.

The idea of a continuum of consciousness is supported by studies of the effects of sedative or sub-anaesthetic doses of anaesthetic drugs. These studies have found a progressive, sequential but dissociative loss of sensation. Hearing is commonly the last sense to be affected and electrophysiological studies have shown that limited sense of hearing can continue despite even deep anaesthesia (Koelsch et al., 2006). Importantly, long-term encoding

of memories is impaired before language and working memory functions (Andrade, 1994, 1996).

What's the risk of consciousness during general anaesthesia?

Consciousness during anaesthesia has traditionally been measured retrospectively, in terms of patients' recollections of surgery. The standard definition of awareness during anaesthesia refers to a situation where a patient has 'woken up' during surgery and recalls doing so when they come round after their operation. Achieving awareness by this definition requires that the period of consciousness is complete enough, in terms of the extent to which sensory and cognitive functions are regained, and long enough to be encoded in memory sufficiently to be recalled and verbalised at a later time. It also requires that

memory encoding is not compromised by the amnesic effects of anaesthetic drugs.

Often these memories of surgery are quite fragile and only become apparent once more vivid memories of the hospital visit have faded. The best studies of anaesthetic awareness therefore interview patients at several time intervals following surgery, to maximise the chance of capturing a faint memory of intra-operative events. These studies of retrospective explicit recall indicate a risk of about around one in every 600 operations for adults (Sebel et al., 2004) and around one in 100 operations for children (Davidson et al., 2005). These incidence rates clearly present a concern given that approximately 2.9 million anaesthetics are conducted in the UK each year (Woodall & Cook, 2011). Moreover, these statistics exclude operations where there is high risk of awareness. Risk of awareness increases if blood circulation is compromised (e.g. during heart bypass or trauma with blood loss), or if the dose of anaesthetic must be minimised (e.g. to avoid anaesthetising the baby during Caesarean section).

Studies using post-operative interviewing may underestimate the true incidence of consciousness during anaesthesia. This is because explicit memory, as assessed using retrospective recall, does not necessarily correlate with consciousness at the time of learning: there can be full consciousness with explicit memory, full consciousness with no explicit memory but with implicit memory, unconsciousness with no explicit memory but with implicit memory, or unconsciousness with no explicit or detectable implicit memory. Many low-dose anaesthesia studies have demonstrated that anaesthetic drugs commonly obliterate explicit recall, giving rise to amnesia, despite the fact that the patient was conscious and communicative during the period the drugs were active (see review by Andrade, 1996). This is particularly common in the case of conscious sedation during unpleasant investigative procedures such as endoscopy, when a benzodiazepine such



Cognition, 15(1), 1–23.

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as midazolam is injected intravenously. Many people have complete amnesia for such procedures and imagine they have been unconscious when clearly they have not (Woodruff & Wang, 2004). It is possible to be wakeful during general anaesthesia and have no post-operative recall for this episode.

How can we assess depth of consciousness?

The major focus of research on assessing depth of anaesthesia has been EEG measures of brain function. There is evidence that these measures can help reduce awareness during anaesthesia (Myles et al., 2004), but at best they provide a probabilistic indication of a patient's state of consciousness. In other words, they tell us that the majority of patients will be unconscious at a particular EEG index reading. But what if the patient is actually at the tail of the normal distribution? A direct measure of consciousness during anaesthesia would tell us if a patient was awake right now. Such a measure could help prevent the worst awareness cases. Much, if not most of major surgery in the Western world involves the use of muscle relaxants, which cause whole-body paralysis. If you are unfortunate enough to become 'wakeful' in the presence of such drugs, you will be incapable of any movement. Anaesthetic awareness patients tell of strenuous and desperate attempts to signal to theatre staff their predicament, without success. Moreover, most anaesthetists believe, and are indeed taught, that they can detect consciousness in the presence of muscle relaxants because of changes in heart rate, blood pressure, tear secretion and sweating. However, there is now abundant empirical evidence that this is simply untrue (Moerman et al., 1993).

Despite comments from eminent/learned bodies that 'Intraoperative



awareness cannot be measured during the intraoperative phase of general anaesthesia' (American Society of Anesthesiologists Task Force on Intraoperative Awareness, 2006), the isolated forearm technique provides a simple yet highly effective method for determining consciousness during anaesthesia (Russell, 1993; Russell & Wang, 1997, 2001). Before muscle relaxants are administered, a tourniquet is applied to one arm using a cuff, ensuring the patient is capable of moving the hand during surgery despite the presence of muscle relaxant in the rest of the body. The patient is then asked to 'squeeze their fingers' by the anaesthetist at regular intervals. In early studies of the isolated forearm technique, Russell (1989) found that 44 per cent of patients receiving a once commonly used anaesthetic could respond sensibly to command at some point during the operation. However, on recovery almost all patients had complete amnesia for the surgical period. The incidence for awareness in children measured directly using the isolated forearm technique is approximately 1 per cent (Andrade et al., 2008), similar to the rate estimated by retrospective recall. During particularly stimulating procedures such as intubation or when anaesthesia is very light, the incidence can be much

higher (Byers & Muir, 1997). The incidence of consciousness in adults receiving modern anaesthetics is currently unknown, but is likely to vary significantly according to the specific anaesthetic technique used and surgical procedure. Early studies suggest the true incidence could be considerably higher than the incidence estimated by recall measures (Messina et al., in press), though the discrepancy between the child and adult data is not yet understood.

