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# Detecting Awareness in Children by Using an Auditory Intervention

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***Background:*** **The incidence of awareness has been reported to be higher in children than in adults. Accurately assessing awareness in children is difficult, and the lack of a specific measure of awareness makes it difficult to determine exactly how many and why children are aware. The aim of this study was to determine the incidence and timing of awareness in children by using auditory stimuli applied during anesthesia.**

***Methods:*** **Three easily identified animal noises were played repeatedly through headphones during three specific phases of anesthesia in 539 children aged 5–12 yr. Children were not told that this would happen. Awareness was determined with a structured interview on days 1 and 3 after the anesthetic. All positive responses were sent to four adjudicators for assessment, and awareness was defined as having occurred if all adjudicators agreed that the child was aware.**

***Results:*** **Five hundred children were interviewed at least once after the anesthetic. Thirty-five reports were sent to the adjudicators, and one child was classified as aware. This child was deemed to be aware even though he did not report hearing an animal.**

***Conclusions:*** **The incidence of awareness in this study is less than reported previously.**

PREVIOUS cohort studies have found the incidence of awareness in children to be between 0% and 5%.[1–4] The incidence reported is generally higher than that reported in similar studies in adult populations.[5] The reason for this high reported incidence is uncertain, though it has been suggested that the use of anesthesia induction rooms and the consequent break in continuity of delivery of anesthesia may be contributing factors.[6] Determining when awareness occurred in children would aid our understanding of the mechanism of awareness in children and, in particular, determine whether transfer from induction rooms is a significant factor.

A crucial factor in studying awareness is the certainty that the memory represents true awareness. A patient's recall of an intraoperative event may be confused with events in the postanesthesia care unit, dreams, or implanted memory. Previous studies have relied on allocating a fairly arbitrary probability that a recalled memory actually matches an intraoperative event.[1] This method is imprecise, and in children is particularly problematic. Children have poorer source monitoring (identifying origin of memory) and are more likely to confuse the timing or origin of a memory. In some situations, they may also be more suggestible than adults (increasing the possibility of false-positive reports). Conversely, children may underreport awareness because they have difficulty retaining and recalling memories without the interviewer carefully constructing the context. In addition, children's recollections may contain sequencing or simple factual errors (such as left–right confusion) and so may not be able to meet strict adjudication criteria for awareness assessment. Brice was one of the first to research awareness, and many studies still use modifications of his original interview.[7] Interestingly, these modifications have dropped a core aspect of his technique: the use of specific auditory stimuli during anesthesia. He considered presenting a salient and unique auditory stimulus during anesthesia to be the best way to confirm that any report that included recollection of the stimulus was a true awareness experience.

Not only can the use of a series of auditory stimuli improve the accuracy of an assessment, it can also provide evidence for the timing of the awareness. This study aimed to determine the incidence and timing of awareness in children by using a series of continuous auditory stimuli.

## Materials and Methods

In a pilot study, we played 13 assorted sounds to 120 children aged 5–12 yr who were scheduled to undergo surgery. Children were asked to identify what they believed each sound to be. From this pilot study, we identified the five sounds that were most easily recognizable to children (dog, cat, horse, cow, and train). These sounds were recognized correctly more than 90% of the time. Compact discs were then created with three tracks. On each track, one of the four animal sounds was played repeatedly. Twenty-four separate compact discs were created to include all possible permutations of three of the four animals. Each track was of variable length but similar volume. For each disc, a separate track was also prepared with the train sound.

After approval from the Royal Children's Hospital Human Research Ethics Committee (Parkville, Victoria,

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Australia) for both the study and the pilot study, and informed consent from the participants' parents, a further cohort of children aged between 5 and 12 yr who were scheduled to undergo surgery at the Royal Children's Hospital were recruited into the study. Children were excluded if they were hearing impaired, developmentally delayed, did not speak English, or were expected to be sent to the intensive care unit postoperatively or if access to their head for placement of the headphones was not possible during surgery (*e.g.*, neurosurgery, tonsillectomy, eye surgery). Children were chosen from the operating schedule in a manner similar to that described in our previous study.[1] Each child was randomly given 1 of the 24 compact discs. Parents were told about the study in detail, whereas children were only told that they would have a hearing test before the operation and that afterward the researcher would come back and ask them some questions. They were not told anything about sounds being played to them during anesthesia, and parents were asked not to tell them about this aspect of the study.

Before anesthesia, while in the day stay area or presurgical holding area, the children were played the test sound (the train), which they were asked to identify. This was done to gain rapport and to test hearing, volume, and understanding. Children were excluded if they could not identify the train, because this was taken to be an indication of possible previously unrecognized cognitive delay or hearing impairment.

All children were anesthetized in an induction room adjacent to the main operating room. Once the child was anesthetized, an appropriately fitted headphones were applied and connected to a compact disc player. For each child, three of the four possible animal sounds were played, each in one of three phases of anesthesia. Each animal track was repeated continuously until the next phase of anesthesia. Track 1 was played from induction of anesthesia to disconnection of the breathing circuit for transfer to the operating room. Induction was defined as the point when the anesthesiologist stated the child was asleep. If this point was not clear, the researcher asked the anesthesiologists to indicate when they thought the child was unconscious. This was before the laryngeal mask or endotracheal tube was placed. Track 2 was played from disconnection to 5 min after reconnection of the anesthesia circuit in the operating room. If the child was not transferred to the operating room and the procedure was performed in the induction room, track 2 was skipped and track 3 was started at the time of first contact with the child for the procedure (*e.g.*, skin prep or removal of cast). Track 3 was played until anesthesia was discontinued (vaporizer turned to zero or total intravenous anesthesia switched off). For each child, one animal noise (the fourth) was not played. If any child reported hearing this animal, it would indicate that some children were guessing and provide a baseline rate of pure guessing.

Children were interviewed in a face-to-face interview on the day of surgery when they were sufficiently alert to engage in conversation with the researcher. On some occasions, the first interview was conducted on the next day if the children were still inpatients and slow to awaken or showed significant discomfort or distress. All families were contacted again on the third day. This was done either face-to-face if the child was in the hospital or over the telephone if the child had been discharged from the hospital. In these interviews, the questions were asked directly to the children.

All interviewers (S.J.S., A.L.E., A.W., and L.P.) were trained by an experienced child psychologist (R.S.) in child interview technique. They were trained how to gain rapport, construct temporal context, and not use leading questions. The interview followed a pro forma constructed to aid the child in creating temporal context without the use of leading questions. The interview pro forma is shown in the appendix. On completion of the study, reports were compiled for all children that indicated whether they had formed any memories during anesthesia. The reports included the child's actual response and were sent to four independent adjudicators (three of whom had acted as adjudicators for our previous study). The adjudicators were asked to rate each child as aware, possibly aware, or not aware. They were told details of the procedure and were also told that the child had animal noises played to them during the operation. The adjudicators were told to use their own judgment on whether accurately reporting animal noises was required to confirm an event as awareness. If all four adjudicators rated the child as aware, the child was classified as aware in the final analysis.

The anesthesia technique, including premedication, was left entirely to the discretion of the anesthesiologist caring for the child. The anesthesiologists knew that the study was designed to detect awareness. The treating anesthesiologists were blinded to the nature of any of the sounds played during anesthesia, and the research interviewers were blinded to the selection and order of sounds on each particular compact disc. Data were also collected about the procedure and anesthetic. At the end of the anesthetic, each anesthesiologist was asked to rate the likelihood of awareness occurring during that particular anesthetic.

The original study design allowed researchers to inform the children that sounds were to be played to them during the procedure. Thirty children were enrolled with this design. We changed the protocol after finding evidence that children were guessing. One child reported hearing an animal that had indeed been played, whereas another reported hearing the "fourth" animal—the one not played. This result indicated that at least some children would report hearing the "correct" animal purely from guessing. We therefore recommenced the study with the new strategy of not informing the children about the sounds to reduce the risk of guessing. The 30 children recruited with the abandoned design were not included in any of the analysis.

The number justification was based on what we decided to be an acceptable degree of precision in our estimate of awareness. We expected the incidence of awareness to be 0.8% from our previous study.[1] Taking into account logistic constraints, we expected to be able to recruit approximately 500 children. When using the sample size of 500, a two-sided 95% confidence interval for a single proportion using the large sample normal approximation will extend 0.008 from the observed proportion for an expected proportion of 0.008 (*i.e.*, 0–0.016). This is an acceptable degree of precision. A prospective decision was made to recruit children until 500 were successfully interviewed.

### *Statistical Analysis*

The rate of awareness is presented as a frequency with 95% confidence interval calculated with the exact binomial method by using STATA 10 (Stata Corporation, College Station, TX).