The isolated forearm technique is not used routinely in clinical practice, and in our experience, clinicians are either not aware of the technique or resistant to adopting it. Electrophysiological measures are also not routinely used in Europe, as there is little evidence that they reduce the risk of awareness in low- or medium-risk cases. Rather than attempting to assess the level of consciousness of individual patients, efforts to reduce awareness have focused on reducing human error.

Can we form memories during unconsciousness?

Although consciousness at the time of learning does not necessarily result in explicit recall, another form of memory may persist. Implicit memory is the enhanced processing, or 'priming' of information, such as improved ability to identify previously presented words embedded in white noise or to recognise or generate a word from its beginning or 'stem'. Priming memory may occur during moments of undetected consciousness, but also occurs during adequate and even deep anaesthesia – at least as defined using an EEG measure and routine patient observation (Deepröse & Andrade, 2006). Thus research by Jackie Andrade and Catherine Deepröse has shown that, on recovery, patients are more likely to complete word stems with target words if they have heard those words during surgery (Deepröse et al., 2004). If patients had been paralysed, then the anaesthetist as well as the EEG monitor may have missed signs of

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consciousness (Russell, 2008a, 2008b). However, patients were not paralysed, and so were free to move and communicate had they woken during surgery. None did, consistent with the conclusion that priming took place during adequate anaesthesia (Deeprise et al., 2005; Deeprise, et al., 2004; see also Keressens et al., 2009).

What are the implications for well-being?

The psychological effects of explicit memory for consciousness during anaesthesia may be persistent and debilitating, including re-experiencing of the traumatic event, avoidance and hyperarousal consistent with post-traumatic stress disorder (Ghoneim, 2010; Leslie et al., 2010). But implicit memory may also impact on psychological well-being. There is an intriguing literature in which patients have developed psychopathology following surgery for which they have no memory and which, on the face of it, appeared to be unproblematic at the time (see review by Wang, 2010). However, subsequent investigation of anaesthetic records has often suggested inadequate anaesthesia, likely resulting in implicit memory for the surgery. It is well established that implicit memory can have a significant impact on behaviour (e.g. Harris et al., 2009; Ijerman & Semin, 2007). For example, experimental work has shown that being 'primed' by an elderly stereotype results in healthy adults walking away from the laboratory more slowly (Bargh et al., 1996). The influence of implicit memory on post-operative recovery has important implications if the implicit memory may exacerbate existing anxieties, or includes strong emotional content, such as an unfavourable prognosis discussed by medical staff during the surgery.

On the opposite side of the coin, there is some limited evidence that the formation of implicit memory during surgery may be used to benefit patients through priming positive expectations, such as 'you will make a good recovery' (Lebovits et al., 1999; Nilsson et al., 2001). However, it has not yet been demonstrated that the processing of this conceptual type of information can take place during adequate anaesthesia, and early positive findings in this field may reflect unintended consciousness during anaesthesia, which was not detected by anaesthetists or consciously recalled by patients on recovery.

The impact of psychology on anaesthetic practice

Given the above considerations, psychology has much to contribute to the evaluation of what constitutes 'adequate anaesthesia'. Unintended anaesthetic awareness appears to be much more widespread than many imagine, and evidence suggests that as many as 50 per cent of people who experience this may go on to develop serious psychological problems such as PTSD (Macleod & Maycock, 1992). Many anaesthetic awareness sufferers make no complaint, perhaps because of phobic avoidance of medical personnel or because they don't wish to make trouble for hospital services. Presently two of us (JA, MW) are members of a joint Royal College of Anaesthetists and Association of Anaesthetists of Great Britain and Ireland committee that is auditing cases of awareness from the whole of the NHS in the UK and in healthcare services in Ireland (National Audit Project 5 – www.NAP5.org). Any reader treating a recently reported case of awareness should notify the project (nap5@nap5.com). One of us (MW) has contributed to the development of a forthcoming NICE report on the use of

"unintended anaesthetic awareness appears to be much more widespread than many imagine"

EEG monitors to detect consciousness and a Cochrane Review on the prevention of unintended anaesthetic awareness (Messina et al., in press).

Conclusion

The research we have reviewed illustrates a point well known to psychologists – that being conscious and being able to remember being conscious are not the same thing. It raises some important questions for psychology. The effects of implicit memory on behaviour have been extensively researched, but effects on psychological well-being are not well understood. Similarly, although we know a lot about explicit and implicit memory, there remain questions about how conscious we need to be, and which brain processes need to operate, to encode memories of different sorts of stimuli. Finally, this interdisciplinary research shows the usefulness of cognitive psychology for providing a framework for understanding and tackling clinical problems.



Michael Wang
is Professor of Clinical Psychology, School of Psychology, University of Leicester
mw125@leicester.ac.uk

I Catherine Deeprise
is Lecturer in Psychology, School of Psychology, Plymouth University
catherine.deeprise@plymouth.ac.uk

I Jackie Andrade
is Professor of Psychology, School of Psychology, Plymouth University
jackie.andrade@plymouth.ac.uk

I Ian F. Russell
is Consultant Anaesthetist, Hull Royal Infirmary
I.F.Russell@hull.ac.uk

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