## Results

Of the 539 children recruited with the improved design, the protocol was not completed or there were no successful interviews in 39 children. Six children did not correctly identify the train and were therefore excluded. One of these children was referred for poor hearing and was indeed found to have a previously undiagnosed hearing impairment. In 15 cases, the child was recruited, but the sounds could not be played because of surgery being rescheduled or cancelled. In 1 case, there was a technical failure, and in 5, the headphones had to be removed because of the extent or site of surgery. In 1 case, the anesthesiologist refused to allow the study to be performed. In 6 cases, there was no follow-up because the child left hospital before being interviewed and the family could not be contacted by telephone. There were also 5 children excluded because the protocol was violated (non-English speaking, too young, recruited into this study previously, or child received sedation rather than anesthesia). Details of the 500 children who were included in the final analysis are shown in table 1. All children had end-tidal agent monitoring. The Bispectral Index monitor was only used in 1 child. No other anesthesia depth monitoring was used. In 97% of cases, the anesthesiologists reported the likelihood of awareness to be "unlikely" or "very unlikely" (table 2).

Ninety-five percent of children reported hearing a train when asked the questions "Do you remember that I asked you to listen to a sound before your operation? Do you remember what that sound was? What was that sound?" A total of 35 children answered "Yes" to the question "Do you remember anything that happened during the operation?" or "Did you hear anything during the operation?" at either the first or the second interview. This is an incidence of 7%, with a 95% confidence interval from 4.9% to 9.6%. Children who answered "Yes" to these questions were younger than those

**Table 1. Patient Characteristics and Anesthesia Details**

| | |
|---|---|
| Patient details | |
| Sex, M/F | 311 (62%)/189 (38%) |
| Age, yr | 8.9 ± 2.9 |
| Procedure | |
| Endoscopy | 107 (21.4%) |
| Circumcision | 46 (9.2%) |
| Plastic surgery | 29 (5.8%) |
| Orthopedic surgery | 149 (29.8%) |
| Urogenital | 37 (7.4%) |
| Ear, nose, or throat surgery | 1 (0.2%) |
| Joint injections | 57 (11.4%) |
| Thoracic surgery | 5 (1%) |
| General surgery | 66 (13.2%) |
| Other | 3 (1%) |
| Induction | |
| Inhalational/intravenous/intravenous and inhalational | 281 (56%)/185 (37%)/33 (7%) |
| Airway during surgery | |
| Laryngeal mask/endotracheal tube/facemask | 372 (75%)/77 (15%)/50 (10%) |
| Agents given | |
| Neuromuscular blocking agents given | 40 (8%) |
| Sedative premedication given (0.5 mg/kg oral midazolam) | 51 (10%) |
| Regional analgesia provided | 176 (35%) |
| Nitrous oxide used for induction | 456 (91%) |
| Nitrous oxide used for maintenance | 432 (86%) |
| Times | |
| Duration of anesthesia from start of track 1 to end of track 3 | 39 ± 32 (4–209) |
| Duration of track 1 | 3.7 ± 3.8 (1–40) |

Continuous data are presented as mean ± SD (range).

**Table 2. Anesthesiologists' Assessment of Likelihood of Awareness**

| | In Children Who Reported a Memory | All Children |
|---|---|---|
| Very unlikely | 23 (68%) | 354 (72%) |
| Unlikely | 9 (26%) | 125 (25%) |
| Neutral | 2 (6%) | 7 (1.4%) |
| Likely | 0 | 2 (0.4%) |
| Very likely | 0 | 4 (0.8%) |

who did not (mean age, 7.2 *vs.* 9.1 yr; $P < 0.0001$). Interestingly, four children reported hearing the train *during* the operation. Reports of all 35 of these cases were sent to adjudicators.

None of the children reported any of the three animal sounds that were played to them during anesthesia. One child was classified as aware after all four adjudicators rated him as aware, giving an incidence of 0.2% with a 95% confidence interval from 0.005% to 1.1%. The child classified as aware was a 9-yr-old boy undergoing anesthesia for injection of keloid. He was taking Ritalin for attention deficit–hyperactivity disorder. He had no premedication. The attending anesthesiologist performed an inhalational induction with 8% sevoflurane in nitrous oxide and oxygen. After induction, the sevoflurane concentration was reduced and continued in nitrous oxide and oxygen *via* spontaneous ventilation through a facemask airway throughout the procedure. Intravenous access was established between induction and first keloid injection. The first track was started 1 min after the start of induction, and keloid injections were started 4 min after the start of induction. Four minutes later, the procedure was completed and sevoflurane and nitrous oxide was discontinued. The injections were all performed in the induction room, without transfer to the operating room. He received no neuromuscular blocking agents. No signs of inadequate anesthesia were noted with the start of the procedure (no movement or tachycardia), and the anesthesiologist rated the likelihood of awareness as "neutral." The animal sounds played were those of a horse and then a dog (track 2 being skipped because there was no transfer).

When asked on day 1 "After you fell asleep do you remember anything that happened during the operation?" he replied "Yes," and after "What do you remember?" he stated "Felt sharp things going in my leg, tiny needles." He answered "No" to hearing anything during the operation, "No" to feeling pain, and "No" to "Did you try to move?" He responded "Yes" to "Did you go back to sleep?" and "Waking up" to "What is the next thing you remember?" He stated that he was not bothered by the memory. On day 3, he again responded "Yes" to "After you fell asleep do you remember anything that happened during the operation?" stating that he remembered "Something going in my leg, sharp things going in my leg." Again he did not remember hearing anything but did say he felt "A tiny bit of pain." He also again remembered going back to sleep again and then waking up and was not concerned by the memory. He had several previous anesthetics and commented that he had also remembered the needles during previous procedures. Another member of the family had also described being awake during an anesthetic.

## Discussion

In this study, only 1 in 500 children was classified as being aware. This result is substantially lower than the 0.8% described in our previous study. There are several possible explanations for the discrepancy between this result and our previous result.[1] The lower incidence may be due to anesthesiologists at our institution being more vigilant for awareness or changing practice as a result of our last study findings. Changes in practice that may reduce awareness include giving larger doses of anesthesia, waiting longer for adequate effect site concentration, or priming circuits in the operating room before transfer. Unfortunately, we cannot determine whether these practices actually did change significantly between studies. Another important difference is that anesthesiologists knew which children were being assessed for awareness in this study, whereas they were unaware which children were assessed in the previous study. It is possible that the anesthesiologists changed practice knowing which children were being studied. It was not possible to blind the anesthesiologists in this study because we were placing headphones. It should also be noted that the patient population was different between studies. The use of headphones excluded some children undergoing particular procedures in the more recent study. Last, the interview used was slightly different. We modified the interview after suggestions and limitations arose after the previous article and after subsequent correspondence with Lopez *et al.* It is important to note that the object of this study was to define awareness with an improved measure, not to directly compare incidence with the previous study.

For the case reported, there was no obvious cause for the awareness. However, the anesthetic was only 8 min long and the injections were started only 4 min after start of an inhalational induction, raising the possibility that the procedure started before effect site concentrations of sevoflurane had reached sufficient levels to suppress encoding of memory. There were no signs of light anesthesia. This is consistent with previous reports of awareness and wakefulness during anesthesia in children.[8] It is also worth noting the previous history of possible awareness. Previous awareness is considered to be a risk factor for awareness.

Compared with previous pediatric awareness studies, in this study we used a new measure of awareness. An accurate measure of awareness is needed to define incidence, determine likely causes, and assess interventions to prevent awareness—particularly the use of anesthesia depth monitors. The simplest measure of awareness is to simply ask a patient whether he or she remembered anything during the anesthesia. In our study, 7% of children reported that they remembered something when asked this question. This is consistent with previous awareness studies in children.[1,2] However, anesthesiologists are most interested in identifying or preventing those patients who remembered what happened when it was intended that they were adequately anesthetized. Just asking whether a patient remembered anything may not differentiate between those who formed memories during anesthesia and those who formed memories in the postanesthesia care unit, those who had dreams, or those who report false memories, either intentionally or unintentionally. This problem of differentiating true memories may be greater in children than in adults, because children have less ability to encode and consolidate memory. Their recall is more likely to be fragmentary, and they may have more difficulty with temporal organization of memory.[2] Assessing awareness requires careful interviewing. Temporal context must be created to help children retrieve memory, but excessive leading questions can lead to implanting of memory. The observation that four children reported hearing trains during the anesthetic in our study provides some support for the concept that children may have difficulty with correct temporal context, although it is possible that the sound of trains was confused with other intraoperative noise.

In previous studies, awareness of an event during anesthesia has been determined by some judgment of the probability that the recall accurately reflects an intraoperative event. To reduce bias, researchers may send reports to independent adjudicators to make this judgment.[1,2,9] Unfortunately, this is inevitably a subjective measure. Brice originally described a method to provide better evidence for awareness.[7] He played choir music or piano music *via* headphones to patients during their surgery. Using this technique in a small sample of adults, he found no evidence of awareness.

Previous studies have found a relatively high incidence of awareness in children.[1,2] Although awareness in children is widely acknowledged,[10] these studies have been criticized because of the possible inaccuracy of a child's memory and because no clear mechanism for awareness was found. We adopted Brice's technique to determine whether we could provide greater evidence that children do indeed have a high incidence of awareness. It has also been suggested that the use of induction rooms and subsequent interruption of anesthesia during transfer to the operating room may contribute to the awareness seen in these studies.[6] We hoped that by playing sequential sounds, we could determine whether transfer was indeed a risk period for awareness. We did not achieve this aim because of the lower-than-expected rate of awareness and the failure of the child who was aware to recall the animal sound. However, it is interesting that in this study, the one child who was aware was not transferred from the induction room.

In this study, we did not use the exact interview described by Brice. His interview involved a series of questions such as "What was the last thing you remembered happening before you went to sleep?" "What is the first thing you remember happening on waking?" and "Did you dream or have any other experiences while you were asleep?" This may work well for adults, but the lack of temporal progression is at odds with how accurate memory should be elicited in children. We also used only two interviews. This was because previous studies in children did not find substantially more cases of awareness in the interviews conducted beyond day 3 after anesthesia.

It is pertinent that the child who was classified as aware did not recall any animal noises. The adjudicators decided this child was aware on the basis of his clear report of nonauditory memory. It is plausible that the auditory stimulus in this case was insufficiently sentinel for memory encoding and consolidation. Certainly, for implicit memory formation there is some evidence that emotionally charged stimuli are more likely to result in memory formation.[11] Although it would make intuitive sense to think this applies to explicit memory as well, we could find no direct evidence to suggest that emotionally charged events during anesthesia are more likely to be recalled. Some episodes of awareness are very detailed, and it would be hard to imagine that such a distinct auditory stimulus would be unnoticed.[12] These descriptions are often in subjects who are paralyzed and hence might be conscious, wide awake with functioning working memory, but unable to move or show signs of being awake. In the unparalyzed subject, such as the child who reported awareness in this study, it is perhaps less plausible that a subject could encode and consolidate detailed memory without moving or signs of being conscious. Perhaps it is not unexpected that in this unparalyzed child, memory was more fragmentary and the nonsentinel animal noises were not remembered. As previously stated, encoding and consolidation also improve with age. These developmental changes might also explain why the awareness in children is more fragmentary and less rich in content, and why a nonthreatening and unexpected auditory stimulus may indeed be less likely to be encoded in children.

In this study, we measured conscious or explicit memory. We did not measure unconscious or implicit memory. Numerous studies have sought evidence for implicit memory formation during anesthesia, with varying degrees of evidence. Implicit memory is relatively simple to demonstrate in children; however, a recent study found no evidence for implicit memory formation during anesthesia in children.[8] It is possible that if we had used a forced-choice paradigm to encourage children to guess what sound they heard, we may have detected some implicit memory.

In our study, children did not know that sounds were played to them during anesthesia. It is possible that if they had known this, they may have been more likely to report things that would otherwise have seemed illogical and therefore not worth mentioning. We did not tell the children because of the risk of children guessing.

In conclusion, using a technique of auditory stimuli similar to that described originally by Brice, we found a lower rate of awareness in children compared with previous studies.

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## Appendix: Format of Face-to-face Interview

*Orientation Questions*

Hi, do you remember me? My name is __________. How are you feeling now? I am going to ask you some questions about your operation. Is that OK?

Do you remember that I asked you to listen to a sound before your operation?

Do you remember what that sound was?

What was that sound?

Later on you went over to the operating room with the doctor and mummy/daddy/relative.

Do you remember how the doctor made you go to sleep?

*If the child is incorrect or does not respond, ask the child:*

Did the doctor put something on your arm or face?

What happened after the doctor (put something on your arm [or face])? [use child's words]

*Experimental Questions (Any Nonspecific Recall)*

After you fell asleep do you remember anything that happened during the operation? *If the child says "Yes," ask the next questions; if "No," go straight to next section.*

What do you remember?

*If the child remembers hearing a sound, ask the child a question to clarify the sound, such as, "What kind of a sound was it— can you give me more details?"*

*If the child indicates he or she remembered something that may be awareness, ask the following questions:*

Did you hear anything?

Did you feel any pain?

Did you try to move?

How did you feel about . . .?

What happened next?

Did you go back to sleep?

What is the next thing you remember?

How do you feel about that now?

*Experimental Questions (Any Recall of a Sound)*

Did you hear anything during the operation? *If "No," go to next section; if "Yes," ask:*

What did you hear?

*If this is vague or not accurate, ask:*

Can you tell me any more about that or what kind of sound was it?

*Reorientation and Finishing Interview*

What was the first thing you remember after you woke up after the operation?

What did you see just after you woke up after the operation?